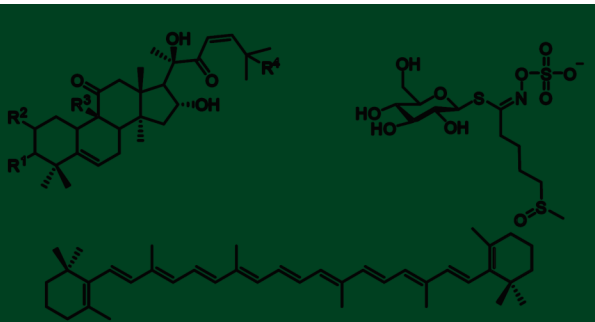
# Comprehensive Insights in Vegetables of Nepal


## Editors

**Sajan Lal Shyaula, Gan B. Bajracharya, Gopal K.C.**
**Shanta Man Shakya, Dilip Subba**




Nepal Academy of Science and Technology
Khumaltar, Lalitpur

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**Sajan Lal Shyaula**
*Nepal Academy of Science and Technology (NAST)*

**Gan B. Bajracharya**
*Nepal Academy of Science and Technology (NAST)*

**Gopal K.C.**
*Academician, Nepal Academy of Science and Technology (NAST)*

**Shanta Man Shakya**
*Institute of Agriculture and Animal Sciences, Tribhuvan University*

**Dilip Subba**
*Academician, Nepal Academy of Science and Technology (NAST)*



**Nepal Academy of Science and Technology (NAST)**
Khumaltar, Lalitpur
GPO Box 3323, Kathmandu, Nepal

*Comprehensive Insights in Vegetables of Nepal*

**Editors :** Sajan Lal Shyaula, Gan B. Bajracharya, Gopal K.C., Shanta Man Shakya and Dilip Subba

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# Message

The National Nutrition Program of the Government of Nepal has issued guidelines for healthy eating to tell people what kinds of foods to eat and how much to eat each day as healthy diet. The healthy diet for Nepali people suggested by the Food and Agriculture Organization and the Government of Nepal recommend roughly the following proportions: 40% staple foods, 25% vegetables, 15% fruits, 10% animal foods, and 10% others. Regular consumption of a vegetable rich diet has undeniable effects on health because it is strongly associated with improvement of gastrointestinal health, good vision and risk reduction of heart disease, chronic diseases such as diabetes, and some forms of cancer. Various studies have demonstrated the importance of vegetables of human health, contributing fibers, vitamins, minerals, bioactive phytochemicals, and other nutrients in our diet. Food is an environmental tool used in the sculpting of the human genome. It is logical to think that eating more natural foods would head to a healthier life. We should continue educating people about the health benefits of fruits and vegetables in a balanced diet and recommend that consumers should eat a wide variety of fruits and vegetables from different sources.

The book entitled *Comprehensive Insights in Vegetables of Nepal* has compilation of the tremendous wealth of knowledge regarding the vegetable in context of Nepal, keeping focus on vegetable diversity, seeds, farming, agrochemicals, nutrients, metabolites, post-harvesting and markets. It timely addresses the issues related to importance of vegetables in Nepalese diet. It contains 21 chapters, contributed by 32 authors who are experts in their respective fields from different institutions of Nepal. The editors have maintained well-placed chapters, mainly associated to vegetable diversity and farming practices; nutritive and medicinal values of vegetables; major diseases of vegetable crops; existing pesticide use pattern; post-harvest handling and market potential. The book is very much informative and the data are well presented in the existing situation of Nepal. Currently, Nepal has 35 open pollinated varieties and 300 hybrid varieties of vegetables crops. Local production of vegetable seeds in Nepal fulfils only about 50% of the total requirement. List of domesticated, wild and semi-domesticated vegetable species including vegetables wild relatives distributed in different ecological zones of Nepal are presented. The 318 species of wild vegetables consumed in Nepal from different literature sources are listed for their promotion and sustainable conservation. The nutritional importance of vegetables are highlighted to improve micronutrient deficiency and lifestyle related chronic diseases. Compilation of nutritional and medicinal information regarding vegetable gourds, mushrooms and brassicaceae vegetables has been presented for proper inclusion in our diet and versatile utility. Drug interactions with fruits and vegetables, and their clinical impact on drug therapy have been explained to better understand therapeutic efficacies. Management of vegetable diseases is a challenge in the vegetable production. The existing diseases and its effective management by combining various methods have been recommended for superior production. The use pattern and the residue work on the pesticides have been reviewed in Nepal to furnish current status and situation on issue of pesticides. Alternative eco-friendly ways using bio-pesticides to control pest have been suggested for increasing agricultural production. A study carried out at Nepal Academy of Science and Technology (NAST) and University of Nebraska Lincoln for Aflatoxin content in foodstuffs were presented to disseminate safe foods and feeds in Nepal.

Post-harvest loss of vegetables during handling is very high in Nepal. Possible preventive measures are highlighted to control nutrients and post-harvest loss. Nepal Living Standard Survey and Nepal Public Health Survey both have depicted the alarming situation of malnutrition among children and woman in Nepal. Improving kitchen and rooftop gardens for production of fruits and vegetables for regular supply of nutritious food is recommended to combat the alarming situation of nutrition insecurity. Commercialization of off-season vegetables has huge potential for profitable business in Nepal and therefore further promotion of vegetable based enterprises is urgent need for vegetable marketing. Since the book provides a comprehensive overview of vegetables in the context of Nepal, I truly hope that all of you will enjoy reading this book. Your valuable comments and opinions are welcome for the improvement in future editions. I would like to express my sincere thanks to the members of the editorial team and the authors of the chapters for their tireless efforts in bringing out the book in this impressive form.

**Dr. Sunil Babu Shrestha**
Vice-Chancellor
Nepal Academy of Science and Technology (NAST)

June 10, 2021

# Foreword

Nepal, though centrally located in Himalayan belt, embraces diversity in physiographic and geo-climatic conditions ranging from terai (65m) to high altitudinal belts covered with snowy carpets. It's an amazing land for agricultural diversity, loaded with many exotic and indigenous food or vegetable crops of different genera and species. So to say, some of these biota are the special boon for specified people as specialized food, dwelling in different altitude and areas.

The present book "Comprehensive Insights in Vegetable of Nepal" is an extensive compilation of papers written by well known Nepalese authors working in different fields of vegetable corps. The book is divided into 21 chapters with compilation of papers in each chapters in different topics related to vegetables. The papers high light on vegetables of different families, different genera and species embracing non flowering plants (mushrooms) to highly evolved taxa. Some where the wild crops and spices are also included. They include the oriental and western local names, areas of high production, trade and amount of consumption, harvesting techniques, post harvest storage, infectious diseases and their control mechanism, use of biopesticides, mycotoxins present in vegetables and seeds after storage, house garden practices, about enterprises involved and comparison of the food value with worldwide literatures. Nutritional profile involving secondary metabolite and bioactive chemicals present in certain crops and conservation strategies are also provided. Lastly the book comprises citation of Nepalese and other relevant literatures. These papers show that there has been little effort on Nepalese and other relevant literatures. The photographs are also provided for identification as far as possible.

These vegetables crops with their different cultivar strains growing in different altitudes and areas may have different percentages of biochemical compounds, which determine to construct the shape, size, health and strength condition of the body. The genetic control determines are uptake of biochemical compounds and minerals on absorption wherever necessary in the body parts. This idea has been already depicted as slok or hymns in "Shree Madbhawat Gita" that "what you eat and what you think so will be your nature, structure and strength of your body".

The book is helpful to planner, gardeners, cultivators, amateurs, students, researchers, enthusiasts and the lovers of vegetable.

**Dr. Mahesh Kumar Adhikari**
Secretary
Nepal Academy of Science and Technology (NAST)

June 10, 2021

# Preface

Vegetable consumption is rising due to desire for diversity and awareness of nutritional benefits, and it is reflecting the consumer's increased income. At the same time, consumers have a rising concern with product safety issues. These changes have increased pressure on farmers to keep up, with the requirements of good seed, efficient practices, hiring help beyond the family, market awareness, and the ability to provide safe and high quality vegetables. Concept of nutrition security has also embedded in the food security and the importance of dietary diversity for good health has moved to therefore.

Diet and health are, in modern thinking, inextricably linked, forming an inseparable two fold approach. Diet is widely held to influence various bodily functions, with a preventive action against numerous pathologies. Increasing evidence suggests that a healthy eating strategy with increased consumption of plant-based foods plays important roles in the prevention of chronic diseases. The dietary patterns and lifestyle, such as increasing the consumption of fruits and vegetables and more balanced intakes of meat and plant foods, are a practical and effective strategy for reducing the incidence of chronic diseases. Nutrition is both a quantity and a quality issue, and vegetables in all their many forms ensure an adequate intake of most vital nutrients, and phytochemicals which can bring a much-needed measure of balance back to diets contributing to solve many of these nutrition problems.

Knowingly and unknowingly, several agro-chemicals have been used by farmers and traders for better yields and good looking products beyond the discipline of recommendations made by concerned agencies. It has created an accelerated human health hazards. Realizing these facts, there have been growing concerns about importance of good agriculture practice.

A world vegetable survey showed that more than 400 vegetable crops are cultivated worldwide, representing 69 families and 230 genera. There are 55 vegetables crop groups identified as most commonly cultivated vegetable crops in survey conducted by central Bureau of Statistics, Nepal in 2010. The most commonly consumed vegetables comprise leafy vegetables and then followed by vegetable fruits, and vegetables with below ground edible organs. Many vegetable crops have more than one part used. The common food taken by Nepalese is Dal-bhat-tarkari which includes diversity of vegetables. The vegetables diversity thus plays a key role in healthy life. Most of the vegetables are marketed fresh with only a small proportion processed because most vegetables are perishable. Consumption shortly after harvest also guarantees the optimal vegetable quality. In this context, awareness and proper information on use of vegetable is required to tap the socioeconomic and nutritional power of vegetables.

The present book *Comprehensive Insights in Vegetables of Nepal* aims to highlights, collect and analysis data of the present scenario of vegetables from the selected diverse fields of Nepal. It provides a comprehensive overview of vegetables in the context of Nepal from the farmer's land to the household kitchen's table. The book comprises of important areas such as vegetable diversity, seeds, horticulture, agrochemicals, nutrients, metabolites, postharvesting and markets in the framework of Nepal. The publication will be considered as the main source of informations and will be entirely different from other related publications. The book has taken shape from generous contribution of experts who

are experienced and working in their respective fields since longtime. It is a collective effort of scientist and researcher to give upto date knowledge in the concerned areas to generate awareness and provide healthy diet life. This book will be useful for the researchers, policymakers and common people working in the vegetable sectors.

We take the opportunity to thank all the contributors for their efforts in offering up-to-date chapters. Further, we express our sincere thanks to the publisher and the authors of the chapters, whose research work has been cited in the present book. We welcome your comments and thoughts for future editions. We like to acknowledge Nepal Academy of Science and Technology and Chief Faculty of Science, Jaishree Sijapati for encourage and support in publication of the book.

**Sajan Lal Shyaula**
**Gan B Bajracharya**
**Gopal K C**
**Shanta Man Shakya**
**Dilip Subba**

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# Chapter 1

## Research Highlights on Vegetable Crops in Nepal and Probable Future Directions for Improvements

**Shanta Man Shakya**
*Rampur Campus, Institute of Agriculture and Animal Sciences*
*Tribhuvan University, Rampur, Chitwan, Nepal*
Email: santa_shakya06@yahoo.com

*The perusal of productivity data of the vegetable crops in Nepal in the last 7 to 8 years shows that it has almost remained constant dwelling around 13.8 ton/hectare. The import of vegetables has far exceeded the export in the previous several years resulting into large trade deficit. Despite the fact that several agencies in the past extended their support for uplifting the Nepalese vegetable sector and, consequently, we currently have more than 35 open pollinated varieties of commercially and semi-commercially grown vegetable crops being recommended and released as well as around 300 hybrid varieties being registered in the National Seed Board of Nepal, yet we have not been able to harness the enormous hidden potential to even a minimum satisfactory level. Out of several reasons for this, lack of improved technology is one of the major ones. In an effort to raising the production, productivity and quality of vegetable crops, several agencies such as National Agriculture Research Council, University Systems and some private companies have been conducting several researches nationwide with major focus on varietal selection, management aspects including off-season production, plant protection, nutrition, etc. Based on the literature review, it shows that in the future more attention should be given on conservation and maintenance of local germplasms, hybrid breeding including biotechnology, precision and protected cultivation, water management, post harvest handling and processing, value addition and studies on wild plants used as vegetables and nutrient contents of the vegetable crops.*

**Keywords:** Breeding; hybrid varieties; open pollinated varieties; resistant varieties; vegetable crops; yield improvement.

## Introduction

Increased production and productivity of vegetable crops play a vital role in the prosperity of the nation as it is directly linked with the health, improved environment and happiness of the people. Nepal is rich in ecological diversity, biodiversity and edaphic diversity.

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Consequently, it has immense potential for producing all sorts of vegetable crops grown on commercial, semi-commercial and local basis; yet, we have not been able to harness the enormous hidden potential to even a minimum satisfactory level. Out of several reasons for this, lack of improved technology is one of the very important reasons.

In the past, several national and international agencies from India, USA, UK, Switzerland, Germany and Netherland have supported in the development of vegetable sector. Due to the co-ordinated efforts of these agencies, we have currently more than 35 open pollinated (op) varieties of commercially and semi-commercially grown vegetable crops being recommended and released as well as around 300 hybrid varieties being registered in the National Seed Board of Nepal. Except a few $F_1$ hybrid varieties such as *Srijana* of tomato crop, most of the hybrid varieties arebeing imported (NPVSDC, 2018). In 2017/18, the total area, production and productivity of vegetable crops in Nepal were 286,864 hectares (ha), 3,958,230 tons and 13.8 ton/ha, respectively. The perusal of productivity data of the vegetable crops in Nepal in the last 7 to 8 years shows that it has remained almost constant. As far as the vegetable export-import scenario of Nepal is concerned, in 2016/17, the export was 5,717 tons (worth NRs 75,699,000), whereas the import was 169,159 tons (worth NRs 4,582,429,000) (MoALD, 2017). Likewise, the import far exceeded the export in the previous years as well resulting into large trade deficit.

Several institutions have been engaged in vegetable researches in Nepal in order to address the problems related to vegetable crops with an objective of increasing their production, productivity and quality (HRD, 2018). Major institutions involved in the technology generation in the field of olericulture are National Agriculture Research Council (NARC) and University systems including Tribhuvan University (TU), Agriculture and Forestry University (AFU) and Purbanchal University (PU). Major aspects of the past researches have been focused on: varietal improvement, management including off-season production, plant protection, nutrition, etc. Based on extensive literature review, the important highlights of the major researches being carried out in Nepal on common vegetable crops grown in Nepal have been presented crop wise or a group of similar crops under one heading, which also includes all the aspects and disciplines related to the specific crop.

## Research Highlights on Vegetable Crops in Nepal

## 1. Cole Crops

Major crops of commercial importance in Nepal under the cole crop group include cauliflower, cabbage, broccoli and knolkhol. The major researches have been focused on varietal development/improvement, management aspect, disease and pest management, nutritional aspect, growth regulation, post-harvest aspects, etc.

### *Cauliflower*

Currently, out of 4 open pollinated (OP) varieties of cauliflower, *Kathmandu Local* was recommended and released in 1990, whereas *Dolpa Snow Ball* and *Sarlahi Dipali* in 1994. Other 46 hybrid varieties have been registered too (NPVSDC, 2018). Later, *Khumal*

*Jyapu*, an early strain of local cauliflower of Kathmandu valley, was developed by NARC and released in 2015 (NARC, 2016).

Co-ordinated varietal trail of hybrid cauliflower varieties conducted at Regional Agriculture Research Station (RARS), Khajura, Nepal in 2017/18 showed that *Whistler* gave the highest yield of 33.55 ton/ha which was at par with *Sweta*, Sv3630AC and *Snow Crown* (one of the popular $F_1$ hybrids which yielded 26.28 ton/ha) (HRD, 2018). In other hybrid cauliflower evaluation trail at NARC, Khumaltar in 2017, *Giewont* gave the highest average curd weight (1.65 kg) and the highest yield (55.85 ton/ha) followed by *Snow Mystique*, a popular $F_1$ hybrid, with average curd weight of 1.5 kg and yield of 54.52 ton/ha (HRD, 2018).

A study was conducted for two consecutive years of 2015 and 2016 to identify suitable high yielding variety of cauliflower for early season of September-November in the eastern mid hills of Nepal (Poudel et al., 2017). *Snow Grace*, a F1 hybrid, gave the highest average yield of 15.13 ton/ha and the highest average curd weight of 0.49 kg followed by other hybrids *viz. White Top*, *Snow Mystique*, *Snow Crown* and *Jyapu Local*, the most popular Nepali op variety, with average yield of 7.98 ton/ha and average curd weight of 0.27 kg, in descending order of magnitude.

Several researches related to nutritional aspects have been carried out resulting into identification of proper doses of nitrogen, phosphorous, potassium and boron, especially in cauliflower. Boron deficiency in the Nepalese soil is one of the major nutritional problems, especially in cole crops. Among the cauliflower growers in Chitwan, application of around 15-20 kg/ha borax as basal dose is a common practice for optimization of the curd yield. In 2004-2005, a study was conducted on cauliflower (variety *Snowball-16*) at Paklihawa Campus, Rupandehi district to see its response to different doses of boron and phosphorus, and reported the highest curd yield (26.47 ton/ha) (Dhakal et al., 2014). Boron and phorphorus uptake by plants and residual available B and P contents in the soil after the crop harvest were obtained by the application of 1.3 kg/ha B + 60 kg/ha P. Recently, a study on efficacy of boron and vermicompost on cauliflower crop (variety *Khumal Jyapu*) conducted at Lamatar village, Mahalaxmi Municipality, Lalitpur showed that 25 kg/ha borax + 6 ton/ha vermicompost gave the highest curd yield (34.21 ton/ha), which was statistically at par with 20 kg/ha borax + 3 ton/ha vermicompost (31.87 ton/ha) (Chaudhary, 2020).

In 2013-2014, a study on effect of different organic manures as practiced by the farmers in Ilam on the economic yield of cauliflower (variety *Kathmandu Local*) showed that vermi-compost yielded the highest (12.94 ton/ha), followed by poultry manure, mustard oil cake, bansoon and farmyard manure (FYM) in descending order of magnitude (Basnet & Shakya, 2016). Moreover, the days to curd maturity was the earliest (89 days only) with vermicompost treatment as compared to the others.

Response of late cauliflower varieties, three hybrid varieties *viz*. *Snow Mystique*, *Snow Crown* and *Snow Dome*, and an op variety *Madhuri* to different sources of nitrogen were studied at Rampur, Chitwan in 2012-2013 (Karki et al., 2017). The highest economic yield of 30.25 ton/ha was given by a combination of *Madhuri* + 50% N from urea + 50% N through FYM, although it was at par with the treatment combination of *Madhuri* + 100% N from urea (29.75 ton/ha). *Madhuri* yielded the highest (27.78 ton/ha)

compared to other three hybrid varieties. Among the nutrient treatments, combination of FYM and chemical fertilizer produced the highest economic yield.

Effective microorganism (EM) is a microbial inoculant containing several kinds of naturally occurring beneficial microbes used in the treatment of organic manures before using it in organic farming. In a study on late season by using cauliflower of variety *Sweta*, a $F_1$ hybrid, it was reported that application of EM treated FYM at 720 g + 250 g EM treated bokashi plant (bokashi is an organic fertilizer used by farmers) produced higher curd yield of 22.5 ton/ha with the highest benefit cost ratio of 1.68 as compared to use of chemical fertilizer in place of EM treated bokashi or as compared to use of reduced level of EM treated bokashi (Pradhan, 2011).

In post-harvest study of cauliflower crop, variety *Snow Mystique*, conducted at AFU, Rampur, Chitwan, the use of low density polyethylene film of 25 µ was found more suitable for modified atmospheric packaging than polypropylene films (Adhikari et al., 2018).

In the mid hills and Kathmandu valley of Nepal, club root disease in cauliflower crop can cause curd yield loss of 18 to 87%, or even 100% in severe condition (Timila, 2006). In an effort to address this problem, different management practices were tested (Gautam, 2020). The result showed that the yield of cauliflower was found significantly highest with the treatment of lime (4 g/L of water) + nebijin (flusulphamide fungicide) (3 g/L water) during transplanting with 36.83 ton/ha curd yield, followed by the treatment of sole nebijin (32.93 ton/ha). Curd diameter was also found the highest (20.28 cm) in lime + nebijin treated plot than that of nebijin (20.07cm).

## *Cabbage*

An op variety *Copenhagen Market* was recommended and released in 1994 and 31 $F_1$ hybrids were registered (NPVSDC, 2018). Varietal selection, and disease and pest managements have been the main focus of research works in cabbage crop.

In an evaluation trail of hybrid cabbage, *Green Coronate* yielded the highest (110.63 ton/ha) followed by *Millenium III* (63.81 ton/ha) and *Shaurya* (61.02 ton/ha) (HRD, 2018). Likewise, among 5 hybrid varieties of cabbage crops tested at Khumaltar in 2017, *Wonder Ball* gave the highest average head weight (2.01 kg) and the highest yield (87.42 ton/ha), followed by *Omphalus* and *Green Coronate* (a popular hybrid, with 1.67 kg average head weight and 68.4 ton/ha yield) (HRD, 2018).

In 2008, six commercial op varieties of cabbage *viz*. *Golden Acre*, *PusaMukta*, T-621, *Pride of India*, *Copenhagen Market* and *Pusa Drum Head*, and two popular $F_1$hybrids *viz*. *Green Coronet* and *Express* were evaluated in winter season in Chitwan, Nepal (Kaphle, 2009). *Green Coronet* gave the highest yield (62.15 ton/ha) with a benefit cost ratio of only 4.39, whereas *Golden Acre* which produced only 50.61 ton/ha head yield, showed the highest benefit cost ratio of 5.77. It was because the price of *Golden Acre* during its harvesting time (i.e. 23$^{rd}$ December) was higher than the price at the time of harvest of *Green Coronet* (i.e. 1$^{st}$February). Kafle has worked on efficacy of different organic manures on cabbage varieties in winter season at farmer's field in Phulbari VDC, Chitwan (Kafle, 2010). The hybrid *Green Coronet* produced 66.12 ton/ha as compared to 59.41 ton/ha by *Copenhagen Market* (an op variety). Poultry manure, applied at 10.4 ton/ha

(2% N content), produced the highest marketable yield (74.84 ton/ha) followed by chemical fertilizer applied at N/P/K, 120:60:60 kg/ha. However, the highest benefit cost ratio of 3.69 was given by chemical fertilizer, followed by poultry manure with benefit cost of 3.42 only. But, the fear was that the use of chemical fertilizer might not sustain the soil fertility.

A comparative study between seasonal and off-season cabbage production in Amargadhi municipality, Dadeldhura district in Nepal showed that the average marketable head yield was 13 ton/ha and 11 ton/ha, with average benefit cost ratio of 1.78 and 2.51, respectively (Joshi, 2018). Higher market price in the off-season was main reason for the difference in the benefit cost ratios.

Cabbage butterfly, diamondback moth and aphid are big problems in eastern hills of Nepal for growing cabbage in off-season (April-October) when the price of cabbage is very high. Sufficient protection from these pests are provided by application of either of commercial azadirachtin formulation 0.003%, aqueous tobacco + soap decoction, deltamethrin 0.003 %, malathion 0.05%, endosulfan 0.15%, or dichlorovos 0.075% twice forth nightly, one week after cabbage seedling transplanting (Bajracharya et al., 2011).

## *Broccoli*

Currently, only 11 $F_1$ hybrids of broccoli crop has been registered and there is no officially recommended and released broccoli variety in Nepal (NPVSDC,2018).

Giri (2007)has studied the response of two popular varieties of broccoli *viz*. *Calabrese* and *Green Sprouting* to different levels of nitrogen at Rampur, Chitwan, and reported that *Green Sprouting* gave a higher total curd yield of 10.81 ton/ha than *Calabrese* with 9.30 ton/ha only. Also, increased doses of N application increased total broccoli curd yield, the highest being 14.67 ton/ha with 200 kg/ha N application, the highest N dose among the treatments. Likewise, Bhattarai and Mishra (2012) have reported that, in broccoli study in Bhaktapur district, integrated application of ½ NPK + 2 ton/ha vermicompost gave the highest per plot yield of 14.2 kg/4 $m^2$plot,which was at par with ¾ NPK+1 ton/ha vermicompost (11 kg/4 $m^2$ plot). Furthermore, after the harvest of broccoli, the highest available residual N (339.23 kg/ha) was recorded in the soil of the plot which received 4 ton/ha vermicompost treatment, but the available residual P and K were the highest in the plot which received ½ NPK+2 ton/ha vermicompost. Later, Lamichhane et al. (2015) have studied the effect of different sources of N on the yield and quality of broccoli varieties at Gaidakot, Nawalparasi district, and reported that variety *Green Sprouting* produced the highest total yield (25.1 ton/ha) among the varieties and N source (50% from urea + 50% from vermicompost) yielded the highest (28.55 ton/ha) among the N sources. However, with regard to the quality, variety *Calabrese* along with 100% N application either from vermicompost or FYM was recommended from the point of view of taste and physiological weight loss.

In a study conducted in Rampur, Chitwan (it naturally possesses a warmer climatic conditions), Dawadi (2005) reported that in case of broccoli variety *Calabrese*, removal of terminal head at marketable stage for fresh consumption produced significantly the highest seed yield of 1,148 kg/ha along with a higher 1,000 seed weight and satisfactory percentage of seed germination. Besides, 1.285 ton/ha fresh broccoli was also harvested.

The total monetary value through this treatment, from both seeds and fresh broccoli, was NRs 550,525/ha, which was the highest among the treatments. In other study of broccoli variety *Calabrese* by Khanal (2013) in Chitwan condition itself, the results showed that the highest seed yield of 1,296 kg/ha obtained in the treatment as 200 kg/ha N + 15 kg/ha borax + main head of broccoli crop plant harvested at marketable stage for consumption. This seed also exhibited higher seed test weight, percent germination and seed vigor index. In another seed production study, impact of different species of honeybee on seed production of broccoli variety *Calabrese* was carried out at Rampur, Chitwan in 1999. The highest seed yield of 425.88 g/plot of 7.2 $m^2$ was recorded in *Apismellifera* pollination, followed by *Apiscerana* with a seed yield of 417.5 g/7.2 $m^2$ and under natural open pollination with 332.75 g/7.2 $m^2$ plot. Seed obtained from *A. mellifera* pollination was also better in quality as compared to others (Devkota et al., 2003).

In case of knolkhol crop, no research work has been reported yet.

## 2. Solanaceous Fruit Vegetable Crops

The major commercial crops under this group of vegetables are tomato, brinjal, chilli and sweet pepper which are grown at highly commercial to commercial levels in Nepal. In the past, there have been several researches depending upon the commercial importance of the crops in Nepal. Major focus has been on seasonal and off-season production with a view to increase production and benefit. The major highlights have been presented below.

### *Tomato*

Tomato is the most remunerative high valued crop in the present Nepalese context. Major researches on tomato crops in Nepal have been focused to increase productivity and quality of the product. Currently, four op varieties of tomato have been recommended and released for general cultivation by the farmers, and one Nepali hybrid (*Srijana*) and 27 imported $F_1$ hybrids have been registered in the National Seed Board, Nepal (NPVSDC,2018). *Srijana* was registered in 2010 and recommended for cultivation in mid-hill and terai (plane) areas with potential yield of 105-110 ton/ha. It has gained high popularity among the farmers.

#### *Tomato esearch highlights under Horticulture Research Division, NARC*

Tomato researches conducted by Horticulture Research Division (HRD), NARC, Khumaltar, Lalitpur reveals that among seven hybrid combinations evaluated against late blight and septoria spot diseases, HRA-14 × HRD-7, HRA-20 × HRD-1, HRA-20 × HRD-2 and HRA-20 × HRD-6 were least affected by late blight disease as compared to *Srijana*. HRA-14 × HRD-7 and HRD-20 × HRD-2 were least affected by septoria spot disease as compared to *Srijana* and other hybrids. However, HRA-13 × HRD-7 gave the highest yield of 3,765 g/plant, followed by HRA-20 × HRD-1 (3,086 g/plant) and HRA-14 × HRD-7 (3,039 g/plant) (HRD, 2018). Likewise, in co-ordinated varietal evaluation trail of nine op tomato varieties performed at Khumaltar, STM-02 was least affected by late blight disease, whereas CLN-2545B, HRD-109, STM-02 and *Pusa Ruby* were least affected by septoria spot disease. In another co-ordinated advance varietal trail on nine op tomato varieties, STM-02 was least affected by late blight, followed by *Pusa Ruby* and

$V_5$; whereas CLN-2545B, HRD-109, STM-02 and *Pusa Ruby* were least affected by septoria. HRD-109 gave the highest yield (51.3 ton/ha), followed by HRDTOM-099 (45.39 ton/ha), whereas *Pusa Ruby* gave only 28.13 ton/ha yield. These superior varieties are under further investigation at the farmers' fields (HRD, 2018).

From the study performed in central mid-hill region condition, Shrestha et al. (2017a) have reported that tomato hybrid HRA-14 × HRD-7 gave the highest yield of 82.12 ton/ha (average of two years 2070 and 2071 BS) with late blight resistance and least incidence of septoria leaf spot, powdery mildew and leaf minor, followed by HRA-13 × HRD-7 (65.19 ton/ha) and *Srijana* (42.61 ton/ha).

To identify suitable varieties for terai and hill conditions, studies were conducted during 2014-2015 in RARS, Nepalganj and HRD, Khumaltar including *Pusa Ruby*, $V_5$ and 10 tomato varieties STM-01 to STM-010 received from the SAARC countries (Shrestha et al., 2017b). In Nepalganj, STM-08 gave the highest yield of 69.76 ton/ha, followed by *Pusa Ruby* (55.85 ton/ha) and $V_5$ (53.27 ton/ha). In Khumaltar, STM-08 gave 27.08 ton/ha and *Pusa Ruby* 23.35 ton/ha only, whereas the highest yield was produced by STM-03 (34.74 ton/ha).

Similarly, a study was conducted in RARS, Khajura, representing mid-western terai region of Nepal, to identify better op and hybrid varieties of tomato for the region (Rawal et al., 2017). Among op varieties tested, STM-10 gave the highest yield of 45.47 ton/ha with a better tolerance against late blight disease, whereas checked variety *Pusa Ruby* produced only 51.08 ton/ha, although it had the highest vitamin C content (25.56 mg/100g) at harvesting time. Among the hybrids tested in the same study, the hybrid 20×2 gave the highest yield (118.88 ton/ha) along with resistance against late blight, whereas the checked hybrid variety *Srijana* produced only 107.14 ton/ha, which was at par with the hybrid 20×2, both having same score for late blight resistance.

Lamichhane et al. (2017) did a survey in the year 2015 on profitability assessment of tomato cultivation under plastic house in western hills (in Lamjung, Kaski and Parbat districts) of Nepal. Maximum monthly production was achieved during Mangsir-Magh and minimum during Chaitra-Asar, whereas maximum price was fetched during Sawan-Kartik (NRs 60-100/kg) and minimum during Chaitra-Asar. The maximum yield recorded under plastic house was 8 kg/plant, whereas it was only 5 kg/plant in the open field condition. So, they have suggested synchronizing production period with the period of high price.

Pandey and Chaudhary (2004) have evaluated 8 tomato varieties at 3 planting dates for commercial production at 2,330 m amslin Rajikot, Jumla district. *Monprecos* produced the highest yield of 33.70 ton/ha, 17.92 ton/ha and 9.63 ton/ha in March, April and May seedings, respectively, followed by CL-1131 and *Pusa Early Dwarf*. Thus, *Monprecos* could be considered for cultivation under Jumla condition. Later, during 2002-2003 (2058-2059 BS), Poudel et al. (2004) evaluated different tomato hybrids including different Nepali hybrids at a site of farmer's field in rainy season in the western hills of Nepal. In plastic house, the potential yield of N-162 (Nepal Seed Industry Tomato Hybrid-162) was 140 ton/ha, followed by LTH-62 (Lumle Tomato Hybrid-62) with 111.11 ton/ha. Among the tested hybrids, N-162 produced the highest yield of 83.3 ton/ha and was found to be resistant against bacterial wilt at farmers' fields in Kavre district.

To study the effect of drip irrigation on tomato crop under plastic house condition, an experiment was conducted at Khumaltar, Lalitpur (NARC, 2016). The treatment gave 20% more yield with 30% water saving as compared to the control (hand watering). It also saved labor cost significantly. Such studies done at Agriculture Research Station (ARS), Belachapi, Dhanusha also gave similar results.

To study the effect of plant growth hormone on summer season tomato crop production under central terai region, an experiment was conducted at Parwanipur, Bara (Shrestha et al., 2011b). The results showed that application of vegimaxat 0.125 mL/L two times on tomato plants increased the yield by 25.2% as compared to the control. It was followed by application of gibberellic acid ($GA_3$) at 50 ppm with 20.5% yield increased over the control. Also, vegimax and $GA_3$ applications provided additional benefit of NRs 81,972 and 69,250 per hectare, respectively.

Four tomato varieties *viz*. *Thims-1*, *Thims-16*, *Srijana* and *Bishesh* were evaluated under plastic house in three different altitudes *viz*. 1,600 m amsl (at Naudanda), 1,200 mamsl (at Hemja) and 800 m amsl (at Tutunga) in Kaski district (Pokharel & Paudyal, 2011). Under plastic house, higher yields were recorded with increased altitude in all the varieties. *Thims-1* gave the highest yield of 7.92 kg/plant (285 kg/36 plants), followed by *Srijana*. However, the yield of *Srijana* was most stable across the altitudes. Furthermore, application of mustard cake resulted into the lowest nematode score both in root and stem, and imida gold was found to be the most effective insecticide for controlling white fly and leaf minor. In another study conducted in 2009 in Naudanda, Dhikupokhari VDC, Kaski district, under plastic tunnel house *Thims-16* produced the highest yield (330 kg/plot), followed by *Srijana* (311 kg/plot) (Simkhada & Pokharel, 2012). In addition, 50 g of ormicomin (neem cake based fertilizer) per plant was found to be most effective to control nematode, followed by poultry manure and mustard cake.

During 2001-2003, HRD seems to have initiated studies towards developing Nepalese tomato hybrid varieties (Regmi et al., 2007). In this process, 18 tomato inbred lines were collected from various sources including popular local landraces. Their naming as HRD-1 to HRD-18 were done, their various morphological traits were studied and inbred lines were maintained, 18 hybrid combinations were made, and heterosis study of 10 $F_1$hybrids was done. Consequently, different inbred lines having various traits are available for developing $F_1$hybrid combinations and various studies are continuing. Several hybrids and op varieties suitable for poly house and open field have been identified.

Studies by HRD before 2007 on comparison of Nepali hybrid varieties *viz*. *Srijana*, *Laxmi*, *Dhana* and *Indra* with other imported hybrids available in the market, under plastic house for off-season production of tomato showed that the average yield of *Srijana* (3.56 kg/plant) was comparable with other hybrids in the market (HRD, 2007). In Lamatar and Dukuchhap sites, *Srijana* gave the second highest average yield of 4.62 ton/ropani under plastic house in rainy season, followed by *Laxmi*, *Indra* and *Dhana*. Though the yield of *Bishesh* (4.83 ton/ropani) was higher than *Srijana*, it was less tolerant to bacterial wilt and late blight in comparision with *Srijana* (HRD,2007).

During 2000-2002, 51 varieties of tomato including op and imported hybrids were tested in Khumaltar, Lalitpur under poly house and open field conditions for 3 years

(Budhathoki et al., 2007). Based on the results, the overall conclusion was that the tomatoes produced in poly house were better in terms of yield as well as quality than that of open field. In poly house, the yield of hybrids ranged from 7.1 to 12.7 ton/ropani, while op varieties ranged from 3.6 to 8.2 ton/ropani. On the other hand, in open field condition, the yield of hybrids varied from1.1 to 4.4 ton/ropani, whereas op varieties varied from 1.3 to 2.1 ton/ropani.

### *Tomato research studies done in other institutions including universities*

Several studies have been done with an objective of finding of better genotypes providing better yields, resistance against diseases and insect pests and other stresses, better quality, etc. In this process, 59 tomato lines inclusive of local landraces, commercial varieties, breeding lines and some $F_1$ hybrids were collected from different locations. They were characterized, evaluated and maintained at Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan during 1992-1993. Average fruit yield varied from 38 g/plant in L-418 to 1.79 kg/plant in CL-1131. There were lots of variation among the genotypes with respect to various morphological, maturity and yield attributing traits (Shakya et al., 1995c).

In the summer of the year 2000, Bhurtyal et al. (2004) evaluated 14 heat tolerant tomato genotypes at Rampur, Chitwan and reported that there was a lot of variations with respect to the morphological and yield attributing traits; yield ranged from 40.53 ton/ha to 9.83 ton/ha. The better performing genotypes were *Bari-5* (40.53 ton/ha), followed by *Bari-4* (39.83 ton/ha), CLN-1621-L (31.33 ton/ha) and *Lapsigede* (29.84 ton/ha), and these genotypes also possessed good fruit qualities. In another study, response of commercial tomato varieties to staking and pruning on yield and incidence of diseases and pests were studied at Rampur during the winter of 1993-94 (Shakya et al., 1995b). In general, staking and pruning treatments increased the yield than the control. In particular, the variety *Pusa Early Dwarf* produced the highest total as well as marketable yield (23.07 ton/ha and 18.57 ton/ha, respectively) with staking + pruning to 2 stems/plant. In *Pusa Ruby* variety, the average fruit size was > 34 and 23.5 g with and without pruning, respectively. Likewise, in *Pusa Early Dwarf*, average fruit size was 33.2 g with pruning and 23.2 g without pruning, and average fruit size was 23.2 g with staking and 16.7 g without staking. Also, the highest disease control (34.4%) was achieved with staking + 2 stems/plant.

Sherchan et al. (2004) studied the effect of EM and other nutrients on *Roma* variety of tomato at Khumaltar condition in March 2000 and reported that EM+ compost gave the highest yield (16.31 ton/ha), followed by compost alone, while the control gave the least. EM helped to activate the function of compost and made nutrients available to the plant.

Effect of compost water extract on late blight disease of tomato was studied at Rampur, Chitwan during 1989-1990 (Dahal et al., 1993). Results indicated that there was no effect of compost extract on the late blight disease incidence on tomato crop. In earlier study, 2 sprays of ridomil reduced the disease intensity of late blight in tomato variety *Pusa Ruby*.

Effect of manures, fertilizers and nematicide on the tomato fruit yield and incidence of nematodes was studied at Rampur, Chitwan during winter of 1993-1994 (Pokharel et

al., 1995). Tomatoes grown with organic manuring were harvested earlier with more early and total yield was compared to the tomato grown with the use of chemical fertilizers. Additionally, goat manure yielded higher (16.84 ton/ha) marketable yield, followed by poultry and FYM, although the differences were not significant statistically. Galling index due to root knot nematode was low with carbofuran treatment (furadan-3G at 2 kg active ingredient/ha as basal application), followed by poultry manure, goat manure and FYM.

In an overview of tomato improvement for fruit quality and disease resistance with integrated approach based on replicated trails conducted at North Carolina State University, USA, Panthee (2016) reported that marker-assisted selection of varieties associated with disease resistance genes, such as tomato mosaic virus or tomato spotted wilt virus was useful to advance the genetic materials from early generation, especially when there was limited opportunity to select genotypes under enough inoculum pressure. Also, development of suitable molecular markers associated with quality traits could minimize the time involved in assessing tomato lines for phenotypic traits for selection.

In 2004, a study on response of spring season tomato to different mulching material s*viz*. rice straw, rice husk, black plastic and red plastic was done in Gulariya, Bardia district, Nepal (Shrestha et al., 2008). Rice husk gave the highest yield (31.35 ton/ha), followed by rice straw and red plastic, the differences being non-significant. Black plastic gave comparatively higher yield than the control, the least yielder. Bhusal (2010) reported that in plastic house, *Srijana* variety of tomato grown in bags (filled with 50 kg soil from rice field) produced 300 kg tomato/40 plants compared to 278 kg/40 plants grown in the pits on the ground. In bag culture, tomato was harvested 2 weeks to 1 month earlier than the harvesting in the field.

Gyawali et al. (2012) studied for 2 years (2010 and 2011) on development of integrated pest management (IPM) package for tomato variety *Srijana* in Dhikurpokhari VDC, Kaski district using biofertilizer having mixtures of different microorganisms, biopesticide (having mixes of various organisms) and farmer's practice, and reported that the combined application of biofertilizer + biopesticide gave the highest average fruit yield (91.1 kg/plot) compared to all other treatments.

Shrestha and Kang (2016) compared the performance of cocopit (an organic and renewable substrate) and rockwool (a non-biodegradable, inorganic and non-renewable substrate that commercially used) on tomato hybrids, and reported that both of these media produced similar yield. It is indicated that cocopit could be a replacer of rockwool, which is commonly used currently.

Khatri-Chhetri and Shrestha (2000) have studied on the natural occurrence of bacterial wilt (*Ralstonia solanacearum*) on *Pusa Ruby* variety of tomato in Rampur, Chitwan during summer of 2001 (Chaitra-Asar/April-July). Highest percentage of plants wilted between the last week of Baisakh and 2$^{nd}$ week of Jestha. Fruit rot at matured stage and viral disease also appeared as serious problems which caused up to 62.7% fruit rot and 80% plant infection, respectively. Thus, the result showed that cultivation of this variety in summer in plain areas of Chitwan might not be profitable and needed to explore other suitable genotypes.

In 1999, isolates of tomato bacterial wilt were collected from different locations of seven districts in Nepal to study their aggressiveness on the tomato crop (Timila, 2008). The isolate of Myagdi district overcame the resistance of moderately resistant variety L-180 and resistant variety L-986 resulting into rapid disease progress in these varieties. Later, Rijal (2020) studied on management of root knot nematode in *Srijana* variety of tomato under plastic house in Bhaktapur district and reported that Serenade ASO (a bio-product of a broad-spectrum fungicide called *Bacillus subtilis* strain QST-713) spray at 2mL/plant gave the highest yield (112 kg/plot) as compared to the control (79.5 kg/plot).

Lamsal (2020) has studied on bio-rational management of tomato leaf minor (*Tuta absoluta*) in Surkhet, Nepal by using botanicals and biopesticides, and reported that alternate sprays of *Bacillus thuringiensis* var. *Kurstaki* at 2 g/L water and neem kernel extract (azadirachtin 0.15 EC) at 4 mL/L water gave the highest yield (40.99 ton/ha) with less (1.8%) fruit damage and the highest benefit cost ratio, whereas the control treatment gave 23.78 ton/ha only with more (6.24%) fruit damage and the least benefit cost value.

GC and Thapa (2000) have studied on monitoring and management of tomato fruit worm (*Helicover paarmigera*) on *Pusa Ruby* variety of tomato in Chitwan condition. March-April was the peak period for the activity of this pest which coincided with the flowering and fruiting of the crop. Bio-neem applied at 5mL/L water at weekly interval gave the highest number of marketable fruits as compared to thiodan, nuclear polyhydrosi virus (NPV) and control in descending order of magnitude. Later, Paneru et al. (2004) in their evaluation work of biopesticides against fruit worm in tomato variety CLN-2026-D under Khumaltar condition reported that the spray of biopesticide (*Bacillus thuringiensis*) at 3 g/L water gave 38.22 ton/ha, which was at par with the highest yield (44.49 ton/ha) given by the chemical pesticides thiodan 35EC and cypermethrin 10 EC sprayed alternately. Thus, *B. thuringiensis* could be a better replacer of chemical pesticides.

Bhattarai and Subedi (1999) have studied post-harvest transportation losses in tomato as influenced by maturity stages at fruit harvest in Syangja district. Fruits harvested at matured green stage, pink stage and full red ripe stage showed 5.3, 19.3 and 24% losses, respectively.

Chapagain et al. (2018) have studied the effect of chemical pre-treatments on quality of solar-dried tomato slice and reported that the pre-treatment of 0.2% solution of potassium metabisulphite (KMS) indicated higher maintenance of carotenoid (33.54 mg/100 g) and lycopene (16.21 mg/100 g) contents while vitamin C content was higher (34.65 mg/100 g) in 1% KMS + 0.2% $CaCl_2$ solution pre-treatment. Also, non-enzymatic browning (NEB) was found to be the least (0.51) in pre-treatment of 1% $CaCl_2$ solution compared to no pre-treatment (NEB value being 1.01).

## *Chilli*

Currently, one op variety of chilli named *Jwala*, released in 1994, has been recommended, whereas 15 $F_1$ hybrids have been registered (NPVSDC, 2018).

Several trails have been conducted in NARC to identify high yielding varieties of hot and sweet pepper. In March 2017, at HRD, Khumaltar, 6 varieties including commercial variety *Pusa Jwala* were evaluated for their performance and reported that AVPP-9905 gave the highest yield (23.03 ton/ha), followed by HRDCH-1014 (17.22 ton/ha) and

AVPP-9813 (15.37 ton/ha), whereas *Pusa Jwala* gave only 13.31 ton/ha and *Kantipure* (6.89 ton/ha), the least (HRD, 2018). Also, *Kantipure* was most susceptible to leaf spot disease. Earlier, in October 2016, in RARS, Surkhet, 6 hybrid chillies were tested. *Hot Shot* gave the highest yield (14.56 ton/ha), followed by *Fire Camp* (13.42 ton/ha) and *Many Sunny* (11.9 ton/ha), while the varieties NSI-1701 and *Pusa Jwala* gave 8.54 and 7.37 ton/ha, respectively (HRD, 2018). *Pusa Jwala* also took more days to 1st harvesting. Similarly, in February 2017, in RARS, Nepalganj, 5 hybrid varieties of chilli together with *Pusa Jwala* were evaluated. NS-1701 gave the highest yield (12.76 ton/ha), followed by SV-1947-HA (11.68 ton/ha) and SV-1551-HA (11.61 ton/ha), whereas *Pusa Jwala* gave only 4.58 ton/ha, but the latter was the earliest in first fruit harvesting (HRD, 2018).

Dahal et al. (2006) did field evaluation of 13 chilli genotypes under hot and dry conditions of western terai (Khajura, Banke district) during spring-summer of 2005, and reported that the variety *Mr. Lee No. 3 Selex* gave the highest marketable yield (9.07 ton/ha), followed by *Susan's Joy* (6.05 ton/ha) and CCA-119A (4.01 ton/ha), whereas *Jwala* gave 2.71 ton/ha only. However, the vitamin C content of NS-1701 was the highest (173.6 mg/100 g), followed by PBC-142, *Mr. Lee No. 3 Selex* and *Jwala* (113.7 mg/100g).

Chaudhary et al. (2006) studied the effect of plant growth regulators on yield and quality of chilli at Rampur, Chitwan during winter-summer of 2003-2004. The foliar application of 2,4-dichlorophenoxy acetic acid (2,4-D) at 2ppm produced the highest yield (21.46 ton/ha), followed by triacontanol at 5 ppm (20.58 ton/ha), whereas the control gave 15.29 ton/ha only. The highest net profit was also shown by 2,4-D treatment. However, the ascorbic acid content was the highest with the application of $GA_3$ at 10 ppm. Similarly, Bishwakarma (2006) studied the response of different chilli genotypes including *Khairapur Local* variety to the spray of 5 ppm triacontanol in spring-summer in Khajura, Banke and reported that NS-1701 and *Pusa Jwala* responded positively to the triacontanol spray giving higher marketable and total yield of red ripe fruits compared to the control. Also, the varieties *Soldier* and *Khairapur Masino* were found to be most suitable for dry chilli production.

A study on quality aspect, such as content of bioactive compounds which work as antioxidants, of 6 different varieties of chilli of Nepal as affected by harvesting time based on maturity stage (fully matured and fully ripened) was conducted (Subedi et al., 2018). Ascorbic acid, β-carotene, total carotenoids, oleoresin and antioxidants content increased with advanced maturation, whereas polyphenols and flavonoids contents decreased. The variety *Akabare* was the best from the point of view of flavonoids, polyphenols, β-carotene and total carotenoids contents. HRD-CHI-012 and HRD-CHI-009 were the best for ascorbic acid and dry matter contents, respectively.

Timila (2013) did evaluation of 13 selected chilli genotypes against Pythophthora blight in farmer's field with the history of this disease in Lalitpur district during 2011-2012. NS-1701, *Tara*, *Angarika* and *Chandani* were found resistant, whereas NS-214, NS-1101, *Goli* and *Premium* were moderately resistant. Lesser fruit rot was found in *Agarika*, NS-1701 and *Pusa Jwala*. It was suggested that resistant to moderately resistant genotypes could be used as one of the tools in the integrated disease management of this disease. Likewise, Timila and Manandhar (2016) studied the bio-control efficacy of *Trichoderma* spp. against Phytophthora blight of pepper in the field condition of Luvu,

Latitpur during 2012-2013. T-69, the local isolate of *Trichoderma harzianum*, was found better in reducing the Phythophthora blight incidence and severity, and yield increased by 57% over the control treatment.

## *Sweet pepper*

In case of sweet pepper, only one op variety *Californe* has been released and recommended in 1994, and *Sagar* (op variety) and NS-632 ($F_1$ hybrid variety) have been registered (NPVSDC, 2018).

Morphological characterization of 6 capsicum genotypes (HRD CAP-001, and HRD CAPs 003 to 006) including *California Wonder*, a commercial variety, has been done for assessing their breeding potentials (HRD, 2018). Average fruit weight varied from 42.5 to 126.1 g and average yield/plant from 1.45 kg to 2.46 kg.

In 1988-1989, at Rampur, Chitwan, effect of two sowing dates and fertilizer doses on the yield of sweet pepper, variety *California Wonder*, was studied (Sharma & Baral, 1993). August 31 sowing with N/P/K, 160:160:160 kg/ha gave the highest fruit yield (25.5 ton/ha) and the highest seed yield (201.8 kg/ha). Also, the first sowing and N/P/K, 160:160:160 kg/ha was better than other treatments. Shrestha (2011) assessed the effect of human urine, urea, compost and their combination on yield and quality of sweet pepper, variety *California Wonder*, in Setidevi VDC, Kathmandu. The treatment 50% N from urine + 50% N from compost gave the highest yield (12.47 ton/ha) and the highest benefit cost value (3.16). However, the longest postharvest life and the highest consumer's acceptability was observed with 100% N supplied through compost. Similarly, Ghimire (2011) studied the effect of different organic manures and their combinations with urea on sweet pepper, variety *California Wonder*, and reported that the treatment in which the required N was fulfilled 50% from FYM + 50% N from urea gave the highest fruit yield (13.53 ton/ha) as well as the highest benefit cost value (5.32)

Poudel (2005) assessed the effect of plant growth regulators on the yield of sweet pepper during spring-summer at Kalyanpur, Chitwan and reported that the spray of 2,4-D at 2.5 ppm gave the highest fruit yield (6.01 ton/ha). However, the application of triacontanol at 2.5 to 10 ppm gave the higher ascorbic acid content (82.75-83.38 mg/100 g) than other treatments tested.

Sharma and Adhikari (1993) conducted a standardization trail on sweet pepper (variety *California Wonder*) seed production at Rampur, Chitwan during the winter season in 1987-1988. The highest seed yield (332.8 kg/ha) was recorded in the treatment combination of 30 × 30 cm spacing + no thinning of the fruits in the plant, followed by the same spacing but thinning up to 5 fruits/plant with seed yield325.4 kg/ha. However, the treatments did not show considerable effect on the 1,000 seed weight.

## *Brinjal*

In Nepal, currently only one op variety *Nurki* has been recommended and released in 1994 and seven $F_1$ hybrids have been registered (NPVSDC, 2018).

In 1988-1989, Khatri-Chhetri and Shrestha (1993) studied the effect of 11 planting dates on yield of brinjal, variety *Nurki*, during summer, rainy and winter seasons in

Sundarbazar, Lamjung district. Although the yield was not significantly different, planting on 25th April gave the highest yield (27 ton/ha), followed by February 6th (26 ton/ha), whereas the lowest yield was recorded on 26th July (9 ton/ha) and 25th June (11 ton/ha) plantings. Likewise, Khatri-Chhetri et al. (1988) studied the performance of 7 brinjal genotypes during rainy season of 1986 in Sundarbazaar, Lamjung and reported that the yield varied from 1.6 ton/ha to 37.8 ton/ha. *Nurki*, a commercial variety, gave the highest yield (37.8 ton/ha), followed by the local variety (20.7 ton/ha). Also, *Nurki*, *Pokhara Local* (Lurke) and local varieties exhibited a high degree of resistance to bacterial wilt, fruit rotting and fruit cracking.

Srivastava (2012) studied on the response of 25 brinjal varieties to growing seasons and nutrient management levels in Khajura, Banke distrct for two consecutive years in between 2004-2006. The average marketable fruit yield was 28.72 ton/ha with 8.43% borer affected fruits/plant during rainy-winter season, whereas 11.74 ton/ha yield and 29.72% borer affected fruits/plant was recorded in summer-rainy seasons. *Neelam Long*, *Pusa Kranti* and *Pusa Purple Long* were the higher yielders with 25.03, 24.13 and 23.96 ton/ha, respectively. Application of FYM at 30 ton/ha+ N/P/K, 80:60:60 kg/ha was found to be enough for optimum yield at Khajura condition. During summer-rainy season, *Pusa Purple Long* and *Neelam Long* produced 19.62 and 13.75 ton/ha, respectively. During rainy-winter season, *Neelam Long* and *Pusa Purple Long* produced 36.56 and 29.5 ton/ha, respectively.

Sharma (2006) studied the effect of growth regulators on the yield of brinjal at Khajura, Banke in summer-rainy season of 2004. The growth regulators had no significant effect on the fruit yield. However, *Pusa Purple Long*, a popular variety, gave higher yield with the application of 40 ppm naphthalene acetic acid (NAA) as compared to others. Similarly, the variety *Pusa Purple Cluster* gave higher yield with the application of benzyl adenine purine (BAP) at 30 ppm.

Devkota et al. (2000) studied on the integrated management of shoot and fruit borer on 6 varieties of brinjal at Rampur, Chitwan. They reported that shoot damage varied from 3.56% in *Gorkha Local* and *Chitwan Local* varieties to 9.45% in *Nurki* variety, whereas percentage fruit damage with netted treatment varied from 20.53% in *Nurki* to 45% in *Began Neelam* varieties and the percent fruit damage without netted treatment varied from 20% in *Nurki* to 52.1% in *Began Neelam*.

Shoot and fruit borer of brinjal has been a major problem (Shrestha et al., 2019). It can be controlled by integrated management approach, such as dipping of the seedlings in spinosad solution (0.3 mL/L water) before transplanting, collecting infested shoots and fruits and destroy, using lucin-lure pheromone at 10 m interval, spraying *B. thuringiensis* var. *Kursataki* (2 g/L), spraying spinosad 45 SC (0.3 mL/L) or nimbicidin (2 mL/L).

## 3. Bulb Crops

The major crops under bulb crops are onion and garlic in Nepal. Onion is propagated either by seed or bulb. Garlic is propagated only by bulb or clove and no varieties have been released or registered. The major highlights of the researches in Nepal have been presented hereunder.

## *Onion*

Currently, *Red Creole* is the single op variety released and recommended in 1990 for cultivation and one op variety *Nasik-53* and 5 $F_1$ hybrids are registered (NPVSDC, 2018). It is estimated that more than 50% of our demand is fulfilled by import, especially from India and China. In this crop, we have several problems including low yielding and limited number of varieties. With an objective of increasing production and productivity, HRD have undergone several research activities.

During 2017/18, HRD introduced 5 onion genotypes from Asian Vegetable Research and Development Center (AVRDC), Taiwan and tested (HRD, 2018). In Khumaltar condition, the genotype AVON-1052 gave the highest yield (36.8 ton/ha), followed by AVON-1027 (36.6 ton/ha), AVON-1028 (33.7 ton/ha), AVON-1016 (28.1 ton/ha) and *Red Creole* (20.7 ton/ha), the least. In Dailekh condition, AVON-1027 gave the highest yield (41.07 ton/ha), followed by *Red Creole* (34.1 ton/ha), AVON-1016 (32.07 ton/ha), AVON-1028 (29.23 ton/ha), AVON-1052 (27.13 ton/ha) and AVON-1103 (25.27 ton/ha). The bulb colour of AVON-1016, AVON-1103 and *Red Creole* was red, whereas that of AVON-1027, AVON-1028 and AVON-1052 was yellowish. The pungency level of bulb was low in AVON-1052, high in *Red Creole* and medium in rest of the genotypes. Further testing at farmers' fields is needed. In another co-ordinated varietal trail in Dailekh, Ti-172 gave the highest bulb yield (72.26 ton/ha), followed by *Light Red* (51.71 ton/ha), *Baitadi Local* (42.92 ton/ha) and *Red Creole* (36.88 ton/ha) (HRD, 2018).

Lohani et al. (2017) tested 5 varieties of onion including *Baitadi Local*, 3 commercial and one hybrid under 5 dates of planting ranging from Asoj 15, 2072 to Mangsir 30, 2072 BS in Horticultural Research Station (HRS), Dailekh. They have reported that, although statistically not different, Kartik 30$^{th}$ planting gave the highest yield (31.41 ton/ha) as compared to others. However, the yield was significantly the lowest (5.38 ton/ha) on Mangsir 30$^{th}$ planting. Among the tested varieties, although non-significant, *Baitadi Local* gave 22.57 ton/ha, which was at par with other varieties including hybrid *Sensu*. The Asoj 15$^{th}$planting gave the highest bolting (30.27 in number) which went on decreasing with later dates of plantings and there was no bolting in the last date, i.e. 30$^{th}$ Mangsir planting.

For off-season (November-December) onion production in Kavrepalanchowk district, a study on the variety *Agrifound Dark Red* was conducted to verify and upscale the off-season technology at Mangaltar (750 m amsl), Pinthali (950 m amsl) and Mamti (650 m amsl) by sowing the seeds on 7$^{th}$ June, 2012 and planting on 20$^{th}$ July, 2012, and reported that the marketable bulb yields were 19, 25 and 21 ton/ha, respectively, whereas in case of green top harvest, the green leaf yields were 6.0, 8.5 and 6.5 ton/ha, respectively (HRD, 2014). The green leaf harvest took 2.5 to 3 months only.

Studies of verification trails on off-season onion bulb production of the variety N-53 through the sets in Lamatar and Dukuchhap VDCs of Lalitpur district revealed the yields of 35.51 and 44.58 ton/ha marketable onion bulb, respectively (HRD, 2007). The farmers of these VDCs very much preferred this technology because of a high profit. Earlier in 2000-2003, Budathoki et al. (2004) assessed the effect of 6 planting dates (ranging from 24 June to 10 September) of onion sets (variety *Nasik Red*, and 1.5-2.0 cm diameter of the set) on off-season onion bulb production in Khumaltar condition (1,360 m amsl), Lalitpur

district. The combined results of 4 years showed that 25th July planting gave the highest marketable bulb yield (5.8 kg/plot of 1.05 $m^2$), followed by July 9th and June 24th. It took 60-65 days for bulb maturity and harvesting.

Likewise, Poon et al. (2013) studied the effect of dates of seedling transplanting of *Red Creole* variety of onion in the field of ARS, Dailekh during 2010/11 to 2011/12 and found that December 15 planting gave the highest bulb yield (29.99 ton/ha). However, November 30 produced the highest number of marketable bulbs (377,500/ha).

Likewise, (Pun, 2004) evaluated 3 elite varieties of onion for off-season production by sets at farmer's field under Dailekh condition, and reported that *Nasik Red* produced the highest bulb yield (15.66 ton/ha) and it was rated as superior for high as well as early onion production through sets during late autumn and winter seasons.

Rokaya and Bhadari (2004) compared off-season onion bulb yield of different varieties by using sets in river basin environment in mid- and far-western regions of Nepal. On-farm studies done in different locations of Doti, Surkhet and Dailekh in the two consecutive fiscal years 2000/01 and 2001/02 showed that, except in the first year in Surkhet in which *Nasik Lal* gave the highest yield, *Nasik Red-53* gave the highest onion bulb yielding from 8.01 to 20.27 ton/ha in all the locations, in both the fiscal years among the tested varieties. Also, this variety was better for green vegetable. Thus, adoption of *Nasik Red-53* has been suggested for higher income generation for the study areas. Shakya et al. (2015) studied the effect of the density of planting of *Agrifound Dark Red* and N-53 varieties of onion on the bulb size and yield of marketable bulbs in Nawalparasi district. They reported that the most preferred sized bulbs (3.5 to 5 cm) were produced at the spacing of 10 × 8 to 10 × 10 cm, which also showed the same trend on marketable bulb yield as well.

## *Nutrition of onion crop*

Gautam and Pande (2005) studied on the nitrogen and boron nutrition on *Kharif onion N-53* variety in Kanpur, India, in June, 2000. Application of 1.1 kg/ha B + 150 kg/ha N gave the maximum yield (35 ton/ha).

## *Onion seed production*

Panthee (1998) studied the storage life of onion seeds as affected by threshing, cleaning and drying methods from June 1995 to April 1998, and found that a combination of hand threshing + seed cleaning by water dipping + 8 hours sun drying was the best in terms of having higher percentage of seed germination.

Basnet et al. (2017) studied the influence of nitrogen and bulb size on the quality of seeds produced from off-season onion variety *Bemausami-1* at Sukranagar, Chitwan, and reported that the qualitative parameters of the seeds were better when bulbs having diameter more than 3 cm were planted with 160 kg/ha N.

## *Onion crop protection*

The first outbreak of downy mildew in onion was noticed at the end of 1999 in Nepal (Timila, 2005). Survey of the farmers' field in different locations of Kathmandu, Lalitpur, Kavre and Sindhupalchowk showed 5 to 90% disease severity with 100% crop losses in some of the pockets.

## *Onion research studies in the university system*

In 1993/94, there were a series of studies on onion crop in IAAS, Rampur, Chitwan for the evaluation of different varieties. Sharma et al. (1995a) evaluated 25 tropical onion cultivars. The hybrid *Rio Roji Red* produced the highest bulb yield (24.9 ton/ha) with the highest average bulb weight (58.5 g), but were sweet in taste, whereas *Red Creole*, a popular variety, gave 11.4 ton/ha only with 27.7 g bulb weight with moderate pungency. Also, Sharma et al. (1995b) further studied the effect of sowing dates on some economic traits of 3 onion cultivars and reported that *Red Creole* produced significantly higher yield of 26.1 ton/ha in September sowing, followed by 23.3 ton/ha in October sowing. November sowing drastically reduced yield in all the three varieties.

In another study performed in 1994/95, ten exotic tropical varieties including *Red Creole*, a commercial variety, were evaluated and found that *Tropical Gold* produced the highest marketable bulb yield (29.9 ton/ha), followed by *Red Creole* (22.8 ton/ha), both being at par statistically. However, *Red Creole* gave the highest number of marketable bulbs per plot (105.6), followed by *Tropical Gold* (100.3) (Sharma & Neupane, 1996).

Acharya (2007) has evaluated 6 landraces of onion collected from different districts of Nepal, along with 3 common cultivars of onion, and reported that the marketable bulb yield of *Doti Local* (10.81 ton/ha), *Dapcha Local* (9.49 ton/ha) and *Dadeldhura Local* (9.13 ton/ha) was comparable with *Red Creole* (13 ton/ha). Also, majority of the local landraces possessed special quality, such as higher total soluble solids (TSS), dry matter content as well as non-bolting traits which could be utilized for onion crop improvement in the future.

Dahal (2009) evaluated the performance of 3 onion varieties including *Dadeldhura Local* at different levels of nitrogen in Chitwan and Nawalparasi for off-season bulb production. *Agrifound Dark Red*, with application of 120 kg/ha nitrogen, produced the highest marketable bulb yield (27.6 8 ton/ha) under Chitwan condition and 26.43 ton/ha under Nawalparasi condition. The highest benefit cost ratio (3.06) was given by *Agrifound Dark Red* + 120 kg/ha N in Chitwan condition.

In 1998-1999, at Rampur, Chitwan, Subedi et al. (2000) did irrigation studies on *Red Creole* variety of onion by planting the seedlings on 17$^{th}$ December, 1998. The highest bulb yield (17.19 ton/ha) was given by the treatment of the amount of water applied equal to 100% of water loss shown by evaporation pan + 10 days gap or interval between two successive irrigations.

Pokharel et al. (1995) studied on the diseases associated with 25 genotypes of onion at Rampur, Chitwan during 1993-1994. Damping off was observed in the nursery beds. Purple blotch was severe in the transplanted field. However, varieties *viz*. *Ben Shemen*, *Australian Brown*, *Kathmandu Local* and *Numex BR-1* had less infection of this disease. Among the plant parasitic nematodes, *Tylenchorhynchus* seemed to be important genus associated with onion crop in Rampur.

Baral et al. (1995) studied the response of *Red Creole* variety of onion crop to micro-nutrients in Rampur, Chitwan during 1993-1994, and reported that most of the yield reductions were associated with inadequate supply of FYM, copper and zinc in the soil.

Jha et al. (1995) did preliminary assessment of the quality parameters in 3 onion cultivars at Rampur, Chitwan and found that cv. *Red Creole* was better in % dry matter and % edible parts. Also, it was mild in pungency.

### *Onion seed production in university system*

Gurung (2012) studied the effect of plant spacing and size of off-season onion bulb (variety used *Agrifound Dark Red*) being planted on yield and quality of seed produced in Palpa district and reported that the highest seed yield (437.85 kg/ha) was recorded in the treatment 30 × 20 cm spacing and >3-4 cm bulb diameter. Also, better quality parameters of the produced seeds were recorded under higher spacing and bigger sized bulb being planted for seed production.

Ghimire (2002) studied the influence of altitude, storage duration and packing materials on storability of onion seeds. The results showed that the germination of the seeds tested after 9 months was the highest (69.8%) in Kathmandu (1,300 m amsl), followed by 68.19% in Pokhara (900 m amsl) and 57.69% in Narayanghat (400 m amsl). Also, the germination, vigor and viability decreased with the increasing period of storage in all the locations. The germination percentage tested after 9 months storage in plastic containers, laminated pouch, 250 gauge polyethylene bag, cloth bag and plastic sack were 72.50, 70.25, 63.25, 54.69 and 52.25%, respectively.

## *Garlic*

Garlic research has received less attention in spite of the fact that it is one of the very high value crops which is used either as green vegetable in immature stage or bulb as spice which is very expensive in the Nepalese market.

A study conducted about varietal trails in Rajikot, Jumla, in which 13 genotypes *viz*. ARM-1 to ARM-9 including some local varieties were included, resulted a highest yield in ARM-1 (28 ton/ha), followed by *Lekpor* (27.25 ton/ha), *Malikabot* (25.77 ton/ha), *Chinese* (24.35 ton/ha), ARM-4 (20.83 ton/ha), *Mugu Local* (17.44 ton/ha), *Kathmandu Local* (16.57 ton/ha), ARM-7 (11.42 ton/ha), *Holeri* (10.06 ton/ha), and the least was 5.58 ton/ha in ARM-5 (NARC, 2018). Earlier, it was reported that the genotype ARM-1 produced the highest yield at HRS, Rajikot, Malepatan and National Ginger Research Program (NGRP), Salyan, followed by ARM-27 at ARS, Belachapi, Dhanusa district (NARC, 2016). In another study, 10 garlic genotypes of ARM series including local variety were tested in HRS, Dailekh in 2017/18 (NARC, 2018). The bulb yield varied from 1.9 to 7 ton/ha. The highest yield of 7 ton/ha was given by ARM-1, followed by ARM-38 (6.1 ton/ha) and ARM-25 (3.6 ton/ha), whereas local variety gave 2.4 ton/ha only.

Earlier, Subedi and Bhandari (2004) conducted a trail on 10 dates of planting ranging from 18$^{th}$ September to 30$^{th}$ January at 15 days intervals for four consecutive years of 1996 to 2000 using cv. *Melpani Local* of garlic in ARS, Surkhet (580 m amsl). Garlic cloves planted on 18$^{th}$ October produced the highest bulb yield (7.6 ton/ha), followed by 3$^{rd}$ October (6.9 ton/ha) and 2$^{nd}$ November (6.6 ton/ha).

## 4. Cucurbits

There are several vegetable crops under this group including cucumber, gourds (bitter, bottle, sponge, ridge, pointed, balsam, etc.), watermelon, muskmelon, chayote, etc. having different level of commercial importance in Nepal.

### *Cucumber*

An OP variety *Kusle* was released in 1994 and recommended for cultivation. Another OP variety *Bhaktapur Local* has been registered in 2013. Altogether 36 $F_1$ hybrid varieties have been registered. Nepalese farmers prefer to use hybrid varieties imported from outside. Keeping this in view, HRD initiated hybrid breeding in cucumber since 2011 (2065 BS) (HRD, 2018). Among several crosses, HRD-CUC-004 × HRD-CUC-001 (as female gynoecious parent × male monoecious parent) has been selected as a promising hybrid and named as *Madhu*. It has around 1:21 male to female flower ratio with 500 g average fruit weight and yield potential of 100-110 ton/ha.

Furthermore, HRD has 15 cucumber accessions (4 gynoecious and 11 monoecious lines) collected from different sources during different years. Their characterizations have been done and their seeds maintained at HRD, Khumaltar for further improvement works (HRD, 2018).

In March 2018, 17 cucumber genotypes (12 newly developed hybrids, 4 OP varieties and 1 Indian hybrid) were evaluated in both open and plastic tunnels at Khumaltar, Lalitpur (HRD, 2018). In open field, HRD CUM 004 × 001 gave the highest yield/plant (10.86 kg/plant), followed by HRD CUM 009 × 001 (9.8 kg/plant) and HRD CUM 006 × 003 (9.3 kg/plant), and the lowest yield by *Dynasty* $F_1$ (1.91 kg/plant). However, in the plastic tunnel, HRD CUM 006 × 003 gave the highest yield/plant (10.19 kg/plant), followed by HRD CUM 009 × 003 (9.9 kg/ha) and HRD CUM 006 × 008 (9.5 kg/ha), and the lowest by *Dynasty* (2.24 kg/ha), although it was the earliest variety which took only 49 days to 1$^{st}$ harvest.

In a study at RARS, Tarahara, HRD CUC 009 × 003 gave the highest total yield (43.54 ton/ha), followed by HRD CUC 009 × 007 (42.32 ton/ha), *Dynasty* $F_1$ (41 .07 ton/ha) and HRD CUC 006 × 003 (40.23 ton/ha) and these were all at par; the lowest total yield was recorded in HRD CUC 003 (*Dadeldhura Local*) (25.2 ton/ha) and HRD CUC 001 (*Bhaktapur Local*) (26 ton/ha). In the studies carried out at 3 different locations in Dhankuta *viz.* National Citrus Research Program (NCRP), Mr. Ghanashyam Ghimire's field and Mr. Narmada Poudel's field using HRD CUC 009 × HRD CUC 003 gave 78.46, 107.08, and 85.86 ton/ha fruit yields, respectively (HRD, 2018). On the otherhand, HRD CUC 003 (DL) gave 29.76 ton/ha at NCRP, Dhankuta and 43.02 ton/ha at Mr. Ghanashyam Ghimire's field, while no fruit was produced at Mr. Dhan Kumar Rai's field in Dhankuta (for which no reasons were furnished in the report).

Earlier in 2013, HRD conducted farmer's field verification trail at Mamti, Vimkhori VDC, Kavrepalanchowk district (650 m amsl) and reported that *Bhaktapur Local* gave 16.2 ton/ha fruit yield, followed by *Kusle* (12.7 ton/ha) and *Dynasty* (5.8 ton/ha) (HRD, 2014). The farmers and consumers liked *Bhaktapur Local* more because of good taste, long fruit and summer season produce and higher price.

In 2007 and 2008, Piya et al. (2011) studied the effect of 5 planting dates on *Pakhribas Local* cucumber. Falgun planting gave the highest fruit yield (48.8 ton/ha), followed by Chaitra planting (3.7 ton/ha). However, average fruit length was maximum from Baisakh and minimum from Asar plantings.

In 2003, at Lumle and Hemja of Kaski district, 7 cucumber varieties including 5 local varieties and some imported hybrids were evaluated under plastic house during late winter-summer season. In Lumle, *Mahico Green Long* yielded the highest (45.5 ton/ha), which was at par with *Kusule* (39.7 ton/ha) and *Rishing Local* (30 ton/ha). In Hemja, *Bhaktapur Local* gave the highest yield (60.97 ton/ha), which was at par with *Paundur Local* (58.13 ton/ha) and *Mahico Long Green* (51 ton/ha). Benefit cost analysis showed that the plastic house culture of cucumber gave 90.7% increase in the yield and 22.96 % increase in net income as compared to the open field cultivation (Upadhyay et al., 2004).

In 2009, Smallholder Irrigation Market Initiative (SIMI) conducted adaptive research on plastic mulching in cucumber variety *Bhaktapur Local* in Lalitpur, Kavre and Kaski districts. Growth, flowering and fruiting were faster with mulching which helped early harvest and fetched higher price. The mulched plot had no weeds and needed irrigation 2 days alternate, while non-mulched plot needed 1 day alternate irrigation and weeding. Also, the average yield was 180 kg and 135 kg per plot in mulched and non-mulched plots, respectively. This technology was proved good for water scarcity areas (Bhusal, 2010).

### *Cucumber researches under university system*

For high temperature and long day photoperiodic tolerance, Shakya et al. (2006) did screening of 139 cucumber germplasms collected from within and outside Nepal by sowing seeds in May, 2000 at Lamjung campus, Lamjung and Yampaphant, Tanahaun. Characterization of the germplasms was done for various traits. At Yampaphant, *Dhankuta Local* collected from Makwanpur and Dhankuta gave the highest yield of 4.69 and 4.50 kg/plant, respectively. At Lanjung campus, *Mahyco Green Long* gave the highest yield of 1.77 kg/plant, followed by *Bhaktapur Local* (1.67 kg/plant). The collection from Suryapur, Chitwan gave the highest yield of 2.59 and 1.17 kg/plant at Yampaphant and Lamjung, respectively.

Similarly, in April-July 2000 at Yampaphant, Tanahun district, Sharma and Bhattarai (2006) evaluated 4 exotic hybrids and OP variety *Bhaktapur Local* during summer-rainy season. The hybrid *Malini* gave significantly higher fruit yield (69.6 ton/ha) with higher number of fruits (252,000/ha) and earlier harvesting (1$^{st}$ picking at 42 days). *Bhaktapur Local* remained androecious and did not produce fruits during summer-rainy season. Subedi (2020) evaluated 7 cucumber genotypes including one op and 6 newly developed hybrids under open field and plastic house at Khumaltar, Lalitpur. Average yield was 104.44 and 57.67 ton/ha under plastic house and open field condition, respectively. Among the 7 genotypes, HRD CUM 004 × 001 gave the highest yield (106.86 ton/ha). Among all the treatment combinations, the highest yield of 141.77 ton/ha was given by HRD CUM 004 × 001 under plastic house condition.

Bhusal (2020) studied the severity of infestation of cucurbit fruit fly on various cucurbits in Kamalamai municipality, Sindhuli district. The result showed that cucumber ranked 1$^{st}$, followed by bitter gourd, pumpkin, sponge gourd and bottle gourd.

### *Other cucurbits*

GC (2000) reported that in bitter gourd, the variety *Creeper* gave higher marketable fruit yield than *Green Long*. The fruit fly damage was 42% in *Creeper* and 68% in *Green Long*. The pheromone trap was effective when used at earlier stage of the crop.

In chayote crop, Gautam and Sharma (1995) reported that the post-harvest weight loss was higher in immature fruit. Fruit sprouting was delayed in immature fruits as compared to over matured ones. For storage, harvesting of fruits 25-30 days after anthesis was suggested. In other experiments, the chayote fruits were stored in pit, cold storage at 7.5 °C, dry rice husk and control for 4 weeks, and the recorded weight losses were 5.23, 12.6, 14.31 and 40.2%, respectively. However, sprouting was a serious problem in all the storage methods. In the same study, blanched (5 min) and unblanched chips prepared from the fresh fruits were sun dried and the percentage recovery of dried chips was 6.5 to 9.69%. However, unblanched chips were superior to blanched ones in quality. Rana et al. (1995) reported that the infestation of nematodes *viz*. *Meloidogyne arenaria*, *Meloidogyne javanica* and *Meloidogyne incognita* could limit the successful cultivation of chayote under Rampur, Chitwan condition. In 1993-1996, Neupane et al. (2006) reported that in Chitwan, Lalitpur and Parbat districts, fruit fly and cotton aphid were the serious pests. The chayote bearing fruits with tough fruit skin, dense and long spines were less susceptible while spineless and smooth fruits were the most susceptible.

In Khumaltar study, HRD reported that in zucchini squash (variety *Bulam House*), compost at 2kg/pit gave the highest yield (4.46 ton/ropani), followed by compost at 2 kg/pit + bokashiat 400 g/pit (4.4 ton/ropani), whereas compost + chemical fertilizer and simply chemical fertilizer gave 4.24 and 4.04 ton/ropani, respectively (HRD, 2007).

In summer squash crop, Bhatt (2020) studied on the management of red pumpkin beetle in the variety *Grey Zucchini* under field condition in Jorayal rural municipality, Doti district and reported that malathion 50 EC (2mL/L water), neemax (a neem based bio-pesticide) (5 mL/L water) and jholmal (200 mL/L water) resulted into 11.95, 11.52 and 10.97 kg/plant fruit yield and these treatments were at par. However, the calculated benefit cost ratio was the highest (3.39) in neemax treatment.

## 5. Root Crops

In Nepal, the major crops under root vegetable crops include radish, turnip and carrot. In Nepal, the major focus of the researches in these crops has been towards variety selection, nutritional requirement, management aspect, off-season production, disease and pest management, etc.

### *Radish*

Four OP varieties *viz*. *Mino Early*, *White Neck*, *Pyuthane* and *Chalis Dine* have been released in 1994 (*Mino Early* in 1990) and other 2 OP varieties *viz*. *Tokinasi* and *Dhankute* have been registered in 1994. Ten $F_1$ hybrids and 2 OP varieties are being registered (NPVSDC, 2018). The major research highlights of the radish crop are presented below.

HRD evaluated 5 radish cultivars *viz*. HRD RAD 001 (*Mino Early*), HRD RAD 002 (*Okura*), HRD RAD 003 (*Pusa Chetaki*), HRD RAD 004 (*Chalis Dine*) and HRD RAD

005 (*Mayasige*) at different research stations and reported that HRD RAD 005 gave the highest yield at Khajura (41.3 ton/ha), Tarahara (21.79 ton/ha), Parwanipur (30.28 ton/ha), and Dailekh (79.2 ton/ha) except at Khumaltar where it was 2nd highest yielder (60.74 ton/ha). Thus, HRD RAD 005 proved to be the highest yielder in most of the locations including hills and terai (Gautam et al., 2017; HRD, 2018).

Sah (2002) assessed the effect of 3 sowing dates on 7 varieties of radish at Rampur, Chitwan. *Chinese-1* produced the highest yields (32.5 ton/ha on September 9th sowing and 36 ton/ha on November 9th sowing). *Mino Early* produced the highest yield (42.6 ton/ha) on October 9th sowing, followed by *Chinese-1* (37.9 ton/ha). *Cherry Belle*, a European type, produced the lowest marketable yield, but it was suitable for salad purpose, harvested within 22-30 days after sowing and fetched higher price.

Adhikari (2006) reported that in the western Chitwan 13.33% of the farmers used borax at 5 to 45 kg/ha in radish crop, while 26.66% used multiplex. However, the field experiment showed that 15 kg/ha borax along with 20 ton/ha FYM was optimum for maximization of radish yield.

Poon et al. (2004) reported that in *Mino Early* variety in ARS, Dailekh, the closest spacing of 45 × 45 cm gave significantly the highest seed yield (2070.48 kg/ha), but the 1,000 seed weight (20.7 g) was similar with other spacings. Similarly, Shrestha and Shakya (2004) reported that in *Chalis Dine* variety tested at Rampur, Chitwan, the highest average seed yield (652 kg/ha) was given by non-detopping +50 days old transplant, followed by de-topping +40 days old trasplant (573 kg/ha), whereas the lowest yield (353 kg/ha) by de-topping + direct seed sowing. The increased transplanting age reduced seed germination percentage in case of non-detopping, whereas it increased in case of de-topping. Highest 1,000 seed weight was recorded with non-detopping +60 days old transplant. Thus, adopting non-detopping along with root transplanting, at 40-60 days after seed sowing, was suggested for higher seed yield and better quality in Chitwan condition.

Poon (2005) studied the economic returns of *Mino Early* variety of radish seed production intercropped with legume crops in ARS, Dailekh in 2001 and 2002. Radish seed crop + S-9 variety of bush bean gave the highest seed equivalent yield (2.069 ton/ha), green bean pod yield (7.012 ton/ha) and net return (NRs 212,591/ha), followed by bean variety *Gaint Stringless* + radish seed crop with net return of NRs 194,779/ha. Likewise, Poon and Chalise (2016) reported that N/P/K, 100:50:75 kg/ha supplied through jiwamrit cum mulching gave remarkebly higher seed yield (1,317.56 kg/ha) as compared to other treatments in *Mino Early* variety in ARS, Dailekh. Similarly, Poudel (2005) studied the economics of radish seed production in Dadhikot VDC, Bhaktapur and found that the average seed yield was 36.2 kg/ropani, average cost was NRs. 2,174.44, average revenue was NRs 3,331.30 and the gross margin was NRs 1,156.86. Also, the gross margin from radish seed was 5.61 times more than that of competing crops.

## *Carrot and Turnip*

In carrot crop, currently, only one OP variety *Nantes Forto* has been recommended and released in 1990 for cultivation. Another popular OP variety *New Koroda* has been registered in 2010. Other 4 hybrids have also been registered. In case of turnip crop,

*Purple Top* was recommended and released in 1990 and *Kathmandu Red*, a selection from local Gante turnip population, having red skin and white flesh inside, was released and recommended in 2016 (NPVSDC, 2018).

In 2006/07 at Rampur, Chitwan, Uprety (2007) reported that in variety *New Kuroda* 50 kg/ha N + 30 ton/ha FYM produced the highest marketable root yield (19.84 ton/ha), although it was at par with 25 kg/ha N +20 ton/ha FYM (18.07 ton/ha). However, significantly higher root forking (26.56%) and green shoulder (20.74%) were observed with 75 kg/ha N + 20 ton/ha FYM, whereas maximum cracking (28.07%) was recorded in 25 kg/ha N + 20 ton/ha FYM.

In 2005/06, at Rampur Chitwan, Poudel et al. (2015) studied the effect of seed primings on germination, field emergence and yield of two varieties of carrot. *New Koroda* exhibited higher seed vigour index, faster early emergence, the highest field emergence and plant stand and higher economic yield (22.13 ton/ha root) in 24 hours seed soaking in tap water as compared to control (i.e., without seed priming). In the variety *Nantes Fancy*, it showed faster early emergence, the highest field emergence, higher plant stand and higher economic yield (17.69 ton/ha) in 12 hours seed soaking at 40 °C warm water compared to control (no priming).

Chaulagain et al. (2012) did the value chain analysis of carrot seed production in Jumla district. Altogether, 388 households were involved in this enterprise and the average productivity was 35-40 kg seed/ropani. The study showed that congenial policies on production and marketing of carrot seed were needed to augment income generation in marginalized and poor communities.

In 2011, HRD evaluated 4 turnip genotypes including *Purple Top* as standard in Khumaltar, Lalitpur and reported that HRD TUR 001 gave the highest yield (29.91 ton/ha) and the highest average edible root weight (224.45 g), followed by *Purple Top* (24.93 ton/ha) with average edible root weight of 187 g (HRD, 2014).

## 6. Okra Crop

*Parvati*, an OP variety of okra crop, was recommended and released in 1994. *Arka Anamika* is another popular op variety which was registered in 2010. *Jaya*, a hybrid, has also been registered.

In 1989, Singh (1993) assessed the effect of nitrogen and spacing on okra (variety *Pusa Sawani*) in Paklihawa, Rupandehi district. The highest fruit yield was recorded at the spacing of 30 × 15 cm with the application of 60 kg/ha N. In 2003, at Rampur Chitwan, Acharya and Shakya (2004) assessed the effect of bio-regulators on spring-summer okra. The highest fruit yield (29.98 ton/ha) was given by application of triacontanol (0.5 mL/L water) which was 16.72% more than control. Furthermore, this treatment gave higher early yield (300.66 g/m$^2$ in the first 15 days harvest), although it was at par with $GA_3$ treatment. It was suggested that due to easiness in using and handling, triacontanol could be a promising growth regulator for the farmer's use. In 2007, Chapagain (2008) tried 4 dates of sowings on 5 okra varieties in spring-summer season at Rampur, Chitwan. Sowing on 17$^{th}$ March gave the highest yield (27 ton/ha), whereas 2$^{nd}$ March gave the least (22.1 ton/ha). The hybrid variety *Anokhi* gave the highest yield (27.64 ton/ha) and

*Parvani Kranti* the least (22.73 ton/ha). *Anokhi* sown on 17th March gave the highest yield (29.81 ton/ha), although it was not significant statistically.

In 2007, Yadav (2007) in his monitoring and management study of okra jassid in Janakpur reported that jassid was a key pest of okra in the study area during rainy reason. Derisom (2mL/L water) gave the highest fruit yield (15.69 ton/ha), followed by dimethoate and margosom (1,500 ppm azadirachtin) used at 3mL/L water with fruit yield 14.96 and 13.32 ton/ha, respectively. Same trend was shown in the case of seed yield e.g. 559.37, 508.36 and 446.51 kg/ha, respectively.

In 2014, at RARS, Khajura, Banke district, Khadka (2016) evaluated 31 okra genotypes against yellow vein mosaic virus and its management during the rainy season. *Arka Anamika* was the only which was found immune against this disease. Application of 25% cypermethrin EC (2 mL/L water) gave the highest total fruit yield (4,981 g/plot), which was, however, at par with nylon net protected treatment and vikron-H (a bio-pesticide) spray. It was suggested that integrated approach using resistant variety, regular spraying of avoiding vectors and use of nets should be adopted.

In 2013, at Rampur Chitwan, a study was done on the effect of apical toping (5 cm tip of the plant was cut 30 days after seed sowing) and different number of fresh fruit pickings on seed yield of okra, variety *Arka Anamika*, and its quality (Gautam, 2015). Seed yield was significantly higher (12.48 quintal/ha) in apical topping compared to no-apical topping (10.96 quintal/ha). Number of fresh fruit pickings did not significantly affect the seed yield, although 2 fruits picking gave higher seed yield compared to other pickings. Thus, apical topping with 2 fruits picking was suggested for higher seed yield under Rampur, Chitwan condition.

Paudel (2020) studied on eco-friendly management of okra shoot and fruit borer in Sainamaina-5, Rupandehi district by taking a popular variety of okra *Arka Anamika*. The percent fruit damage (weight basis) by the pest was the least (7.98%) in 18.5% chlorantraniliprole SC (0.3 mL/L water) treated plots compared to 11.38% damage recorded with the treatment of *B. thuringiensis* var. *kurstak i* 0.5% wettable powder at 2 g/L water, whereas the damage in the control was 19.01%.

## 7. Leafy Vegetable Crops

The major leafy vegetable crops under this group consist of broad leaf mustard (BLM), cress, spinach, methi, lettuce, amaranthus, etc.

Four OP varieties of BLM have been recommended and released: *Khumal Chaudapaat* in 1990, and *Marpha Chaudapaat*, *Khumal Ratopaat* and *Tankhuwa* in 1994. Other 4 OP BLM *viz*. *Gujamujje Rayo*, *Dude Rayo*, and other two have been registered. In case of cress, local OP variety *Thimi Chamsur* was registered in 2018. In case of spinach, *Hari Pate*, an OP variety, was recommended and released in 1994, whereas *Patane Palungo*, a local OP variety, was registered in 2018 (NPVSDC, 2018).

HRD evaluated 7 genotypes of BLM at different stations. HRD BLM 004 gave the highest yield at Khumaltar (55.14 ton/ha), Parwanipur (19.79 ton/ha) and Lumle (31.85 ton/ha) (HRD, 2018). Thus, HRD BLM 004 performed the best in all the tested locations.

Earlier in 2014, HRD evaluated 31 BLM genotypes collected from the farmer's fields, Kathmandu market and released/registered varieties by sowing in Aswin, Kartik and Mangsir in the high hill (1,850 m amsl) (HRD, 2014). Overall results showed that leaf yield/$m^2$ decreased from Aswin sowing to Mangsir sowing. Likewise, days to 50% bolting also decreased from Aswin to Mangsir. However, all the genotypes reached to 50% bolting by the end of Chaitra. Few genotypes yielded better even in short span of time and thus suggested for further promotion. In another study on the effect of 3 elevated temperature regimes (within full and half open top chamber along with open field as control) on yield of BLM, varieties *Marpha Chaudapaat* and *Khumal Ratopaat*, no significant change in the yields noticed indicating that a small change in growing temperature could not bring significant effect on BLM leaf yield (HRD, 2014). Similarly in another study, direct seed sowing and transplanting method were tried under 3 growing condition *viz*. complete rain shelter, agro-net 50% and open condition in summer. The highest leaf yield (948 g/$m^2$) was given by transplanting method under complete rain shelter. In general, the leaf yield in summer was much lower than in the normal season (HRD, 2014).

In 2016-2018, Bhattarai et al. (2018) assessed the effect of organic and conventional nutrient management on BLM in Dakshinkali municipality, Kathmandu, and reported that integrated application of ¾ NPK + 1.5 ton/ha vermicompost yielded the highest (24.22 ton/ha), followed by ½ NPK + 3 ton/ha vermicompost (23.56 ton/ha). During dry summer period, Khatiwada (2008) studied the effect of whole plant or periodic harvesting of BLM leaf (variety *Marpha Broad*) and planted at 9 different spacings in the south facing slope of ARS, Pakhribas, Dhankuta (1,750 m amsl) for 3 consecutive years (2000-2002). Periodic harvesting yielded more green leaves compared to whole plant harvesting. The highest yield (42.74 ton/ha) was recorded in periodic harvesting at 45 × 10 cm spacing. The highest unmarketable yield was recorded in closest spacing (15 × 10 cm) with periodic harvesting.

In 1995/96, Panthee (1999) studied the seed dormancy of BLM (variety *Marpha Local*) collected from Salija (2,000-2,200 m amsl) and garden cress (variety *Kathmandu Local*) collected from Deupur (1,000-1,200 m amsl). Immediately after harvest, the seeds were subjected to study at Lumle center, Kaski (1,670 m amsl). Dormancy intensity was 94% in BLM and more than 95% in cress. Average dormancy period in BLM was 38 weeks and that of cress was 24 weeks. In BLM, the treatment pre-chilling of seed at 5-7 °C for 5 or 7 days + 0.2% solution of potassium nitrate or pre-chilling alone gave around 90% seed germination. In the case of cress, pre-chilling for 3 days + 0.2% solution of potassium nitrate treatment gave around 90% seed germination.

Kangkong (*Ipomea aquatic L.*), also called as Thai spinach, is grown in tropical parts of the world. In Khumaltar, Lalitpur, HRD evaluated 3 kangkong genotypes obtained each from Thailand, Cambodia and Srilanka through Hellen Keller International, Nepal (HRD, 2018). Thailand genotype gave the highest yield (107.5 ton/ha), followed by Bangladesh (104.53 ton/ha) and Cambodian (98.52 ton/ha) genotypes. Likewise, in 2017/18, at Khajura, Banke, the Co-ordinated Varietal Trail (CVT) trail showed that Thailand genotype gave 95.87 ton/ha, followed by Bangaladesh genotype (87.42 ton/ha) and Combodia genotype (82.36 ton/ha).

## 8. Leguminous Crops

Major crops of commercial importance in this group are garden pea, asparagus bean, frenchbean, cowpea and fababean. Three OP varieties of garden pea have been released and recommended in 1994. In case of frenchbeans, *Trishuli Ghiu Simi* and *Jhange Simi* are two OP varieties recommended and released in 1994, and *Mandir*, an another OP variety, has been registered in 2010. In case of asparagus bean, two OP varieties *viz*. *Khumal Tane*and *Sarlahi Tane* have been recommended and released in 1994, and other 4 OP varieties have also been registered (NPVSDC, 2018). There is very limited number of researches done in these crops in Nepal.

### *Garden pea*

Ghale et al. (2004) studied the yield potential of 8 pea genotypes at Malepatan, Kaski in 2000 and 2001. *Sikkim Local* gave the highest pod yield (8.72 ton/ha). However, this variety had vigorous vegetative growth with long vines and thus needed staking unlike *Arkel*.

Poon et al. (2017) evaluated 11 pea genotypes (10 determinate and one indeterminate types) in HRS, Dailekh in 2013/14 and 2014/15. ARS DGP-02 gave the highest green pod yield (19.41 ton/ha), followed by ARS DGP-03 (18.86 ton/ha) and ARS DGP-09 (18.21 ton/ha), and the latter two genotypes showing the highest 1,000 grain weight (240 g). The former genotype also produced the highest dry grain yield (2.5 ton/ha). The checked varieties produced only 8.6 ton/ha pod yield and 1.097 ton/ha dry grain yield. Likewise, similar study was conducted at Rajikot, Jumla (2,300 m amsl) with same genotypes including *Arkel*. DGP-09 gave the highest average pod yield (10.08 ton/ha) and the highest 1,000 grain yield (47.33 g), whereas *Arkel* gave the lowest (4.3 ton/ha) pod yield and 40.83 g of 1,000 grain weight (Giri et al., 2017).

In 2017/18, seven genotypes of garden pea were evaluated at ARS Pakhribas with *Sarlahi Arkel* as a checked variety (NARC, 2018). The marketable pod yield varied from 10.16 to 15.78 ton/ha. The genotype DGP-08 gave the highest pod yield (15.78 ton/ha), followed by DGP-09 (15.16 ton/ha) and *Sarlahi Arkel* (12.79 ton/ha). Similarly, in 2017/18, at HRS Dailekh, *Arkel* gave the highest green pod yield (7.4 ton/ha), followed by DGP-08 (7.3 ton/ha) and DGP-02 (7.1 ton/ha) (NARC, 2018).

Shah (2004) recorded the highest seed yield (2.173 ton/ha) in the closest spacing of 15 × 15 cm + 6$^{th}$ November sowing along with satisfactory level of 85% seed germination and 1,000 seed weight (173.5 g) in *Arkel* variety of pea at Rampur, Chitwan.

### *French bean*

During 2009 and 2010, Pandey (2011) tested 11 exotic and indigenous pole type French bean genotypes in ARS, Malepatan, Kaski (848 m amsl) during summer and autumn seasons. *Chinese Long* gave the longest pods (20.47 to 20.67 cm). During summer, *Makwanpur* produced the highest fresh pod yield (23.91 ton/ha) and the lowest by *Tarabare* (8.63 ton/ha). During autumn, *Four Season* gave the highest yield (28.43 ton/ha), and the lowest by *Tarbare* (7.7 ton/ha). Most of the genotypes gave higher yield during autumn than summer. Similarly, in 2010 and 2011, Pandey et al. (2013) tested 3 high

yielding pole type French bean varieties on 3 dates of sowings at HRS, Malepatan, Pokhara (848 m amsl), and reported that the genotype *Arka Suvidha* sown on 16th August gave the highest fresh pod yield (13.08 ton/ha) and the longest pod (14.13 cm). Likewise, Shrestha et al. (2011a) evaluated 7 genotypes of French bean in ARS, Dailekh (1,300 m amsl) during August of 2008/09 and 2009/10. *Trishuli*, *Chaumase*, LB-37 and *Salyan Local* produced 505, 449, 467 and 430 kg/ropani fresh bean pods and these were at par to one another. This was higher than those of LB-31, LB-33 and *Dolpa Local*.

Likewise, it is reported that in Mamti, Kavrepalanchowk (650 m amsl), *Four Season Bean* produced the highest pod yield (17.1 ton/ha) with the longest pod length (19.5 cm), followed by *Trishuli* (12 ton/ha yield and 17.7 cm pod length) (HRD, 2014). The farmers liked *Four Season Bean*. In 2017/18, 6 genotypes of French bean were tested at HRS, Dailekh. *Chaumase* gave the highest green pod yield (21.1 ton/ha), followed by *Bhatte* (19.3 ton/ha) and *Trishuli* (18.7 ton/ha) (NARC, 2018). Pandey et al. (2012) reported that in bush type French bean (variety *Arka Subidha*), poultry manure + effective micro-organism gave the highest pod yield (13.63 ton/ha), although it was not significantly different from other treatment combinations.

## *Asparagus bean*

In a study carried out at HRS Dailekh, Chalise and Pun (2016) have reported the highest pod yield (28.99 ton/ha) and the longest pod (64.47 cm) from HRD ASB-001. *Khumal Tane* gave the lowest pod yield (14.21 ton/ha) and the shortest pod length (46.97 cm).

Likewise, out of six tested genotypes of asparagus bean, *Malepatan Meter Long* (MML) produced the highest pod yield with the longest pod length at RARS, Nepalganj, followed by HRD ABS 009, which had the longest pod of 67.9 cm with the highest pod yield of 3.9 ton/ha at ARS, Belachai, Dhanusha, whereas MML has the longest pod length (64.6 ton/ha), but HRD ASB 008 produced the highest pod yield (18.6ton/ha) at HRS, Malepatan (NARC, 2016).

In 2017/18, at RARS Khajura, Banke, HRD ASB-007 gave the highest yield (41.3 ton/ha), followed by HRD ASB-009 (36.92 ton/ha), HRD ASB-010 (31.67 ton/ha) and *Khumal Tane* (30.52 ton/ha) (NARC, 2018).

## *Faba bean*

Ten genotypes of fababean were selected from previous years' entries and tested in Kartik month at Khumaltar, Lalitpur (HRD, 2018). The genotypes HRD FB 008, HRD FB 016 and HRD FB 013 gave the green pod yield of 22.05, 19.79 and 18.51 ton/ha, respectively, and days to pod set was 69, 64 and 71, respectively. Similarly, at HRS, Malepatan, Kaski, HRD FB 016 gave the highest green pod yield (13.73 ton/ha), followed by HR FB 001 (13.26 ton/ha) and HRD FB 014 (13.06 ton/ha), and their days to 50% flowering were 82, 72 and 77, respectively. In 2017/18, at HRS, Dailekh, out of 9 genotypes tested under the farmer's field trail (FFT), HRD FB 013 gave the highest pod yield (12 ton/ha), followed by HRD FB 003 (11.6 ton/ha) (NARC, 2018). Likewise, in 2017/18, at HRS, Belachapi, Dhanusha, HRD FB-016 gave the highest pod yield, followed by HRD FB 004 (NARC, 2018).

### *Cowpea*

In the rainy season of 1984, at Rampur, Chitwan, Timilsina (1988) evaluated 13 vegetable type cowpea lines obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The highest green pod yield (9.63 ton/ha) was given by the line IT81D-1228-10, followed by the line IT81D-1228-15 (9.51 ton/ha) with 60.3 and 59.0 days to maturity, respectively. In similar study along with a local variety *Tane Bodi*, Neupane and Pant (1988) reported that IT83S-911 gave the highest pod yield (196.25 kg/ha), followed by IT81D-1228-12 (170.83 kg/ha) and local *Tane Bodi* (106.63 kg/ha). Also the former two lines made the staking redundant thus reducing the cost of cultivation.

KC et al. (2011) worked on identification of suitable vegetable type cowpea variety in 3 conditions of Malepatan, Kaski; Rampur, Chitwan and Paripatle, Dhankuta, in 2006/07 and 2007/08. Among the tested lines, IT 86F-2089-5 Green produced the highest fresh pod yield (7.73 ton/ha), followed by IT 86F-2062-5 White (7.62 ton/ha), and the least yield (4.94 ton/ha) was given by *Surya*. Also, the former genotype was determinate in growth habit, short duration (<90 days), fiberless even at ripened stage and good cooking quality. Thus, this genotype was proposed to release in the name of *Malepatan-1* in 2010.

HRD performed verification test of cowpea varieties at the farmer's field in Mumti, Vimkhori VDC, Kavrepalanchowk (650 m amsl) (HRD, 2014). *Cowpea 324* produced the highest green pod yield (12.44 ton/ha), but had staking problem, followed by *Khumal Tane* (10 ton/ha) with a long pod of 50.4 cm, but with staking problem, and *Malepatan-1* (8.33 ton/ha) with no need of staking, but having thicker and fibreless pods which fetched higher price.

Thapa et al.(2012) performed experiment for 4 years (2064 to 2067) on acidic soil in ARS, Malepatan, Kaski to assess the response of manure and fertilizer combinations on the nutrient status of soil and fresh pod yield of cowpea of variety *Malepatan-1*. The treatment N/P/K, 40:20:40 kg/ha + poultry manure (1 ton/ha) gave the highest pod yield (5,197.6 kg/ha), but not significantly different from other combinations except control. Higher dose of NPK + FYM helped to increase the percentage organic matter and N content in the soil.

## 9. Tuberous Crops

The crop members under this group in Nepal are sweet potato, cassava, etc. Hardly few research studies have been reported in Nepal.

In 2017/18, at HRS, Dailekh, among 8 sweet potato genotypes tested, the total yield varied from 14.5 to 23.7 ton/ha. PRP 134769.1 gave the highest yield (23.7 ton/ha), followed by PRP 226567.2 (23.2 ton/ha), whereas variety *Desiree* gave 15.8 ton/ha only. Likewise, in other experiment, the highest marketable yield of 24.4 ton/ha was recorded in *Motipure White*, followed by *Thutabari White* (17.3 ton/ha) and CIP440008 (14.6 ton/ha). At Tarahara, Sunsari, sweet potato clone CIP 440267 gave the highest yield (27.25 ton/ha), followed by CIP 440012 (19.27 ton/ha). In a study at RARS, Lumle, *Japanese Red*, CIP 440328 and CIP 44026 gave 25.67, 22.4 and 15.56 ton/ha, respectively (HRD, 2018).

In a three years of study (2014-2016) at the farmer's field in Tarahara, Sunsari district (136 m amsl), Bhattarai et al. (2017) have reported that among 5 orange fleshed sweet potato genotypes received from International Potato Center (CIP), Peru, including *Japanese Red* and *Sunsari Local-1* as checks, CIP 440267 gave the highest total tuberous root yield (22.5 ton/ha), followed by CIP 440012 (20.63 ton/ha), whereas *Sunsari Local-1* gave the lowest mean yield (5.98 ton/ha). The farmers in Sunsari preferred the former two genotypes as these were also tolerant to pests' damage.

In 1993, at Bangladesh Agricultural University (BAU), Mymensigh, Bangladesh, Gautam (1998) studied the effect of pre-harvest vine removal (0, 4 and 8 days before tuberous root harvest) on quality and postharvest behaviour of sweet potato variety *Tripti*. Vine removal 4 and 8 days before harvest increased the dry matter and free sugar content in the tubers, but loss of starch on dry weight basis was noticed. Also, the tubers sprouted earlier infested by weevil and so could not be stored longer.

## 10. Spice Crops

There are limited reports on ginger, and particularly on turmeric and cumin in Nepal. There are no official releases of cultivars on these crops.

KC and Sharma (2004) assessed the appropriate cropping pattern and its effect on ginger rhizome rot in Kapurkot, Salyan (1,500 m amsl) for succeeding 6 years (1997-2002) under rainfed condition. Among different cropping sequences tested, maize-toria → pole bean-toria → ginger in the first 3-years cycle and repetition of the same crop sequence in the second 3-years cycle was found to be the most sustainable cropping pattern with the highest ginger yield at the end of the second cycle (i.e. 35.8 ton/ha). The result was followed by soybean-wheat → finger millet → ginger cycles (yield 34.12 ton/ha, at the end of the second cycle). The net returns of worth from the former and latter cases were NRs 114,400 and 800,100 respectively. Also, these treatments reduced rhizome rot severity (25.9 to 26%) compared to 50.9% severity when ginger crop was taken continuously.

From the work performed at Kapurkot, Salyan, it has been reported that ginger cv. ZI 1010 comparatively produced more fresh rhizome yield (17.77 ton/ha), followed by a local cv. (15.47 ton/ha) and KK-1 (15.3 ton/ha) in CVT trail (HRD, 2018). In Dhankuta, cv. ZI 8502 gave significantly more yield (20.01 ton/ha), followed by KK-1 (18.56 ton/ha) and local (17 ton/ha). But, ZI 1007 gave more ginger recovery (19.5%), followed by KK-1 (19.33%) and 1027 (19%). Likewise, at farmer's field in Bhumirajmandu, Doti, CI 0210 gave 36.89 ton/ha, followed by CI 0209 (35.78 ton/ha), which were about 10 ton/ha higher than that of local variety.

In 2017/18, at RARS, Dipayel, Doti district, 5 ginger genotypes including local varieties were tested. A local variety gave the highest yield of 58.06 ton/ha fresh rhizome and 2.61 ton/ha of mother rhizome, followed by *Kapurkot Aduwa-1* (55 ton/ha fresh rhizome + 3.19 ton/ha mother rhizome). Both of these cultivars were free of rhizome rot (NARC, 2018).

In 2017/18, RARS, Khajura evaluated 9 genotypes including local varieties under co-ordinated varietal trail (HRD, 2018; NARC, 2018). A local variety gave the highest fresh rhizome yield (14.19 ton/ha), followed by genotype 507 (13.03 ton/ha) and 207 (11.93 ton/ha).

Earlier in 2014 and 2015, at Kapurkot, Salyan, Gautam (2017) evaluated five storage methods of ginger rhizomes after a week of curing. The highest healthy rhizome recovery (95.49 to 96.75%) was found both in indoor and outdoor raw brick bhakari as well as indoor storage made of bamboo mat. Also, these treatments showed the lowest weight loss, and minimum fly and rhizome scale infected rhizomes.

Sharma and Aacharya (2005) tried different fungicides to see their efficacy against Phyllosticta leaf spot of ginger crop (variety used *Kapurkot Aduwa-1*) in Kapurkot, Salyan, in 1997-1999. Chlorothallonil (Kavach) of 0.15% spray showed the highest (54%) disease control with the highest rhizome yield (48.8 ton/ha), although not significantly different from other treatments.

Gautam (2013) did a field survey of ginger crop in 9 districts during August-September of 2011 and 2012. White grub, ginger shoot borer, red ant, termite and leaf roller were mostly found in most of the districts. Rhizome rot infestation was found to be associated with rhizome fly in patches. White grub and rhizome fly were found economically important pests.

In turmeric crop, KC (2013) did stability analysis of 7 genotypes for rhizome yield by using their yield data of 5 consecutive years (2004 to 2007 and 2010) from two diverse condition *viz*. Kapurkot, Salyan (1,480 m amsl) and Nepalgunj, Banke (181 m amsl). Joint regression analysis model was used to determine stability parameters. The analysis showed that the genotype CI 9801 came out to be the most ideal one with higher mean yield (27.83 ton/ha) than overall mean (26.67 ton/ha), statistically unit regression (b = 1.175) and lowest deviation from regression (SE = 0.146). It was followed by CI 9804, which yielded higher (27.32 ton/ha), above average stable (b = 0.934) and adapted to poor environments. The genotype CI 0209 was the highest yielder (34.05 ton/ha) and more specifically adapted to favourable environments (b=1.313).

In cumin crop, Rawal et al. (2016) did evaluation of 5 genotypes of cumin crop, collected from Rajasthan, India, at Ginger Research Program, Kapurkot, Salyan (1,480 m amsl), and RARS, Khajura, Nepalganj (181 m amsl) during October 2014 to April 2015. No yield and yield attributing characters could be noted due to high incidence of blight and root rot in Khujura. In Kapurkot, the cumin genotype *Guha 104* gave the highest yield (0.59 ton/ha), followed by *Sri Ram Gold* (0.53 ton/ha) and *Ratna* (0.52 ton/ha), all of them being at par. Thus, it showed the feasibility of commercial cumin cultivation in the mid hills of mid-western Nepal, but not in the mid-western terai due to incidence of soil born diseases which demands for appropriate disease management packages.

## Wild or Under-exploited Plant Species used as Vegetables

In Nepal, there are hardly very few research studies regarding the wild or under-exploited plants, which are used as vegetables or other forms of food. In this regard, Shakya et al. (1995a) did study on exploration of wild or under exploited plant species used as vegetables in Mangalpur, Saradanagar, Meghauli, Kabilas and Korak VDCs of Chitwan

district. Altogether 117 plant species comprising 37 families were collected. Their habitat, growth, propagation method, consumable parts and methods of utilization, period of availability were documented; and their demand, supply and market opportunities were explored. The classification of the identified plant species based on the plant parts used as vegetable included 68 with leaf and tender shoot, 19 with fruits, 17 with underground parts, 9 with flower or floral buds, and 5 with seeds or pods as edible parts.

## Probable Future Directions for Improvements

There are plenty of suggestions regarding policy matters, infrastructure development, manpower development and mobilization, structural modification in the context of new federal system, resources allocation, mechanism of co-ordination among different stake holders, etc. which have been dealt elsewhere several times. The suggestions presented in this paper are more of specific types which may be considered for conducting researches related to vegetable crops.

The perusal of the nature of researches on vegetable crops being conducted in Nepal shows that the major focus has been in the introduction of the varieties from outside, evaluation in different agro-ecological zones of Nepal, and then recommending and releasing them as promising varieties for general cultivation in Nepal. The other focuses have been on the management aspects, such as agronomic aspects including off-season and organic production, nutritional aspect, and disease and pests management. Poor attention has been given to researches on breeding aspect including the use of bio-technology; precision and protected cultivation; post-harvest handling, processing, packaging, storage, transportation and value addition; and irrigation aspects including micro-irrigation etc. There has been very poor attention on studies related to estimating nutrient contents of the vegetable crops and their nutritional quality improvement.

The present review on Nepalese vegetable crop researches shows that the crops which received comparatively more attention are tomato, cauliflower, onion and cucumber. The second category of crops receiving medium level of attention is cabbage, radish, carrot, broad leaf mustard, chili, broccoli, beans, etc. There are several other vegetable crops having high values but have received no or very less attention.

In the present context, the Nepalese farmers are demanding hybrid varieties. Except a few Nepalese hybrid varieties, such as *Srijana* variety of tomato, we are lacking behind in this aspect and there is an urgent need of developing our own hybrid varieties sustainably which would address the needs of specific locality, specific needs of the farmers and specific commercial or industrial purposes. There are several problems in the development of hybrid varieties. Lack of vegetable breeders is the major one. There is an urgent need of specific crop breeders who should lead the whole research and development of the specific crop or a group of similar crops to meet the varied needs of the farmers, other clients or market demands. The experts of other disciplines should be integrated to the specific crop breeder so that there will not be wastage of scarce resources, energy and time or will avoid duplication of the same work without fulfillment of the targeted objective. The types of researches being conducted have not been able to address the real needs of the clients. The experts of different disciplines are going towards

their own direction and there is lack of co-ordination among the related experts on a particular crop or issue, and thus ending with no fruitful or targeted outcome.

More often, the farmers have illusion that the imported hybrids are far better than the OP improved or local varieties and thus the hybrid seeds' import has shoot up drastically since the past few years. This is not always true especially from the point of view of quality and/or even yield. There are several instances where even our local cultivars have yielded at par or out yielded the imported hybrids. To convince the farmers, we need to have data generated through researches consisting of comparative study of the local varieties or commercial op varieties with the imported hybrids along with the comparative benefit cost ratios.

We have farmers of different economic status and our major concern has always been poor or/and small farmers. Also, there are different categories of poor farmers, such as ultra poor, poor and well to do poor. Now, it is also high time to give attention for generation or development of pro-poor technology or pro-ultra poor technology. 'Less input-more output' kind of technology should be generated on top of the technologies suitable for commercial agriculture. It is one of the major challenges in the Nepalese vegetable research works.

In the present context of Covid-19 crisis, it is high time to prepare vegetable research projects of short, medium and long term types that will help the forthcoming post-lockdown crisis period which is expected to continue for a long time to come. Some of the suggested areas of research could be on rooftop vegetable farming, use of bio-technological tools for speedy propagation of diseases, pest and stress resistant vegetable seedlings under protected and precision culture, nutritional gardening, use of low cost micro-irrigation, atmospheric nitrogen harvesting, etc.

In Nepal, there are several local landraces which are at the brink of extinction. More focus should be given on their conservation, maintenance and utilization rather than importing foreign varieties, especially hybrids, only. Research priority should be directed towards improvement and/or utilization of our indigenous varieties or local landraces including indigenous practices or technologies. Studies on nutritional contents of our landraces and local varieties, their preservation, proper utilization and value addition are some of the areas where little or no attention has been given.

Furthermore, Nepal is having unlimited number of wild or under-exploited plants used as vegetables on which hardly any attention has been given. These are the hidden treasures of our country. There is an urgent need of exploring and/or exploiting these valuable natural bio-resources including studies on their agronomy and nutrient contents.

In modern agriculture, especially in vegetable farming and nursery enterprises, there has been increased use of plastic materials either in the form of mulching materials in the main field or in poly house culture for off-season production or use of several nursery accessories, such as trays, pots, baskets, buckets, tools, etc. These are the non-biodegradable materials which are contributing to environmental pollution. So, it is very high time that due attention be given towards such researches in search of bio-degradable plastic materials or other alternatives in collaboration with developed countries working on these areas.

## Conclusion

Nepal is very rich in natural resources including the bio-diversity of the plants, some of which can be used as vegetables in our day to day life. Our effort is very weak in exploring and exploiting these hidden treasures. There is a need of well thought short, medium and long term vegetable research plans and programs to help augment food requirement, alleviate poverty, minimize malnutrition at lower cost, income raise of Nepalese farmers and support commercialization of Nepalese agriculture.

**Abbreviations:**2,4-D = 2,4-dichlorophenoxy acetic acid; AFU = Agriculture and Forestry University; amsl = above mean sea level; ARS = Agriculture Research Station; AVRDC = Asian Vegetable Research and Development Center; BAU = Bangladesh Agricultural University; BLM = broad leaf mustard; CIP = International Potato Center, Peru; EM = effective microorganism; FYM = farmyard manure; HRD = Horticulture Research Division; HRS = Horticultural Research Station; IAAS = Institute of Agriculture and Animal Science; IITA = International Institute of Tropical Agriculture, Nigeria; NARC = National Agriculture Research Council; NCRP = National Citrus Research Program; NGRP = National Ginger Research Program; NRs = Nepali rupees; PU = Purbanchal University; RARS = Regional Agriculture Research Station; SIMI = Smallholder Irrigation Market Initiative; TU = Tribhuvan University; VDC = Village Development Committee.

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# Author's Biography



Born in Kathmandu in 1950, Shanta Man Shakya did his B.Sc. (Hons.) Ag. in 1973 and Ph.D. (Horticulture) in 1990 both from G.B. Pant University, Pantanagar, UP, India, and M.Sc. (Horticulture) in 1982 from the Ohio State University, USA. He had several short term trainings in country and abroad. He served the Institute of Agriculture and Animal Science (IAAS), Tribhuvan University as a faculty member from 1978 till 2013. During his service, he served the IAAS in different capacities such as Department Head, Farm Superintendent, Planning Chief, Assistant Campus Chief and Assistant Dean. He also worked as Project Leader of different research projects and short term consultant. He has worked as major adviser of more than 20 M.Sc. and 2 Ph.D. students at IAAS, and more than 25 B.Sc. Ag. students at HICAST. He was awarded with 'Shikchhya Puraskar', 2057 BS and 'Dirga Sewa Padak', 2061 BS. He was elected as Executive Member, Nepal Horticulture Society in 2070 BS and has been working as Editor-in-Chief of the journal 'Nepalese Horticulture' from 2070 BS to till now. He has more than 50 publications including three books.

# Chapter 2

## Vegetable Seeds Development, Present Status and Future Perspectives

**Indra R. Pandey**
*Khumaltar, Lalitpur Metropolitan Ward No. 15, Lalitpur, Nepal*
Email: pandeyindraraj1947@gmail.com

*With the rise in population and knowledge on health benefits, the demand for fresh vegetable is increasing day by day. The requirement of vegetable seeds is also increasing. At present, local production of vegetable seeds fulfils only about 50% of the total requirement and the rest is met either by import or by farmer to farmer exchange of low quality seed. The coordinated indigenous species collection and preservation and also coordinated variety maintenance program in all the government farms and designated private sector farms as the way forward for conserving in situ and collection in gene bank has become inevitable for future use. Nepalese indigenous vegetable varieties and land races have great potential for future vegetable breeding and development activities as these are the national wealth of plant sources with great perspective.*

**Keywords:** Agro-biodiversity; agro-ecological zones; conservation strategy; gene bank; pollination; breeding; hybrids.

## Introduction

Nepal is a land of wonder with her agro-biodiversity, climatic variability and ethnic diversity. Almost all types of world climate and a wide range of bio-diversity exist in Nepal. Domestication and cultivation of vegetables and its seed preservation has always been the integral part of agriculture in Nepal since time immemorial. The recorded food plants in Nepal are distributed among 172 families, 296 genera, 599 species and 35 sub-species found in the country. Out of 599 species of food plants 400 species belong to horticultural groups of which 200 species are vegetable crops (Regmi, 1982). Among 200 species of vegetables around 50 species are in cultivation (Pandey, 1995). The recent listing of vegetable species in use are 127 with 57 leafy, 14 stem, 36 fruit, 11 legume and 15 root and tubers (Pandey et al., 2018). Among these 127 species, 30 species are in seed production and marketing in Nepal. Presently, vegetable seed production and marketing is

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regularized by Seed Act and Seed Rules of Nepal government. As per the record from Government of Nepal, Seed Quality Control Center (GoN/SQCC), total released and registered vegetable varieties are 329 of 35 different kinds of vegetable crops. Among them 252 varieties are hybrids and the rest 77 are open pollinated (OP) (SQCC, 2016). Nepal released 35 varieties in 1995 and additional five varieties during 2014 to 2018 totaling 40. After the establishment of gene bank, local varieties collected in the National Gene Bank includes 1,249 legumes, 493 fruits, 506 leafy vegetables. All these vegetable species are diverse in their breeding behaviour based on pollination behavior from highly cross pollinated to highly self-pollinated. Among these species, some commercial varieties are imported and adapted, whereas many are indigenous and maintained by farmers.

There are many species maintained and used by people as local land races and are yet to be collected, evaluated, conserved and recommended for commercial cultivation or to be conserved for future breeding purposes. The cultivation of these vegetables is omnipresent in different parts of Nepal in different seasons and agro-ecological zones. In recent years, most of the traditional and indigenous varieties of vegetables are replaced by improved varieties, and are no more available for cultivation. The conservation strategy, variety maintenance, breeders and foundation seed production are the challenges faced by Nepal Agricultural Research Council (NARC), Department of Agriculture (DoA) and private sectors as well. Despite the suitable climate, comparative advantages, expanding markets for fresh vegetable which in turn increased the demand of vegetable seed, the growth of domestic vegetable seed industry has remained slow. Work on vegetable research is inadequate and extension programme is very general and imported vegetable seeds dominated. Donors, NGOs, INGOs and other development partners are interested in fresh vegetable production; however, they do not give priorities to Nepalese seed, but promotes use of imported hybrids. In the light of the huge agriculture trade deficit and Nepal's comparative advantage in seed production, there is an ample scope of domestic production and value chain development of all types of vegetable seeds for import substitution and export promotion. There is need of production and promotion of both OP and hybrid seed of vegetable varieties for fulfilling the domestic demand and promote export.

## Vegetable Seed in Ancient Nepal

Nepal has *Arya-Mongol* civilization with multi-culture and vivid ethnicities. The culture, civilization and history of Nepal have been influenced by its position in the lap of Himalayas and its two neighbours, India and China. During ancient times, cow herders (*Gopalbansi*) came to Nepal valley (present Kathmandu valley) from the Ganges Plain of the modern-day India and the sheep herders came from Tibet and inhabited in northern Nepal. Newars (Nationality of Nepal valley) are specialized in vegetable production in the valley since long time. The vegetable production techniques they have developed are known as Jyapu Technology. This Jyapu technology of vegetable and vegetable seed

production is endangered. Now, Nepal is a multi-ethnic, multi-cultural, multi-religious and multi-lingual country and the people in common are Nepalese. *Gopalbansi, Mahisapalaka, Lichchhavi, Kirats, Thakuris, Malla* and *Shah* ruled Nepal since ages. Nepal's physiographic and agro-ecological settings, due to altitudinal variation and multi-sphere facings, have contributed to ethno-biodiversities. The Indo-Aryans from the south and Mongols from the north settled in different altitudes suitable to their climatic requirements in Nepal. Thus, whatsoever came to this part of the earth also brought plant materials including vegetables with them. Thus, domestication and cultivation of different vegetables as integral part of civilization and agricultural system goes back to the era, when present Nepal was scattered in many local states and royal units. Whatsoever local states and royal units existed, subsistence agriculture was the means of livelihood. The study of ancient writings and archaeological evidences show that vegetables were as an integral part of agriculture and civilization since more than 2,000 years. However, the official effort of vegetable research and development could be traced back to mid 19$^{th}$ century (Pandey, 1994).

## History of Official Start of Vegetable Seed Production in Nepal

The official record of some exotic vegetable introduction and cultivation in the manorial gardens of Rana (the then *de-facto* rulers of Nepal) could be traced back to mid 19$^{th}$ century when the then Nepal's Rana Prime Minister Mr. Jung Bahadur Rana and his dignitaries received the European vegetable seeds as gift during his visit to the United Kingdom and Europe. Such vegetables were cultivated in Ranas' gardens. Slowly, these vegetable seeds leached out to the local farmers of Kathmandu valley through the gardeners of Rana palaces and the cultivation of temperate vegetables such as cauliflower, cabbage, turnip, etc. became popular in Kathmandu valley. Along with these crops, the indigenous vegetables like broad leaf mustard (Rayo), Pyuthane Rato radish, pumpkin, gourds, colocasia, yam, cowpeas, beans, were cultivated for family use and for the sale in the local markets of Kathmandu and seeds were saved by the farmers themselves (SDC, 1994). After Jung Bahadur Rana who contributed in vegetable development in Rana's manorial garden, Chandra Samsher Jung Bahadur Rana established Agricultural Council as the first government entity for agricultural development in 1937. The council opened agricultural farms in Tahachal and Balaju, Kathmandu valley. At present, Tahachal farm, Balaju nursery has been converted to a modern park. The government initiated research and development in modern agriculture including vegetable since 1940 with the testing of some exotic and indigenous vegetables in the Central Experimental Farms at Tahachal and Balaju Nursery in Kathmandu since 1942. In these farms, seeds of different vegetable crops such as tomato and cabbage were produced. To promote sales of the vegetable seeds, the government opened vegetable seed store during 1942 in New Road, near Taleju temple in Kathmandu, to make the seeds available to the general farmers. In Balaju nursery, cabbage seed production was successfully done in 1946 (old record of Agriculture Council). During 1948, first agricultural farm outside Kathmandu valley was

established in Parwanipur, Bara as a multi-crop research station where vegetable research for tropical region was one of the important activities.

Rana regime ended in February 1951 and new democratic era started in Nepal. The Agriculture Council established in 1937 was converted to the Department of Agriculture in 1952 with Horticulture Section within it to look after the development of fruits, vegetables and flowers. Horticulture Section established two plant introduction units (1) Putali Bagaicha, Singh Durbar and (2) Plant Introduction Unit, Godavari to introduce exotic vegetables and fruits, and to study their adaptability. During 1952, Horticultural farm was established in Kakani to study fruits, vegetables and flowers. United States Overseas Mission in 1952 and Mountaineering Troops from Japan in 1953 had been the two principle formal sources to import exotic vegetable varieties. Japanese Mountaineering Troop gifted some vegetable seeds of radish, carrot, turnip, etc. to the government and Radish White Neck was commercialized in and around Kakani areas of Nepal. During five year's period from 1952 to 1956, studies and trials conducted by the Horticultural Section recommended some new vegetable varieties for general cultivation, and seeds were made available to the common people from seed store at Basantpur, New road, Kathmandu.

## Vegetable Seed in Planned Development

Nepal started planned development from 1955/56 when the first five year plan was implemented with high priority to agriculture for better and efficient use of resources. Donors like USAID and Indian Cooperation Mission (ICM) supported in agriculture including vegetable. Since 1956/57 a new programme in agriculture development was initiated as "Tribhuwan Gram Bikash (Tribhuwan Rural Development)" with block development approach and Block Development Officers (BDOs), Gram Sewaks and Gram Sevikas (Village Development Workers) were posted at village level for rural awareness and development. This was an integrated community development model including agriculture, health and sanitation, adult education, home science and agriculture. This programme introduced different vegetables related programs in rural Nepal with people's participation. Youth clubs, 4-H clubs, cottage industries were the components of this programme.

During second five year plan (1962/63–1964/65), government opened different agriculture/horticulture farms/stations in the different agro-ecological zones of Nepal. In 1961 Central Horticulture Center, Kirtipur was established for all horticultural activities in fruits, vegetables, potato and flowers. New horticulture farms were opened in Daman, Makawanpur; Dhunibeshi, Dhading; and Satbanjh, Baitadi with the help of Indian Cooperation Mission (ICM). In the vicinities of these farms/stations, vegetable production activities were demonstrated and extended. Mainly home gardening was emphasized which slowly developed to produce vegetable for the local markets and haat bazaar. In terai, new agriculture farms were opened in Nepalgunj, Bhairahawa, Janakpur and Terahara. In the hills also, horticultural farm/stations were established in Dhankuta;

Kirtipur, Kathmandu; Trishuli, Nuwakot; Pokhara, Kaski; and Bhagetada, Doti. These farm/stations were mandated to test, multiply and sale/distribute the horticultural planting materials (fruit saplings and vegetables seeds). By the end of this plan total horticultural farm/stations reached to 14. District Agriculture Development Offices (DADOs) were established for agriculture extension and development. In the center, Horticulture Section was under the DoA. The programmes of horticulture in the farm/stations were controlled by the Horticulture Section of DoA. All these farm/centres were responsible for vegetable research, seed production and distribution through extension network and also sale directly from farm gate. Farm/centers and DADOs promoted vegetable production for home consumption and local sale.

The Department of Agriculture was reorganized in 1966/67 to five different departments (Department of Agriculture Education and Research, Department of Agriculture Extension, Department of Livestock Development, Department of Horticulture, and Department of Fisheries). Department of Horticulture was housed in Kirtipur with two major sections viz. Fruit Development Section and Vegetable Development Section. Kirtipur was the main center of research and development for fruits, vegetables, potato and flower. Horticulture farms of different agro-ecological zones were under the Department of Horticulture (DoH). Vegetable research, seed production and seed sale used to be done by these horticultural farms and some seeds were sold from Basantpur, New Road seed store as well. District Agriculture Development Offices also purchased vegetable seed from horticulture farm stations and Basantapur seed store as there were no other private and government outlets for vegetable seed.

During 1967 to 1970, the DoH established additional horticultural farms/station in Humla; Jumla; Dolpa; Mustang; Rasuwa; Helambu, Sindhupalchowk; Bonch, Dolakha; Panchkhal, Kavre; and Nawalpur, Sarlahi to push the horticulture development, and the number of horticulture farms reached to 23. All these farm/centres contributed in vegetable research, seed production and fresh vegetable production in their command areas, and served as the growth centers for fruits and vegetable development.

The Department of Horticulture had both research and extension responsibilities. Researches activities were focused on introduction, selection and identification of vegetable crop varieties, and produce all types of seed viz. nucleus, source and improved seed. Though the Horticulture Department of 1967 had no extension network at grass root level, extension activities used to be carried out by the horticulture farms/centres within their limited command areas.

The five different departments were integrated to one Department of Agriculture in 1972, with integrated responsibility of research and extension both. Establishment of Vegetable Development Division (VDD) and Vegetable Seed Production Center at Khumaltar during 1972 was the milestone in vegetable research and development. Vegetable research activities continued in the farm/centres as it was under the separate Department of Horticulture and the responsibility of vegetable extension was given to DADO. The horticulture farm/centres were administratively under Regional Directorate

and technical link was with commodity divisions called Vegetable Development Division, presently Vegetable Development Directorate. Between 1975 and 1985, two new farms viz. Vegetable Seed Production Center in Rukum in 1977 and Vegetable Seed Production Center in Dadeldhura in 1981 were established to expand vegetable research and seed production.

## Agro-ecological Approach for Vegetable Development

During fifth five year plan (1975/76–1979/80), VDD adopted agro-ecozonal zone based approach in vegetable development. Nepal has three broader distinct agro-ecological zones namely; Terai/plain, Midlands and High hills with some specific zones in Trans-Himalayan region. Within these zones, specific micro-climatic situations and special pockets exist due to variation in altitude, slopes, facings, surrounding hills and valleys. Nepal being situated in the northern hemisphere in temperate zone, there is four distinct seasons in a year, such as spring, summer, autumn and winter from vegetable production point of view. Due to high agro-biodiversity of vegetables, more than 55 kinds of vegetable crops are commercially grown in Nepal. To fit into these agro-ecological zones and micro-climatic pockets for each region and season, at least four sets of adaptable vegetable varieties under each kind of vegetable crop and their seed availability is the ideal requirements for the year round supply of a particular kind of vegetable. Thus, it involves two tiers of research viz. fresh vegetable production and seed production. Considering four varieties of each popular vegetable crop to be developed with fresh and seed production techniques the task appeared to be Herculean. To cope with above task, VDD since 1975 adopted the agro-ecozonal approach for fresh vegetable research and seed production research with the following four major strategies:

1. Introductions of exotic germplasm; and collection, evaluation and selection from both indigenous land races and exotic germplasm to develop high yielding vegetable varieties suitable for different agro-ecological zones and seasons
2. Generation of improved and appropriate crop husbandry, plant protection and seed production techniques for development of new improved varieties
3. Commercial/market oriented fresh vegetable production demonstration in accessible areas along road corridors, and
4. Technology generation and vegetable seed production in the remote areas where fresh vegetable marketing is difficult.

According to the above strategies, nine major centres for vegetable research and farmer's field vegetable seed production zones were identified and adopted. Vegetable Seed Production Center Khumaltar, Horticulture Farm Sarlahi, Horticulture Farm Panchkhal, Agriculture Station Dhankuta, Horticulture Farm Mustang and Dolpa, Vegetable Seed Production Center Rukum and Dadeldhura were identified as the eight major centres for research. Under the technical guidance of these farm/centres, contract seed production of major vegetable varieties were started in Bhaktapur,

Nuwakot, Sarlahi, Dhankuta, Tehrathum, Bhojpur, Mustang, Dolpa, Rukum, Salyan and Dadeldhura. Agriculture Input Corporation (AIC) was given the responsibility of vegetable seed marketing from 1975. Seed buying contract used to be done by AIC and foundation/source seed supply and field supervision by VDD and respective DADOs.

These nine farm/centers were recognized as center of excellence for vegetable research, variety development, maintenance and breeders and foundation seed production as presented in Table 2.1.

**Table 2.1.** Farm/Centres selected for vegetable research and variety development.

| S. N. | Name of Center | Altitude (amsl) | Micro-climate | Priority crops for research/seed production |
|---|---|---|---|---|
| 1 | Horticulture Farm Dhankuta | 1,200–1,400 | High rainfall, high humidity and warm winter | Radish, mid-season cauliflower, broad leaf mustard, pea, cress, spinach, etc. |
| 2 | Horticulture Farm Sarlahi | 200 | High rainfall, high humidity, hot summer, mild winter | Early cauliflower, radish, all Solanacious and Cucurbitaceous crops, beans, cowpeas |
| 3 | Vegetable Seed Production Center Khumaltar | 1,350 | High rainfall, high humidity, frosty winter, warm spring through summer | Radish, cauliflower, broad leaf mustard, beans, Swiss chard, cress, spinach, turnip, tomato, eggplant, onion, chili, capsicum |
| 4 | Horticulture Farm Panchkhal | 865 | High rainfall, high humidity, hot summer, foggy winter | Bean, rajma bean, bitter gourd, cucumber, squash, eggplant, tomato |
| 5 | Horticulture Farm Mustang | 2,522 | Low rainfall, snow in winter, low humidity, mild summer | Late cauliflower, cabbage, carrot, broad leaf mustard (Marpha), late radish |
| 6 | Horticulture Farm Dolpa | 2,242 | Low rainfall, snow in winter, low humidity, mild summer | Late cauliflower, cabbage, carrot, broad leaf mustard (Marpha), late radish |
| 7 | Vegetable Seed Production Center Rukum | 1,440–1,500 | Mild rainfall, mild humidity, chilly winter, warm summer | Radish, mid-season cauliflower, broad leaf mustard, beans, cress, spinach, turnip, tomato, eggplant, sweet pepper, onion, peas, squash |
| 8 | Vegetable Seed Production Center Dadeldhura | 1,400 | Mild rainfall, high humidity, warm summer, chilly winter | Radish, mid-season cauliflower, broad leaf mustard, beans, cress, spinach, turnip, tomato, eggplant, sweet pepper, onion, peas, squash |
| 9 | Horticulture Farm Jumla, Rajikot | 2,200 | Medium rainfall, warm summer, chilly winter | Broad leaf mustard, cabbage, carrot |

Besides above nine farms, two British aided farms – Lumle Agricultural Center (LAC) and Pakhribas Agricultural Center (PAC) were also linked and coordinated for vegetable research, development and seed production.

## Donor Support in Vegetable Development

With the beginning of sixth five year plan (1980/81) onward different donors supported to gearing up the research and development in vegetable sector. The first Fresh Vegetable and Vegetable Seed Production Project was funded by the Swiss government through FAO as a Technical Cooperation Project from 1980/81 to 1994/1995 (sixth to eighth five year plan) for 15 years and worked in three phases as the counter part of VDD. This project further strengthened the approach initiated by VDD during fifth five year plan and continued till eighth five year plan. Eleven other projects also supported vegetable in development, some of them worked with the government and some of them directly with community and some of them worked with other donor funded project, Seed Entrepreneurs' Association Nepal (SEAN), NGOs, etc. (Annex 2.1).

## Establishment of NARC and Vegetable Research after 1990

As a separate organization to give impetus in agricultural research, NARC was established in 2090/91, and new departmental reorganization was made. The horticultural farm/centres were divided between NARC and DoA, and vegetable research and variety maintenance was distorted. From 1995 to 2014, only five additional new varieties of vegetables were officially released but not linked to variety maintenance scheme and commercial seed production. Thus variety development, maintenance and seed production of Nepalese vegetable varieties could not keep pace with the market demand. To meet the market demand, import of vegetable seeds increased while production and marketing of Nepalese vegetable varieties remained slow.

### *Released, Registered Varieties, Endangered and Lost Landraces*

At present, farmers are demanding hybrids and high yielding improved varieties. Development of such varieties in Nepal could not keep the pace and imported vegetable seeds are increasing. Analysis revealed the following status of released registered and endangered varieties and lost landraces.

- Officially released vegetable varieties were 35 in 1995, and only 5 varieties were released from 1995 to 2014. Thus, at present, the released Nepalese vegetable varieties are 40 only Horticulture Research Division Nepal/Agricultural Research Council (HRD/NARC, 2016).
- The registered imported vegetable varieties are 329 of 35 different kind of vegetable crops of which 252 are hybrids and 77 are OP (SQCC, 2016).
- Forty released Nepalese vegetable varieties have not been maintained well, breeders and foundation seeds are not available for commercial seed production, and not properly linked with seed production and marketing by private sector.

- Among these released varieties, cauliflower varieties viz. Kibo Giant, Dolpa Snow Ball, and eggplant varieties viz. Sarlahi Green, Nurki, etc. have not been maintained well and are endangered (probably lost).
- Many traditional/indigenous varieties of vegetables are replaced by imported improved varieties and are no more available for cultivation. Examples: Long white, Kakaniko moola, Nepali large and white cucumber varieties of mid-hills and sub-urban Kathmandu, Choto radish and Koere moola of high hills are endangered.

### *Reasons for Slow Variety Development in Vegetables*

- While establishing NARC, most vegetable research farms (Khumaltar, Sarlahi, Rukum, Marpha and Dadeldhura) were kept under DoA and not mandated for research, variety maintenance and variety development,
- Vegetable research in NARC is at low key due to lack of specialized research farms. For long time, HRD/NARC was housed in VDD premises as an orphanage,
- The horticulture units of most NARC research centres are cereal crop dominated,
- Thus variety development, maintenance and seed production of Nepalese vegetable varieties could not keep the pace with market demand and import of hybrid seed dominated to meet the demand,
- There is no international linkage for exotic vegetable germplasm import, evaluation, new variety development and government investment is low in vegetable research and new variety identification and development,
- Vegetable specific research team including vegetable breeders, vegetable agronomists (olericulturists), soil scientists, plant protection and post-harvest specialist in specific farm/centre with full leadership of vegetable and crop specific regional research farms and demo farms with fully equipped lab is lacking both in NARC and DoA,
- There was no policy and program to go with Universities, Nepal Academy of Science Technology (NAST), NARC, DoA and private sector in vegetable research and development as Public Private Partnership (PPP). It has been a slogan only.

### *Reasons of Increased Demand of Vegetable Seeds*

The main drivers of the increased demand for vegetable seed are:

- Increased demand of fresh vegetable as a result of increased knowledge on food and nutritional consciousness and health benefits,
- Increased urban population with increased per capita income overtime,
- Farmers are increasing the areas of commercial vegetable production as vegetable crop gives 3–5 times higher income compared to traditional cereal crops in short duration and so vegetable seed demand is also increasing,
- Along with the availability of fresh vegetable varieties for year round production the demand of such variety seeds (imported) are also increasing,

- The demand of quality vegetable seed is increasing because of the increased areas due to year round seasonal and off-seasonal production in different geographical areas for off-season marketing and income generation.

***Reasons of Increased Demand of Imported Vegetable Seed***

During last 60 years of vegetable research, Nepal has developed and registered its own 40 varieties with one hybrid variety in tomato. Neighbouring and other developed countries have rapidly developing hybrids and also OP varieties which can give higher and uniform yield. Hybrids are also claimed to be tolerant to many diseases and insects pests. Seasonal and off-seasonal vegetable production in the different agro-ecological regions of Nepal demand suitable high yielding, but short duration varieties with uniform harvesting. Because of globalization of trade and commerce and as Nepal is a member of World Trade Organization (WTO), any trade is open and same is the case with vegetable seed. There are following simple reasons of growth of demand and increased import of vegetable seed in Nepal.

1. Slow research and no suitable vegetable varieties developed in Nepal to comply with the demand of commercial vegetable farmers.
2. Imported hybrids and OP gives better and uniform yield compared to local varieties.
3. Imported seeds have better packaging, good looking with colour photographs and have good promotional activities and advertisement.
4. Traders prefer to import and sell because of higher profit margins.
5. Local production, quality assurance and collection is cumbersome compared to import.
6. No seed production of early and late varieties of cauliflower (e.g. Sarlahi Deepali, Kibo Giant; little bit being done in Dolpa Snow-ball in Jufal farm, Dolpa). Some seeds of Jyapu and Kathmandu Local varieties are produced; however, no demonstration and promotional activities being done by national extension system and demand is low for these varieties. On the other hand, large number of early, mid-season and late varieties of high quality, high yielding, well packed with attractive photographs of cauliflower hybrid seeds are available in the world market and their demand is high and import is increasing in Nepal as well.
7. In case of cabbage, no variety maintenance except in small quantities in Copenhagen Market in Mustang and almost all the commercial cabbage varieties are imported hybrids.
8. Only one tomato hybrid variety, Srijana, also has limited seed production and has questions in quality maintenance. Imported hybrids (both registered and unregistered) are marketed freely in Nepal and their demand is growing rapidly.
9. The cucurbit hybrids of crops such as bitter gourd, bottle gourds, sponge gourds and cucumber are available in plenty in China, India and even Bangladesh and imported easily. Only one better performing and highly demanded cucumber OP variety Bhaktapur Local has been lately released/registered.

10. The most important reason for increased demand of imported seeds including hybrids are: slow variety development, poor varietal quality maintenance, poor seed chain maintenance of Nepali varieties and better profit margins to traders in trading and marketing of imported vegetable seed.
11. Farmers have been highly convinced with imported hybrids. Even highly self-pollinated crops like cowpeas and peas, which are imported, are also sold as hybrids without checking its reality as to whether it is really hybrids or not, and we are not managing the production of such easy crops also in Nepal.

## Trends of Vegetable Seed Demand and Production in Nepal

Projection of effective demand of vegetable seed is still gloomy. Since 1975/76, vegetable seed production increased continuously in farmer's field through contract production between farmers groups/cooperative and seed traders. This increase in seed production at farmer's field is the cumulative results of all the supports done by project, private and public sector. The increase in vegetable seed production in farmer's field and government farms from 1975 till 2017 is presented in Table 2.2. The seed production in government's farm is almost constant around 10 metric ton (MT); however, it is in decreasing trend in recent years as farm/centre mostly concentrated in breeder's and foundation seed production.

**Table 2.2.** Vegetable seed production trend and domestic requirement from 1975 to 2018.

| Year | Government sector (MT) | Private sector (MT) | Total domestic production (MT) | Total domestic requirement (MT) | Gap (MT) | Gap (%) |
|---|---|---|---|---|---|---|
| 1975/76 | 9 | 1 | 10 | 293 | 283 | 97 |
| 1979/80 | 12 | 8 | 20 | 343 | 322 | 94 |
| 1984/85 | 12 | 21 | 33 | 770 | 737 | 96 |
| 1989/90 | 15 | 190 | 205 | 775 | 570 | 76 |
| 1994/95 | 11 | 250 | 261 | 855 | 594 | 69 |
| 1999/00 | 12 | 430 | 442 | 1,310 | 868 | 66 |
| 2004/05 | 11 | 810 | 821 | 1,569 | 748 | 48 |
| 2009/10 | 8 | 930 | 938 | 1,840 | 902 | 49 |
| 2014/15 | 8 | 1,050 | 1,058 | 1,920 | 862 | 45 |
| 2015/16* | 8 | 1,050 | 1,058 | 1,950 | 892 | 46 |
| 2016/17* | 8 | 1,050 | 1,058 | 1,980 | 922 | 47 |
| 2017/18* | 8 | 1,050 | 1,058 | 2,010 | 960 | 48 |

Source: (MoALD, 2018; CEAPRED, 2014b)

Since 1975 to 2017, there has been manifold increment of seed production in Nepal (10 MT in 1975 to 1,050 MT in 2016/17). Fresh vegetable area increases by roughly 10,000 hectares every year (MoALD, 2020). Average 3 kg seed (average of 30 small seeded and large seeded vegetables) per hectare is required. The projected requirement of vegetable seeds for the fiscal year 2017/18 is 2,010 MT. As the area increases by 10,000

hectares every year, so seed requirement increases by 30 MT per year (Shrestha, 2009). The projected shortfall is still nearly 50%. Rest of the requirement is met either by farmer-to-farmer exchange of often sub-standard seeds or by import of OP and hybrid seeds.

### *Vegetable Seed Import to Nepal*

Commercialization of fresh vegetable production is increasing fast in Nepal. Farmers are demanding short duration, high yielding varieties suitable to a particular season and agro-ecological zone, and the demand of such varieties are increasing. Though small quantities of seed import started since 1990, the trend increased from 2002 onward (CEAPRED, 2010). To meet the increasing demand of quality seeds, especially hybrids, seed import has been increasing during recent decades. The number of imported and registered vegetable varieties by entrepreneurs reached to 20 OP and 272 hybrids (SQCC, 2019). Flow of vegetable seeds from India has been a common practice since long due to open boarder. It has always been difficult to assess the amount of seed import from India. Both registered and unregistered vegetable seed easily penetrates to Nepal, and Indian traders have strong linkage with Nepalese traders of terai areas. Recently, a survey conducted by SEAN (October 2017) reported that altogether 182,148.02 kg of seed was imported in the year 2016, of which OP variety seed import was 137,784.5 kg (75.64%) and hybrid seed import was 44,363.52 kg (24.36%). Detail is given in Annex 2.2.

### *Opportunities for Vegetable Export*

Nepal has potential market access to different countries such as India, China, Singapore, Bangladesh, etc. Commerce Policy 2072 has identified vegetable and vegetable seed as the potential export commodity. Production of off-season vegetables for fulfilling the demand of tourism sector and neighbouring countries is abundant. Vegetable demand, especially safe/organic, is increasing due to nutritional consciousness, health benefits of vegetables and increasing urban population and their income. In 2014/15, some 20,953 MT of vegetable, with the value of Rs. 262,557,000.00 was exported to India and neighbouring countries. Mostly cabbage, potato, tomato, green peas, radish, etc. were exported (MoALD, 2015).

## Future Prospect and Way Forward for Vegetable Development

Fresh vegetables play very important role in nutrition security, food security, income generation and livelihood improvement. Increased production and productivity of vegetables depend on high quality seed including hybrids. Lessons learned from successes and pitfalls have resulted in shaping the future prospect and way forward. As we move along the path of progress, several opportunities will appear, and these needs to be utilized for the benefit of wider farm families.

### *Variety Development*

A large proportion of improved seeds, particularly hybrids, in vegetables are being imported, particularly from Japan, India, Thailand, Korea and China. Nepal must collect,

evaluate and develop pest resistance and stress tolerant varieties for climate resilience from local germplasms. In order to reduce the import of hybrids, NARC should lead Hybrid Research in collaboration with Agriculture Departments, Universities, NAST and other related organizations including National Commodity Programs and Divisions with adequate fund and human resources as envisaged in National Seed Vision, 2025. The vision document envisaged to develop 30 hybrids in vegetables comprising 20 by public sector and 10 by private sector, and to increase seed replacement rate from 68 to 90 percent by 2025.

### *Variety Maintenance*

Variety maintenance is an important component of quality source seed production. Maintenance of crop varieties in their original ecological domain is essential to produce quality source seed, and retain original genetic purity and unique characteristics of the varieties. However, currently, there is a limited use and compliance of zoning concept in varieties maintenance. Based on the mode of pollination and breeding behaviour of recommended vegetable varieties, the variety maintenance program and methods were developed during the sixth and seventh five year plan by VDD and the project. To ease the variety maintenance work, varietal (morphological) characteristics of identified varieties with their marked genetic trait, maintenance methods, and technical procedures for each group of crops were developed and documented for the use and reference. A well-defined variety maintenance techniques and system of one farm one variety was adopted (Annex 2.3). Until 1990, in various agro-ecological zones, there were 33 horticultural farms under unified DoA including 9 centres of excellence (see: Table 2.1) and including Lumle Agriculture Center (LAC) and Pakhribas Agriculture Center (PAC) for vegetables, research and variety maintenance under one command of DoA/VDD and maintenance was easy. A variety maintenance chart was developed denoting farm/centres, and varieties to be maintained and produce breeders and foundation seed. To clarify the maintenance scheme as for example cauliflower variety Kathmandu was to be maintained by Khumatar, Rukum and Dhankuta; Snow Ball was to be maintained by Dolpa; Kibo Giant by Dadeldhura; and Deepali by Sarlahi; and cabbage by Marpha. Similar arrangements were made with other cross pollinated crops as well. However, at present, variety maintenance schemes are further modified by SQCC (Annex 2.4), but this arrangement is dysfunctional. Variety maintenance chart for vegetables prepared during the 80s by VDD and recently revised by National Seed Board (NSB) has to be implemented based on agro ecological zones, domains of the research centres and farms. Original genetic trait and unique characteristics of some of the popular vegetable varieties of Nepal have been published by CEAPRED in 2014 (Annex 2.5) (CEAPRED, 2014a). These could be further revised and made in to use and practice.

### *Special Impetus to Achieve the National Seed Vision Target*

Government of Nepal has launched National Seed Vision 2013–2025 by setting specific targets to be achieved in variety development and seed production by 2025. However,

support programmes and projects are still not implemented effectively in case of vegetable crops and the targets set by National Seed Vision for vegetable seed sector seem unachievable. In this context, the following analysis and working proposal have been made.

National Seed Vision 2013-2025 has the following targets in vegetable crops:

- Thirty hybrid vegetables variety to develop of which 20 by public and 10 by private sector
- Seed replacement rate to reach 90% from the present 65% by improved vegetable seeds.

Hybridization is a technique to create increased vigor (heterosis) in variety development. It is generally observed that hybrids have high yielding ability by 15–25 percent higher than OP varieties. For this reason, there is an increasing trend of using hybrids among farmers. The first hybrid variety in Nepal was officially released in maize (Gaurav) in 2004. However, it was not successful due to non-synchronization of silking and flowering of the inbred lines. A hybrid variety in tomato (Srijana) was registered in 2010. A large number of imported hybrids in vegetables are gaining popularity among the farmers in Nepal.

Research in hybrid development was initiated in tomato in 1988 by VDD, but was discontinued due to organizational and mandatory change in 1990. Again it was revived by HRD/NARC and Srijana tomato hybrid was registered in 2010. It has been ten years then and a single hybrid variety has not been developed. National Seed Vision 2025 was formulated in 2012 and a good eight years have passed. Our initiation of hybrid variety development in public sector is very limited and slow in HRD. ***If not now, when? And if not us, who?*** Therefore, let us identify the crops research farms and immediately enhance the job.

## Major Niche Production Pockets and Niche Commodities

Vegetable seed production is a long term enterprise compared to fresh vegetable production. Many vegetables are consumed during juvenile phase and have shorter production period. On the contrary to fresh vegetable, all the vegetable seed production have longer period and have to pass from juvenile to reproductive phase. Climate is the main decision making factor for seed production. The climates of terai, inner terai, river basin areas and foot-hills are suitable for the seed production of tropical and sub-tropical vegetable like cucurbits, okra, chili, tomato, eggplant and many legumes. Mid-hills are suitable for the production of mid- season cauliflowers, radish, peas, beans, spinach, cress, onion, etc. Higher mountain has temperate climate, and is suitable for the production of high chilling varieties of cruciferous crops, carrot, beet root, etc. Many kinds of vegetable seed can be grown in different parts of the country in different seasons adjusting the sowing and flowering time. There are some vegetables crops which need both vernelization and long day condition for flowering and maturity which are available in Nepal.

With the long experiences of vegetable seed production the following districts have been developed as the commercial sites for specific crops and varieties. The specific niche pockets for niche commodities within the districts are always pushing towards remote villages. The niche districts for vegetable seed production are presented in Figures 2.1, 2.2, 2.3 and 2.4.

(**A**) **High Chilling Long-day Vegetables:** Cauliflower (Snow Ball Groups), carrot, radish (Tokinasi), beet root, rayo (Marpha)
**Existing Districts:** Jumla, Dolpa, Mustang
**Potential Districts:** Kalikot, Humla, Mugu, Baglung (Rayo Marpha)

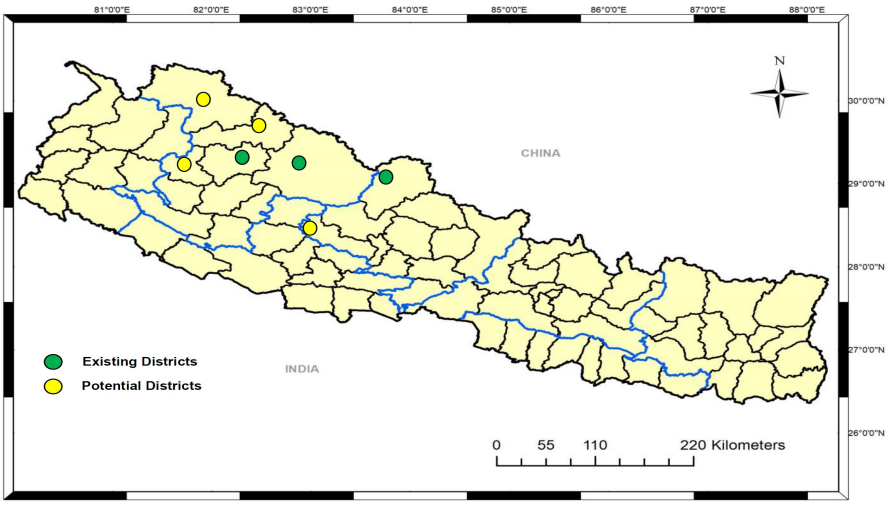



**Figure 2.1.** Temperate region districts and prioritized vegetables.

**(B) Warm Temperate Vegetables:** Mid-season cauliflower, beans, peas, radish (Mino Early, Chalis Dine), onion (Rukum, Dailekh, Surkhet), Rayo Marpha (Dolpa)
**Existing Districts:** Baitadi, Dadeldhura, Rukum, Dailekh, Salyan, Surkhet, Parbat, Kavre, Palpa, Rolpa, Dhankuta
**Potential Districts:** Darchula, Doti, Achham, Gulmi, Sindhupalchowk, Lalitpur

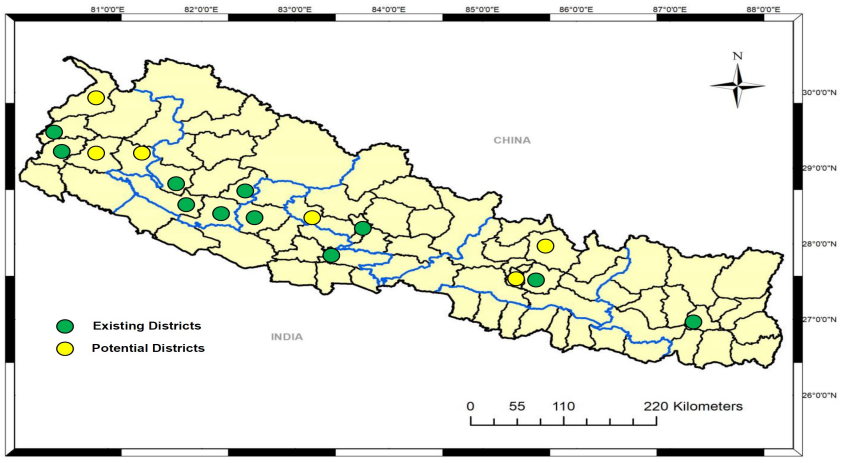



**Figure 2.2.** Warm temperate region districts and prioritized vegetables.

**(C) Sub-tropical Vegetables:** Cucumber, bitter gourd, bottle gourd, tomato (Srijana, Lapsi Gede), okra, Cress, spinach

**Existing Districts:** Parbat, Surkhet, Kavre, Dolakha, Lalitpur, Dadeldhura

**Potential Districts:** Parbat, Myagdi, Nuwakot, Okhaldhunga, Khotang

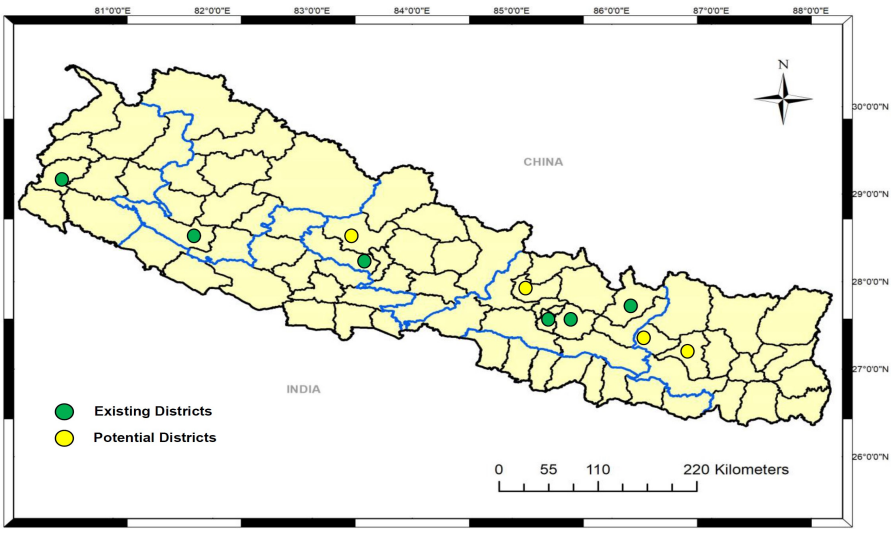



**Figure 2.3.** Sub-tropical region districts and prioritized vegetables.

**(D) Tropical Vegetables, Prioritised Crops:** Pea, asparagus bean (Tane bodi), okra, watermelon, tomato, eggplant, chilli

**Existing Districts:** Sunsari, Sarlahi, Banke

**Potential districts:** Mahotari, Bara, Rupandehi, Bardiya

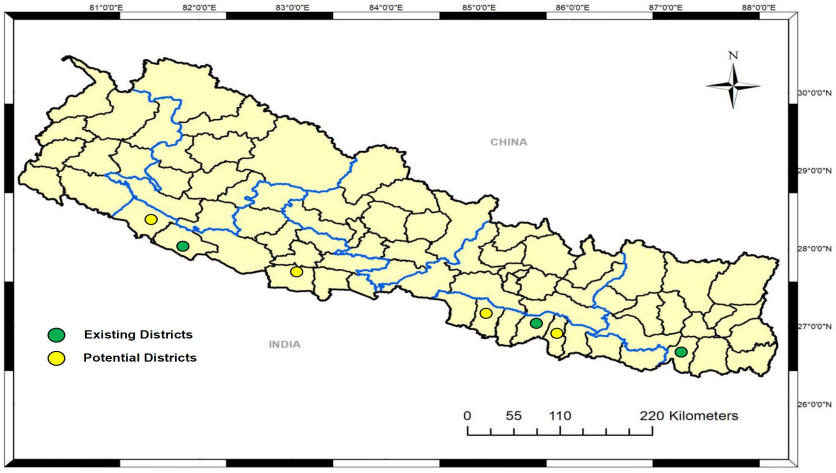



**Figure 2.4.** Terai region districts and prioritized vegetables.

## Conclusion

Vegetable is a complex sub-sector as it has to address a wide range of vegetable species, sub-species and varieties adaptable to varying agro-ecological environments. Thus, research inputs from both public and private sectors (Seed companies, Non-governmental organizations and Farmer's Cooperatives) are very critical to meet the target set in National Seed Vision and Agriculture Development Strategy (ADS). In the present context of rapid replacement of OP varieties by imported hybrids, the need for intensive researches has crucially emerged for identifying indigenous cultivars, demonstrating their commercial values, developing new OP varieties and parental lines for hybrid variety development. Public sector research could be led by NARC in collaboration with Potato, Vegetable and Spice Development Center, NAST and Universities (Tribhuwan University, Agriculture and Forestry University and Purbanchal University) having post-graduate and Ph. D. programme in horticulture/vegetable. Private sector research could be done by private seed companies and NGOs in partnership with public sector in participation with farmers.

Production, consumption and marketing of fresh vegetables have been increasing during recent decades. Farmers are demanding imported hybrid vegetable varieties that are high yielding, short durational and suitable to different agro-ecological environment and different season. However, this should not be at the cost of Nepali OP varieties which possess the immense potential of farmer's acceptance, adaptability to local climatic stresses and tolerance to many pests and diseases. Therefore, investment on farmer's preferred priority vegetable crop researches for development of new OP varieties, parental lines development for hybrid variety development, their seed production and proper maintenance of released and registered varieties and parental lines must be stream lined. Sustaining the seed value chain from breeder's (nucleus) seed to improved/labeled seed production with proper quality assurance through truthful labeling under a collaborative action involving all the related government, non-government, private and cooperative stakeholders can increase the competitiveness of Nepali seeds both in domestic and international market through quality assurance, branding and packaging. National Seed Vision 2025 has developed strategies and set targets to develop OP and hybrid varieties in vegetable crops to increase replacement rate to 90% from the existing 68% rate during 2014 by developing 30 hybrid varieties in vegetable crops.

Fresh vegetable production and marketing is always led by supply of good quality inputs: mainly seed and market management. Safe produce with no or within the limit of pesticides and mainly hazardous pesticide free products are in demand. The demand for clean, well branded, nicely packed and well displayed fresh vegetable produce is increasing. Fresh vegetable market function and trader's behaviour should be changed to benefit both fresh vegetable producers and consumers with well planned production programme along with regular supply chain for heading towards international standards of fresh vegetable and seed market development.

The comparative advantages both for vegetable seed production and fresh vegetable production need to be harnessed in all the ecological zones of Nepal for year round commercialization of fresh vegetable production, consumption and export. Huge potentiality for vegetable seed production of temperate to tropical crops from terai to high

hill must be exploited and utilized with proper zoning of seed production. Hills and high hills are suitable for temperate vegetable seed production and terai, inner terai and lower hill basins are suitable for solanaceoous, cucurbits, okra and legume seed production.

**Abbreviations:** AIC = Agriculture Input Corporation; CEAPRED = Center for Environmental and Agricultural Policy Research, Extension and Development; CIDA = Canadian International Development Agency; DADO = District Agriculture Development Office; DANIDA = Danish International Development Agency; DFID = Department for International Development; DoA = Department of Agriculture; DoH = Department of Horticulture; GoN = Government of Nepal; HRD = Horticulture Research Division; ICM = Indian Cooperation Mission; INGO = International Non-governmental Organization; LAC = Lumle Agricultural Center; NARC = Nepal Agricultural Research Council; NGO = Non-governmental Organizations; NSB = National Seed Board; PAC = Pakhribas Agricultural Center; SDC = Swiss Agency for Development and Cooperation; SEAN = Seed Entrepreneurs' Association Nepal; SQCC = Seed Quality Control Center; USAID = The United States for International Development; VDD = Vegetable Development Division; VSPC = Vegetable Seed Production Center.

**Annex 2.1.** Summary of donor support in vegetable and vegetable seed sector with major contribution and achievements

| S. N. | Name of Project | Donor | Project year | Main achievements |
|---|---|---|---|---|
| 1 | Fresh vegetable and vegetable seed production project | Swiss Assistance through FAO as technical cooperation | 1981–1995 | During these 15 years, it worked in three phases as the counter part of VDD. This project further strengthened the approach initiated by VDD during fifth five year plan and continued till eighth five year plan. The commendable impacts of this period were as under-supported VDD for variety development evaluating 350 new germplasm and improving already popular 25 varieties and total 72 varieties identified.<br>Based on the mode of pollination and breeding behaviour of identified vegetable variety, maintenance chart was developed denoting farm/centres and varieties to be maintained and produce breeders and foundation seed for 18 farm/centres (Annex 2.3 and 2.4).<br>To ease the variety maintenance work, varietal (morphological) characteristics of identified varieties with their marked genetic trait of the identified varieties documented for the use and reference (Annex 2.5).<br>VDD/FAO facilitated to establish SEAN in 1989 and registered in 1991; there were 32 members which now have more than 300 members spread over Nepal and seed dealing entrepreneurs are more than 2000.<br>Supported AIC and strategic government farms to establish seed processing and air-conditioned seed storage facilities. |
| 2 | Japan International Cooperation Agency (JICA) | Japan | 1983–1987 | Introduced protected cultivation of tomato and sweet pepper in half opened plastic tunnel in Khumaltar and proven success. |
| 3 | Regional Vegetable Research project RAS/89/04 | FAO/Regional Office | 1987–1988 | Contributed in germplasm exchange among Asian countries like China, Korea, and Thailand and SAARC countries. |
| 4 | South Asia Vegetable Network (SAVERNET) | Taiwan | 1991–1993 | Introduced different varieties of vegetables for adaptive test; however, the conclusive results could not be reached due to administrative anomalies among researchers. |
| 5 | Vegetable, Fruits and Cash Crops Development Project, (VFC/Rapti) | USAID | 1984–1990 | Scale up seed production and marketing by many folds in Rapti zone through No Frills Consultancy. However, due to its negligence in providing quality foundation seed and quality control services, it lost Nepalese radish seed market in Bangladesh. This project failed to collaborate with research and seed chain maintenance. |
| 6 | Koshi Hills Seed and Vegetable Project (KOSEVEG) | DFID | 1992–1997 | Aimed to develop an effective, sustainable and market oriented seed and vegetable programme for increasing household income. The social mobilization process of the project was notably a successful and it supported in forming Kosi Seed Entrepreneur and Production Association Nepal (KOSEPAN) and linked the seed growers with national and regional seed traders for sustainability. |

| | | | | |
|---|---|---|---|---|
| 7 | Community Based Economic Development Project (CBED) | CIDA | 1997–2002 | CBED adopted the demand based vegetable seed production programme linking seed growers with seed traders through regional seed contracting workshops. It was successful in introducing the seed production practice in the far western hill districts. |
| 8 | Market Access for Rural Development (MARD) | USAID | 1997–2002 | MARD Project supported farmers groups and cooperatives for vegetable seed production and marketing in Surkhet, Dailekh and Nuwakot districts. Due to poor linkage with GoN line agencies the impact could not last long. |
| 9 | Seed Sector Support Project (SSSP) | DFID | 1998–2003 | As a successor of the KOSEVEG project and adopted the same approach for seed production and marketing. The approach was based on contractual seed production agreed by seed producer groups/cooperatives and seed buyers during seed planning workshops. The model was later replicated in other districts (Dadeldhura and Achham). SSSP contributed in enhancing the seed industry of Nepal and is also particularly known for private seed sector growth. It supported processing equipment and laboratory establishment of SEAN Seed Service Center (SSSC), Thankot, a well-equipped company owned by more than 50 SEAN members. |
| 10 | Participatory Vegetable Seed Project (PVSP) | DANIDA | 2001–2003 | Vegetable seed production project implemented by NGO – Center for Environmental and Agricultural Policy Research, Extension and Development (CEAPRED) in six districts of Nepal including both hill and terai districts. |
| 11 | Vegetable Seed Project (VSP) | SDC | 2004–2014 | Implemented by CEAPRED, in order to benefit poor farmers in remote areas by diversifying their income opportunities through vegetable seed production and marketing. The main contribution of this project included:<br>Synergistic approach of combining seed production in the remote districts and fresh vegetable in road corridors with focus on poor, women and disadvantaged households for increased income and food security,<br>Institutionalizing farmers groups into seed cooperatives and linking them with entrepreneurs through Pre-contract Marketing Agreement,<br>Seed Producers' Central Co-operative Federation Ltd registered as umbrella organization of primary seed cooperatives that facilitates for demand based production and nationwide marketing of seeds linking with seed entrepreneurs of all over the country for sustainability, and<br>For quality assurance at production level, Internal Quality Control (IQC) has been established which needs further formalization by DADO and SQCC. |

Source: (Pandey & Shakya, 2016)

**Annex 2.2.** Vegetable seed import with crops, types and amount imported in 2017.

| S. N. | Vegetable type | Seed Import (kg) | | Total (kg) | Share (%) | |
|---|---|---|---|---|---|---|
| | | OP | Hybrids | | OP | Hybrids |
| 1 | Cauliflower | 142 | 1,343.2 | 1,485.2 | 0.08 | 0.74 |
| 2 | Cabbage | 117 | 819.6 | 936.6 | 0.06 | 0.45 |
| 3 | Broccoli | 25 | 121 | 146 | 0.01 | 0.07 |
| 4 | Knolkhol | 7 | 3 | 10 | 0.00 | 0.00 |
| 5 | Other winter vegetables | 100 | 200 | 300 | 0.05 | 0.11 |
| 6 | Tomato | 356 | 371.07 | 727.07 | 0.20 | 0.20 |
| 7 | Brinjal | 66 | 289.07 | 355.07 | 0.04 | 0.16 |
| 8 | Bitter gourd | 603 | 1,499.4 | 2,102.4 | 0.33 | 0.82 |
| 9 | Okra | 8,305 | 3,979 | 12,284 | 4.56 | 2.18 |
| 10 | Hot chili | 97 | 313.58 | 410.58 | 0.05 | 0.17 |
| 11 | Capsicum | 15 | 182.2 | 197.2 | 0.01 | 0.10 |
| 12 | Cucumber | 343 | 1,424 | 1767 | 0.19 | 0.78 |
| 13 | Pumpkin | 195 | 742 | 937 | 0.11 | 0.41 |
| 14 | Zucchini | 100 | 200.5 | 300.5 | 0.05 | 0.11 |
| 15 | Bottle gourd | 441 | 681.2 | 1,122.2 | 0.24 | 0.37 |
| 16 | Sponge gourd | 109 | 799.2 | 908.2 | 0.06 | 0.44 |
| 17 | Snake gourd | 187 | 83 | 270 | 0.10 | 0.05 |
| 18 | Water melon | 15 | 69 | 84 | 0.01 | 0.04 |
| 19 | Other cucurbits | 4 | 6 | 10 | 0.00 | 0.00 |
| 20 | Pea | 15,891 | 18,108 | 33,999 | 8.72 | 9.94 |
| 21 | Bean | 11,800 | 0 | 11,800 | 6.48 | 0.00 |
| 22 | Cowpea | 43,451 | 250 | 43,701 | 23.85 | 0.14 |
| 23 | Broad bean | 10 | 0 | 10 | 0.01 | 0.00 |
| 24 | Soybean | 1,800 | 0 | 1,800 | 0.99 | 0.00 |
| 25 | Other legumes | 104 | 550 | 654 | 0.06 | 0.30 |
| 26 | Broad leaf mustard | 1,976 | 0 | 1,976 | 1.08 | 0.00 |
| 27 | Spinach | 3,342 | 940 | 4,282 | 1.83 | 0.52 |
| 28 | Rapeseed | 7,142 | 1,500 | 8,642 | 3.92 | 0.82 |
| 29 | Fenugreek | 1,571 | 0 | 1,571 | 0.86 | 0.00 |
| 30 | Other leafy vegetables | 9,850 | 1,500 | 11,350 | 5.41 | 0.82 |
| 31 | Radish | 2,296.5 | 5,701.5 | 7,998 | 1.26 | 3.13 |
| 32 | Turnip | 35 | 0 | 35 | 0.02 | 0.00 |
| 33 | Carrot | 185 | 864 | 1,049 | 0.10 | 0.47 |
| 34 | Onion | 13,854 | 324 | 14,178 | 7.61 | 0.18 |
| 35 | Asparagus | 30 | 0 | 30 | 0.02 | 0.00 |
| 36 | Other vegetables | 13,220 | 1,500 | 14,720 | 7.26 | 0.82 |
| | **Total** | **137,784.5** | **44,363.52** | **182,148.02** | **75.64** | **24.36** |

Source: (SEAN & SQCC, 2017)

**Annex 2.3.** Crop and variety-wise maintenance chart at various farms and stations developed during sixth five year plan.

| S. N. | Farm/Station and crop | Variety |
|---|---|---|
| 1 | **VSPC Dadeldhura** | |
| | Knol Khol | White Vienna |
| | Radish | Mino early |
| | Turnip | Improved White |
| | Broad leaf mustard | Khumal Red Leaf |
| | Tomato | Monprecos |
| | Peas | NLP |
| | French bean | Contender, Kentucky Wonder |
| | Cucumber | Local |
| 2 | **VSPC Rukum** | |
| | Cauliflower | Kathmandu Sthaniya |
| | Radish | Mino early |
| | Turnip | Purple Top White Globe |
| | Broad leaf mustard | Khumal Broad Leaf |
| | Cress | Local |
| | Onion | Red Creole |
| | Sweet pepper | California Wonder |
| | Tomato | Pusa Ruby |
| | Peas | Arkel |
| | French bean | Contender |
| | Squash | Black Zucchini |
| 3 | **Horticulture Farm Pokhara** | |
| | Radish | Mino early |
| | Okra | Pusa selection I |
| | Sponge gourd | Pusa Chillo |
| 4 | **Horticulture Farm Marpha** | |
| | Cauliflower | Snow Ball |
| | Radish | Tokinasi |
| | Turnip | Purple Top White Globe |
| | Broad leaf mustard | Marpha Broad Leaf |
| | Peas | Arkel |
| | Bean | Carlos favorite |
| | Cress | Local |
| | Cabbage | Large Late Drum Head, Copan Hagen market, Pride of India |
| | Carrot | Nantes Forte |
| | Swiss Chard | Ford Hook Giant |
| | French bean | Kentucky Wonder |

| | | |
|---|---|---|
| 5 | **Agriculture Station Lumle** | |
| | Knol Khol | White Vienna |
| | Cauliflower | Kathmandu Local |
| | Radish | Pyuthane red, 40-days |
| | Spinach | Patane |
| | Peas | Arkel, Sikkim |
| | Coriander | Local |
| | Fenugreek | Kauri |
| | Eggplant | PPL |
| | Squash | Grey Zucchini |
| | Cucumber | Bhaktapur Local, |
| 6 | **VSPC Khumaltar** | |
| | Cauliflower | Kathmandu Local |
| | Radish | Mino early |
| | Turnip | Purple Top White Globe |
| | Broad Leaf Mustard | Khumal Broad Leaf |
| | Peas | Perfection New Line, Sikkim |
| | French beans | Kentucky Wonder |
| | Tomato | Monprecos |
| | Okra | Pusa Sawani |
| | Spinach | Patane |
| | Squash | Grey Zucchini |
| | Cress | Local |
| | Broad bean | Local |
| | Chili | Dandicut and Kathmandu Local |
| | Swiss Chard | Ford Hook Giant |
| | Fenugreek | Kasuri |
| | Cowpea (Asparagus bean) | Khumal Tane (Red seed) |
| | Cucumber | Bhaktapur Local |
| 7 | **Horticulture Farm Sarlahi** | |
| | Peas | Arkel, Boonville, NLP |
| | Tomato | Pusa Ruby, Roma, CL 1131, Pusa Early Dwarf |
| | Okra | Pusa sawani, Parwani Kranti |
| | Sweet pepper | California Wonder |
| | Beet spinach | All green |
| | Cucumber | Poinsett |
| | Eggplant | Nurki, Sarlahi Green |
| | Watermelon | Sugar-baby |
| | Cauliflower | Pusa Deepali |
| | Radish | Pusa chetki |

| | | |
|---|---|---|
| | Fenugreek | Kasuri |
| | Chili | Pusa Jwala |
| | Eggplant | Nurki, PPL, Sarlahi Green |
| | Cowpea | Sarlahi Black |
| | Pumpkin | Local |
| | Bitter gourd | Pusa Domousami |
| | Bottle gourd | Pusa Summer Prolific Long |
| | Sponge gourd | Pusa Chillo |
| | Ash gourd | Local |
| 8 | **Agriculture Station Dhankuta** | |
| | Cauliflower | Kibo Giant |
| | Radish | White Neck |
| | Broad leaf mustard | Khumal Broad Leaf |
| | Peas | Perfection New Line |
| | Beans | Contender |
| | Tomato | Monprecos |
| | Capsicum | California Wonder |
| | Onion | Red Creole |
| | Turnip | Purple Top White Globe |
| | Cress | Local |
| | French bean | Kentucky Wonder |
| 9 | **Agriculture Station Pakhribas** | |
| | Broccoli | Green Sprouting |
| | Cauliflower | Kathmandu Local |
| | Radish | Mino early, 40-days |
| | Broad leaf mustard | Khumal Broad Leaf, Tangkhuwa |
| | Cress | Local |
| | Table beet | Detroit Dark Red |
| | Chili | Akabare |
| | Sweet pepper | California Wonder |
| | Peas | Boonville, Sikkim |
| | French bean | Kentucky Wonder |
| | Cowpea | Kathmandu Red |
| | Bitter gourd | Coimbatore Long |
| | Squash | Black Zucchini |
| | Sponge gourd | Local |
| 10 | **Horticulture Farm Panchkhal** | |
| | Peas | Arkel |
| | Pumpkin | Local |
| | Tomato | Marglobe |
| | Eggplant | Sarlahi Green |
| | Bottle gourd | Pusa summer Prolific Long |

| | | |
|---|---|---|
| 11 | **Horticulture Station Parawanipur** | |
| | Peas | Arkel |
| | Pumpkin | Local |
| | Tomato | Marglobe |
| | Eggplant | Sarlahi Green |
| | Bottle gourd | Pusa summer Prolific Long |
| 12 | **Agriculture Station Jumla** | |
| | Cabbage | Golden Acre |
| 13 | **Agriculture Station Dolpa** | |
| | Cauliflower | Snow Ball 16 |
| | Carrot | New kuroda |
| | Broad leaf mustard | Marpha Broad Leaf |
| 14 | **Horticulture Farm Janakpur** | |
| | Radish | Chetki |
| | Peas | Perfection New Line |
| | Okra | Pusa Selection I |
| | Chili | Cyanne |
| | Eggplant | Pusa Kranti |
| 15 | **Agriculture Farm Palpa** | |
| | Cauliflower | Early Snow Ball |
| | Radish | Pyuthane |
| | Onion | Nasik red |
| 16 | **Agriculture Station Nepalgunj** | |
| | Tomato | Money Maker |
| | Eggplant | Pusa Purple Cluster |
| 17 | **Horticulture Farm Dailekh** | |
| | Broad Leaf Mustard | Marpha Broad Leaf |
| | Onion | Agri-found Dark Red |
| 18 | **Horticulture Farm Sindhuli** | |
| | Chili | Yatsufusa |
| | Eggplant | Pusa Purple Round |

Source: (VDD, 1993a)

**Annex 2.4.** Organizations responsible for maintaining crop varieties in Nepal as proposed by SQCC, Harihar Bhawan in 2016.

| Crop | Variety | Variety maintenance organization |
|---|---|---|
| Tomato | Sirijana hybrid | Horticulture Research Division,Khumal, NARC |
| Tomato | Pusa Ruby | Sarlahi Horticultural Farm (DoA) |
| Tomato | NCL | Horticulture Research Station, Malepatan, NARC |
| Radish | Mino Early | Agriculture Research Station Dailkeh, NARC |
| Radish | Pyuthane Red | Horticulture Farm (DoA), Palpa |
| Radish | 40 days | Regional Agriculture Research Station Lumle |
| Radish | Tokinashi | Horticulture Research Station, Jumla (NARC) |
| Rayo | Marpha Broad Leaf | Horticultural Farm Mustang (DoA) |
| Rayo | Khumal Red Leaf | Vegetable Seed Production Center, Dadeldhura |
| Rayo | Khumal Broad Lead | Horticulture Research Division,Khumal, NARC |
| Onion | Red Creole | Agriculture Research Station Dailkeh, NARC |
| Pea | Sarlahi Arkel | Regional Agriculture Research Station Nepalganj (NARC) |
| Pea | Sikkim Local | Regional Agriculture Research Station Lumle |
| Cauliflower | Kathmandu Local | Horticulture Research Division,Khumal, NARC |

Source: (SQCC, 2016)

**Annex 2.5.** Released vegetable varieties and their distinguishing characters.

| S. N. | Crops and varieties | Released year | Distinguishing characters |
|---|---|---|---|
| 1 | **Cauliflower** | | |
| | Sarlahi Dipali | 1994 | Plants are medium tall of erect habit, green and waxy leaves having rounded apex. Curd are somewhat round, white to creamy white, compact, medium sized weighing 600–700 g. Average yield is 15 ton/hectare (t/ha). |
| | Dolpa Snowbal | 1994 | Late variety maturing in 130 days after transplanting, curd round, white, smooth, weight 1.5–2 kg. Suitable for autumn transplanting and spring harvest. A selection from Snowball-16. |
| | Kathmandu Local | 1990 | A well adapted mid-season variety maturing in 110–120 days after transplanting. Wide adaptability to the different conditions. Excellent white to creamy white, flatish compact curd, fine grained, semi-self-protected by outer leaves. Curd weight 1.5–2 kg. |
| | Khumal Jyapu | 2014 | Matures in 65–80 days after transplanting and have around 1 kg size with better taste, developed by Horticulture Research Division, Khumaltar. |
| 2 | **Radish** | | |
| | Chalis Dine | 1994 | Variety early, maturing 35–45 days. Roots white 15–25 cm long, pungency very low. Leaves are upright, erect, light green, non-hairy, sweet and shining white. |
| | Pyuthane Rato | 1994 | Late season variety, maturity 70–80 days after sowing, root red with white flash, 20–30 cm long, thick tapering. Red neck with light red or whitish red root end. |
| | White Neck | 1994 | Maturity 60–65 days. Roots 35 cm long, 6–8 cm diameter, cylindrical, pure white and smooth. Flesh white, mild pungency. Leaves upright, light green in colour, top green. Yield 30–40 t/ha. |
| | Mino Early | 1990 | Early variety, maturity 45–50 days. Roots pure white, tapering rooted, have tendency to grow above ground level. Pungency mild. Leaf grayish green having deep cuts with spreading habit. Yield 30–40 t/ha. |
| 3 | **Broad leaf mustard** | | |
| | Tangkhuwa Rayo | 1994 | Light green leaf with cream white leaf vein, very smooth and wavy leaf margin. |
| | Khumal Rato Pat | 1994 | Late variety, matures for first harvest in 60–70 days after transplanting, leaves are green with purple-red pigments, puckered, non-hairy, petioles curved and leaves are also curved to a cup-shape, fleshy, 25–30 cm long and 20–25 cm wide, bolts later than Khumal and Marpha broad leaf; yields 25–30 t/ha green leaves. |
| | Khumal Chaudapat | 1994 | Mature for first harvest in 40–50 days after transplanting and continues for another 100–120 days, leaves dark green, fleshy, non-hairy and puckered, 40–50 cm long and 25–30 cm wide, yield 30–40 t/ha green leaves. |

| | | | |
|---|---|---|---|
| | Marpha Chaudapat | 1994 | Mature for first harvest in 55–65 days after transplanting; leaves light green, non-hairy, puckered, 40–50 cm long and 20–30 cm wide with flat petioles; late bolter; yield 25–30 t/ha green leaves. |
| 4 | **Turnip** | | |
| | Purple Top | 1994 | Leaves dark green with deep cuts, roots globe shaped white with purple exposed crown. Flesh white, maturity 60–70 days after sowing. Plants top erect. Suitable for autumn plantation. |
| | Kathmandu Rato | 2015 | Early variety, root matures in 50–55 days of sowing. Root globe to flatish, outer colour red, flesh white, strong flavour. |
| 5 | **Onion** | | |
| | Red Kriole | 1990 | Deep red skinned thick flat bulb, white flash, medium late variety, bulb matures in 160–180 days after transplanting. Bulb weightabout 175 g. |
| 6 | **Tomato** | | |
| | Srijana (Registered) | 2010 | Hybrid variety developed by NARC, bacterial wilt resistant, fruit ovate, 60–80 g weight, uniform and red and heavy yielder, indeterminate variety. |
| | Roma | 1995 | Mid-season variety, fruits ready for first harvest in 60–70 days after transplanting. Fruits smooth, uniformed fleshy thick, bi-chambered, less seed content, leaves broader, potato type, plant determinate and bushy. |
| | Manprekas | 1995 | Medium early variety, fruit ready for first harvest in 80–90 days after transplanting, fruits globe shaped, smooth, uniformly red, bi-tri-chambered, firm flash seed content low, plant vigorous, indeterminate, erect. |
| | NCL-1 | 1990 | Heat resistant and wilt tolerant variety, fruits ready for first harvest in 65–75 days after transplanting, fruits plum shaped to flatish round, firm, thick skinned, yellowish red with a slight green shoulder when ripe, suitablefor rainy season and autumn season harvest. Plant semi-determinate toindeterminate depending upon climate. A selection from CL-1131 cultivar. |
| | Pusa Ruby | 1990 | Fruits ripe in 60–65 days after transplanting fruits flatish round, uniform red, smooth surface, seed content comparatively higher, determinate growth habit. |
| 6 | **Carrot** | | |
| | Nantis Forte | 1990 | Very high quality roots. Suitable for autumn and spring plantation. Excellent internal and external colour. Roots 15–20 cm long, cylindrical blunt tipped. Matures in 90–100 days after sowing. |
| | New Koruda OP (Registered) | 2010 | Well adapted variety for tropical and sub tropical conditions. Roots 15–20 cm long with conical flat shoulder, tapering towards the root end. Bright orange coloured surface with few deep eyes. Matures in 80–100 days after sowing. |

| | | | |
|---|---|---|---|
| 7. | **Cabbage** | | |
| | Copenhagen Market | 1994 | Mid-season variety; mature 70–90 days after transplanting, head round, blue green, 1.5–2.5 kg, good for school garden. |
| 8. | **Asparagus bean** | | |
| | Sarlahi Tane | 1994 | A bit early variety. Pods ready for first harvest in 50–60 days after sowing. Plants climbing, pods 25–30 cm long, light greenish white, seed black when ripe. |
| | Khumal Tane | 1994 | Climbing long podded type, pods 30–45 cm long white to greenish white, seeds red when ripe. Needs warm climate for successful results. Yields 6–8 fresh pods t/ha. |
| 9 | **Pole bean** | | |
| | Trishuli Simi-1 | 1994 | Popular climbing type pods 20–25 cm long. Green fleshy, long curved ('S' shaped), fibreless at prime pickingperiod. Seeds light to coffee brown with purple eye ring. Yield 6–8 t/ha. Suitable for autumn and spring through summer harvest. |
| | Jhange Simi-1 | 1994 | Bush type variety, resistant to common bean mosaic. Maturity 50 days after sowing. Pods dark green and 15 cm long. Yield 5–6 t/ha. |
| 10 | **Peas** | | |
| | Sarlahi Arkel | 1994 | Early variety, ready for first picking in 60–65 days after sowing, pods deep green 7–8 cm long, well filled with 7–8 grains seeds wrinkled on drying, yields 5–7 t/ha green pods. Suitable for late autumn sowing and early spring harvest. |
| | New Line | 1994 | Mid to late season variety, flowers in 60–65 days of sowing, pods are ready for first picking in 85–90 days of sowing, plant medium tall and vigorous in growth, leaves are dark green and broader, flower borne in double, pods straight green, 7–8 cm long, well filled with 6–7 grains seeds wrinkled on drying. Suitable for autumn plantation. |
| | Sikkime | 1994 | Late variety, flowers in 80–85 days and pods ready for first picking in 105–110 days after sowing, plants are tall and vigorous, leaves are light green with very wide leaf lets, pods light green, well filled, short with 6–7 grain, seeds are bold, creamy whitish with black helium, smooth on drying, suitable for rainy season in high hills. A selection form Sikkim Local variety. |
| 11 | **Capsicum** | | |
| | California | 1994 | Fruits ready for first harvest in 80–90 days after transplanting, plants 70–75 cm tall, erect somewhat busy, leaves single entire broader than normal chili, dark green with pointed tip, fruits are 3 to 4 lobed generally. Yields 25–30 t/ha. |

| | | | |
|---|---|---|---|
| 12 | **Chilli** | | |
| | Jwala | 1994 | A high yielding variety with long slender fruits, brilliant red when ripe. Selection of Pusa Jwala variety. Slightly earlier than other commercial varieties. |
| 13 | **Brinjal** | | |
| | Nurki | 1999 | Plant medium, stem and leaves pinkish in colour, thronless leaves and stem but thrones in fruit petiole. Fruit 15–25cm long, soft, 4–5 fruits in a bunch. Maturity 60–70 days. |
| 14 | **Sponge gourd** | | |
| | Kantipure | 1994 | |
| 15 | **Cucumber** | | |
| | Kushle | 1994 | Early variety, fruits ready for first harvest in 75–80 days after sowing. Fruits straight 15–25cm long with 6–10 cm diameter, fruit light green with more white towards distal end. |
| 16 | **Squash** | | |
| | Ashare Squash | 1994 | Fruits are medium sized, flesh is tender and delicious at immature stage when it is used as vegetables. Duration 60–80 days. Yield 20–35 t/ha. |
| 17 | **Swiss chard** | | |
| | Susaag | 1994 | Duration 60–70 days. Yield 20–35 t/ha. |
| 18 | **Bitter gourd** | | |
| | Green Karela | 1994 | Fruits are dark green, Duration 90–100 days. Yield 20–25 t/ha. |
| 19 | **Lady's finger** | | |
| | Parbati | 1994 | An early heavy yielding variety, more tolerable to yellow vein-mosaic virus. Plant medium tall. Fruits fleshly, medium green in colour. Well adapted for spring, summer and rainy season harvest. A selection of Parvani Kranti variety. |
| 20 | **Spinach** | | |
| | Haripate | 1994 | Plants ready for harvest in 50–60 days after sowing, leaves erect, smooth, vigorous, and green to dark green, petioles and lower base pinkish. Suitable for autumn and spring sowing. |

Source: (VDD, 1993b)

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## Author's Biography



Indra Raj Pandey, born in Nuwakot, Rawalaswanra, has received M.Sc. Agriculture (Horticulture) degree from Himachal Pradesh Krishi Vishwa Viddhyalaya, India in 1982. He has involved in vegetable and vegetable seed research and development work for the Government of Nepal from 1972 to 2003. He has served as an Expert and Specialist in Hellen Keller International funded by USAID, Senior Agriculturist in Integrated Bagmati Watershed Management funded by EU, Team Leader of Vegetable Seed Production project funded by SDC in CEAPRED, Technical Advisor of Nepal Market Development Project funded by DFID. He is continuing works and studies as free lancer horticulturists and consultants for different project. He has written 10 books and mannuals, and published several papers and research articles.

# Chapter 3

## Vegetable Genepools in Nepal: An Update on Semi-domesticated, Wild and Wild Relatives Awaiting Conservation and Sustainable Utilization

**Ram Chandra Poudel[1]* and Bal Krishna Joshi[2]**
[1]*Molecular Biotechnology Unit, Faculty of Science*
*Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal*
[2]*National Agriculture Genetic Resources Centre (NAGRC, National Gene Bank)*
*Nepal Agriculturl Research Council (NARC), Khumaltar, Lalitpur, Nepal*
*Email: ramc_poudel@yahoo.com

*Complex landscapes in mountainous areas of Nepal are not only the habitat for unique biodiversity, such diversity has also provided immense opportunities for local livelihood and food and nutritional security of indigenous people. Nepal is rich in plants and associated traditional knowledge of their uses on domesticated and semi-domesticated species, landraces of various crops and wild edible species. From time immemorable, native communities of Nepal are consuming varieties of wild and semi-domesticated plants as seasonal vegetables. Such species are highly preferred among the people living in periurban and urban areas too. Unsustainable collection and over exploitation of such resources could limit our capacity in developing cultivars with quality traits that can be commercialized in global scale. Moreover several wild and semi-domesticated vegetable species have multiple use values as medicine and food supplements, which can be exploited for economic benefits of the communities. In this chapter, we have provided a revised list of domesticated, wild and semi-domesticated vegetable species including vegetables wild relatives distributed in different ecological zones of Nepal. Genomics of domesticated vegetables, importance of vegetables wild relatives in developing high quality cultivars and available techniques, hotspots of wild vegetables and vegetable wild relatives, methods adopted in conservation assessment, ongoing conservation practices, existing threats and challenges in sustainable management are discussed.*

**Keywords:** Biodiversity; domestication; landraces; nutritional security; wild cousin.

## Introduction

Nepal Himalaya lies in the middle of 3,000 km long complex mountain system which was formed when Indian plate collided into central Asiatic Tibetan plate at north about 50

*Comprehensive Insights in Vegetables of Nepal*
Sajan Lal Shyaula, Gan B. Bajracharya, Gopal K.C., Shanta Man Shakya and Dilip Subba (Editors)
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million years ago. Formation of Himalaya has created diverse array of habitats for the flora and fauna around this region (Searle & Treloar, 2019). Impressive diversity of plants and animals along Himalaya is attributed to migration of different species into this incredible area from all directions. Nepal Himalaya host around 13,067 species of flora and 17,097 species of fauna (GoN/MoFSC, 2014). These biodiversity resources are source of livelihood and income for diverse communities who moved to this small paradise from different region of Asia over the ages. Our ancestor foraged plants and animals for different purposes. Traditional knowledge on uses was developed by trial and error over long periods. Tested knowledge thus obtained was then transferred from generation to generation through oral teaching and practice (Manandhar, 2002). Therefore, multi-ethnic country Nepal is rich in traditional knowledge and cultural practices. Manandhar (2002) has documented about 20% of total flora used by different ethnic groups of Nepal for different purposes. Out of 651 wild and semi-domesticated species reported for their food value, more than 36% are used as vegetables. Wild and semi-wild vegetables have significant role in nutritional diet and food security of Nepalese rural people (Uprety et al., 2012). Similarly, 65% population in Nepal are dependent in agriculture and they grow 599 species of food plants and among them 200 species are vegetables (Regmi, 1982). Collection of vegetables from wild and semi-wild condition and growing seasonal landraces and varieties are an important part of locals livelihood (Manandhar, 2002; Miehe et al., 2015; Pandey et al., 2017). In the following sections information on wild, semi-wild and cultivated vegetable species including their wild relatives are dealt in detail.

## Vegetables, a Major Source of Human Diet

Vegetables are an important part of human diet because they provide a major portion of caloric and protein intake. Additionally leafy and other green vegetables are good supplies of vitamins, minerals and dietary fibers (Pandey et al., 2017). Most probably, vegetables were the first plants those were tested and started to regularly consume by early human. Different types of seasonal vegetables account substantially to the food of human that comes from plant.

## Vegetables and History of Domestication

Around 10,000 years ago, semi-nomadic early human who has also started sedentary life were assumed to begin domestication of plants in the areas where abundant supply game and diversity of edible food were present (Harlan, 1992; Rubatzky & Yamaguchi, 1997). First cultivated plant or plants naturally growing near human settlements or in disturbed area were definitely from wild origin. Early human might have selected those species for domestication in successive generations. Such species could become established through domestication because of less competition in disturbed area as well as human protection nearby settlements. After thousands of years of such practice semi-domesticated species were evolved and fully adopted in more organized cultivation system. Depending on the geographic and climatic zones of the regions, first domesticated plants were propagated through vegetative parts or seeds. Vegetative propagation through roots and tubers is most likely the first means of domestication rather than from seeds. Study suggests that

vegetative means of reproduction is prevalent in lowlands of Americas, southeast Asia, and Africa having humid tropical and semi-tropical climate, while seed based propagation was dominant in the regions with marked wet and dry seasons where environment was favorable for plants to flower and permit seed maturation (Rubatzky & Yamaguchi, 1997).

Domestication has resulted unprecedented changes on the morphology in the cultivated species compared to their wild progenitors. Through artificial selection and systematic breeding, domesticated plants have accumulated several valuable characters to humans. According to specific usage and preferences, domesticated vegetables show typical characteristics like varied sized leaves, flower, fruits, stems and roots, less seeds, absence of bitterness/toxins, loss of self-propagation capabilities and range of physiological adaptations.

Vegetables are mostly succulent, bulky and fresh thus must be consumed or processed within short period. Nowadays, vegetables produced in one area are widely distributed through national and international transportation facilities (Khoury et al., 2016). Some of the vegetables are perishable within a short time. Perishable vegetables can be transported adopting improved packaging or in refrigerators.

Indigenous people inhabiting different parts of the world started domestication of indigenous plants as crops including vegetables (Harlan, 1992). Such plants were transferred widely between different continents through international trade, colonization and by scholars and immigrants. Transfer of such plants took place from the centres of origin to other areas, which were later developed into centre of diversity as well (Sauer, 1993; Smith, 1969; Vavilov, 1952). Continuous movements of people have also led to change in food use patterns in many parts of the world (Rubatzky & Yamaguchi, 1997).

## Classification of Vegetables

Plant or parts of plant that are eaten raw or cooked are termed as vegetables. Vegetables are grouped according to their habit or plant life span, their edible parts and climatic conditions, and preferred habitat in which they grow (Figure 3.1). In most of the cases, such classifications are not universal, loosely grouped and do overlaps (Rubatzky & Yamaguchi, 1997). Most of the world's vegetables belong to succulent, starchy and leguminous vegetables. Green pods and green leaves of legume crops grown for dry seeds are also widely consumed as vegetables. Starchy vegetables comprising tuberous and rhizome crops are important source of energy food. These types of vegetables are grown widely in the tropical-temperate regions. Among the starchy vegetables, potatoes, yams and taro are predominant. Succulent vegetables are extensively cultivated and are comparatively widely used worldwide as a source of vitamin, minerals and fibres. Vegetable, like tomato, has broadest use throughout the world (Khoury et al., 2016). Starchy, succulent and leguminous vegetables are also classified into three groups as leafy vegetable, fruity vegetable, and tuberous and rhizomatous vegetables.

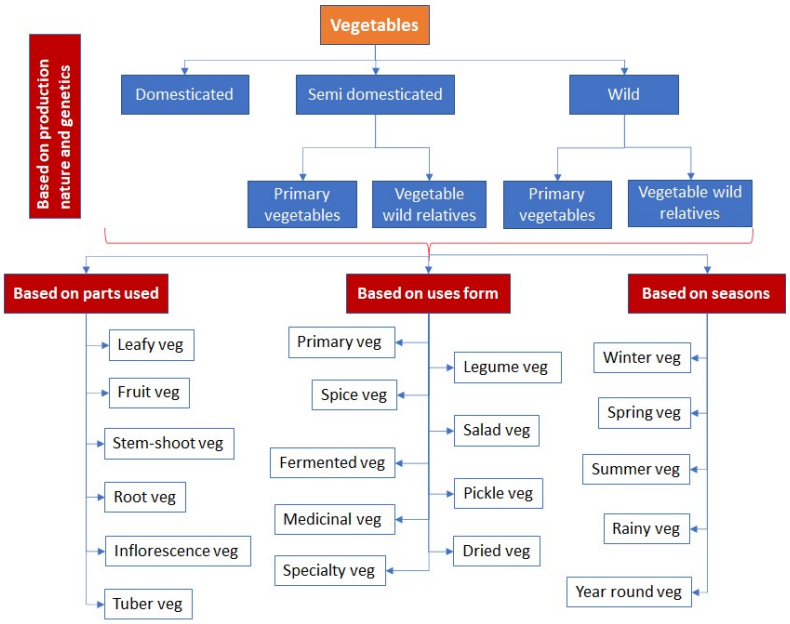



**Figure 3.1.** Classification of vegetables based on different criteria. Further groups of vegetables can be based on (i) growth habit, e.g. herb, shrub, tree, climber and creepers; (ii) lifespan, e.g. annual, biannual and perennial; and (iii) mode of propagation, e.g. self pollinated, cross-pollinated and vegetatively propagated.

## Sources of Vegetables

Vegetables are collected from wild, semi-wild or grown for edible parts, which are consumed as a part of a meal. Rich biodiversity and agro-biodiversity have greater impact on food habits and livelihood of Nepalese communities inhabiting different parts of the country. Local people are known to rely on vegetables from wild and semi-wild conditions since time immemorial. Rural communities are still using diverse kind of edible species in myriad of ways. In some rural areas of Nepal, people consume wild vegetables for more than three months of the year (Aryal et al., 2018; Uprety et al., 2012). Depending on the availability in wild or semi-wild conditions, various seasonal vegetables reach in Nepalese kitchen of both rural and urban areas throughout the year (see: Tables 3.1, 3.2 and 3.3). A large number of people consider wild vegetables are tastier, highly nutritious, organic and relatively cheap than cultivated exotic varieties (Uprety et al., 2012). People in rural areas are widely practicing subsistence farming where they keep indigenous breeds of goat, cattle and chicken, and grow local landraces of crops including vegetables (Joshi et al., 2020b). Extension of rural hill road networks and expansion of market oriented activities have increased introduction of exotic crop varieties causing imbalance on traditional organic farming practices. Many introduced vegetables species provide higher yield but they need intense care and high amounts of chemical fertilizers and pesticides. Exotic vegetables have caused complete loss of indigenous varieties in many semi-urbanized and remote areas.

## Vegetables in Nepal

Vegetables are an integral part of Nepalese cuisine. Vegetables, both wild and farm origin, are playing important roles in nutrition security, food security and livelihood improvement of the people inhabiting different agro-climatic zones of Nepal. Indigenous people of Nepal collect different types of wild vegetables from forest and pasture land. Such vegetables are also marketed in nearby town (Manandhar, 2002). In addition to collection from wild, unique agro-ecological setting of the country has also favoured cultivation of different local landraces of vegetables such as broad leaf mustard (rayo), beans, cowpeas, gourds, pyuthane radish, pumpkin, yam, taro etc.; those have been traditionally maintained by local communities since long. Exotic vegetables were occasionally introduced by pilgrimage from India; however, recorded cultivation of introduced species from India and England was in the time of Rana prime minister Jung Bahadur Rana, during mid 19$^{th}$ century (Pandey et al., 2017; Regmi, 1982).

## *Domesticated Vegetables in Nepal*

An estimated 200 species of vegetables are grown in different agro-ecological zones of Nepal; however, among the estimated figure about 127 species are reported to be in common use; out of them the majority i.e. 57 are leafy followed by 38 fruit, 13 root and tubers, 11 legume, and 8 stem vegetables (Pandey et al., 2017). There are many species that are nutritionally and geographically unique but most of them are neglected (Joshi et al., 2019, 2020a). Table 3.1 presents commonly grown vegetables in Nepal.

**Table 3.1.** Different kind of cultivated vegetables with their Nepali, English, scientific names and botanical family (modified from Pandey et al. (2017)).

| S. N. | Nepali name | English name | Scientific name | Family |
|---|---|---|---|---|
| | | | **Leafy vegetables** | |
| 1 | Banda Kopi | Cabbage | *Brassica oleracea* var. *capitata* L. | Brassicaceae |
| 2 | Bethe | Lamb's quarter | *Chenopodium album* L. | Chenopodiaceae |
| 3 | Chamsur | Cress | *Lepidium sativum* L. | Brassicaceae |
| 4 | Chervil | Chervil | *Anthriscus cerefolium* (L.) Hoffm. | Apiaceae |
| 5 | Chhyapi | Leek | *Allium porrum* L. | Amyrillidaceae |
| 6 | Chhyapi | Shallot | *Allium ascalonicum* L. | Amaryllidaceae |
| 7 | Chikori | Chicory | *Cichorium intybus* L. | Asteraceae |
| 8 | Chinese Banda | Cabbage (Chinese) | *Brassica chinensis* L. | Brassicaceae |
| 9 | Dandu | Onion (fragrant) | *Allium tuberosum* Rottler ex Spreng. | Amaryllidaceae |
| 10 | Dhaniya | Coriander | *Coriandrum sativum* L. | Apiaceae |
| 11 | Indive | Endive | *Cichorium endivia* L. | Asteraceae |
| 12 | Ishkush | Chayote | *Sechium edule* (Jacq.) Sw. | Cucurbitaceae |
| 13 | Jimbu | Garlic (aromatic leaf) | *Allium hypsistum* Stearn | Amaryllidaceae |
| 14 | Jiriko Saag | Lettuce leaf | *Lactuca sativa* L. | Lamiaceae |
| 15 | Jiriko Saag | Mustard (curly) | *Brassica japonica* (Thunb.) Siebold ex Miq. | Brassicaceae |
| 16 | Kalo Bethe | Goose foot | *Chenopodium murale* L. | Chenopodiaceae |

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|---|---|---|---|---|
| 17 | Kalo Tori | Mustard (black) | *Brassica nigra* (L.) K.Koch | Brassicaceae |
| 18 | Lasun | Garlic | *Allium sativum* L. | Amaryllidaceae |
| 19 | Latte Dana | Amaranth (grain) | *Amaranthus cruentus* L. | Amaranthaceae |
| 20 | Latte Dana | Amaranth (grain) | *Amaranthus caudatus* L. | Amaranthaceae |
| 21 | Methi | Fenugreek | *Trigonella foenum-graecum* L. | Papillenaceae |
| 22 | Nepali Rayo | Mustard (Nepali) | *Brassica juncea* var. *rugosa* (Roxb.) Kitam. | Brassicaceae |
| 23 | Neuzealand Palungo | Spinach (New Zealand) | *Tetragonia expansa* Murray | Aizoaceae |
| 24 | Palungo | Spinach | *Spinacia oleracea* L. | Chenopodiaceae |
| 25 | Parsale | Parsley | *Petroselinum crispum* (Mill.) Fuss | Apiaceae |
| 26 | Parsanip | Parsnip | *Pastinaca sativa* L. | Apiaceae |
| 27 | Pidalu/Karkalo | Colocation/Taro | *Colocasia esculenta* (L.) Schott | Araceae |
| 28 | Pudina/Babari | Mint | *Mentha longifolia* (L.) L. | Lamiaceae |
| 29 | Pyaj | Onion | *Allium cepa* L. | Ámaryllidaceae |
| 30 | Rato Latte | Amaranth (red) | *Amaranthus tricolor* L. | Amaranthaceae |
| 31 | Rayo | Mustard (leaf) | *Brassica juncea* var. *crispifolia* L.H.Bailey | Brassicaceae |
| 32 | Rayo | Mustard (Indian) | *Brassica juncea* (L.) Czern. | Brassicaceae |
| 33 | Rayo | Mustard | *Brassica juncea* var. *cuneifolia* Prain | Brassicaceae |
| 34 | Sakharkhanda | Sweet potato | *Ipomoea batatus* (L.) Lam. | Convolvulaceae |
| 35 | Salagam | Turnip | *Brassica rapa* L. | Brassicaceae |
| 36 | Sarshiyu | Mustard (Colza) | *Brassica campestris* var. *sarson* Prain | Brassicaceae |
| 37 | Seleri | Celery | *Apium graveolens* L. | Apiaceae |
| 38 | Swap | Fennel | *Foeniculum vulgare* Mill. | Apiaceae |
| 39 | Swish Chard | Swiss Chard | *Beta vulgaris* var. *cicla* L. | Chenopodiaceae |
| | | **Stem vegetables** | | |
| 1 | Chini Kale | Kale (Chinese) | *Brassica oleracea* var. *acephala* DC. | Brassicaceae |
| 2 | Gyath | Knol khol | *Brassica oleracea* L. | Crucifareae |
| 3 | Kauli | Cauliflower | *Brassica oleracea* var. *botrytis* L. | Brassicaceae |
| 4 | Kurilo | Asparagus | *Asparagus officinalis* L. | Liliaceae |
| 5 | Ool | Devil's tongue | *Amorphophallus campanulatus* Decne. | Araceae |
| 6 | Tama | Bamboo shoot | *Bambusa* spp. | Poaceae |
| | | **Fruit vegetables** | | |
| 1 | Badaure Kakro | Cucumber (garden) | *Cucumis sativus* var. *sikkimensis* HooK. f. | Cucurbitaceae |
| 2 | Ban Chichindo | Gourd (snake wild) | *Trichosanthes cucumerina* L. | Cucurbitaceae |
| 3 | Ban Karela | Gourd (Chattel ) | *Momordica cochinchinensis* (Lour.) Spreng. | Cucurbitaceae |
| 4 | Barela | Balsam apple | *Momordica balsamina* L. | Cucurbitaceae |
| 5 | Bhanta | Brinjal/eggplant | *Solanum melongena* L. | Solanaceae |
| 6 | Bhede Khursani | Chili/Bell pepper | *Capsicum frutescens* var. *grossum* (Mill.) L.H. Bailey | Solanaceae |
| 7 | Chichindo | Gourd (snake) | *Trichosanthes anguina* L. | Cucurbitaceae |

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| 8 | Ghiraula | Gourd (sponge) | *Luffa cylindrica* (L.) M.Roem. | Cucurbitaceae |
| 9 | Ghurmi | Melon (orange) | *Cucumis melo* var. *agrestis* Naudin | Cucurbitaceae |
| 10 | Golbheda | Tomato | *Lycopersicon esculentum* Mill. | Solanaceae |
| 11 | Hatti Sude Khursani | Chili/Cone pepper | *Capsicum frutescens* var. *conoides* (Mill.) L.H.Bailey | Solanaceae |
| 12 | Hiude Pharsi | Pumpkin (winter) | *Cucurbita maxima* Duchesne | Cucurbitaceae |
| 13 | Jhine Khursani | Chili/red cluster | *Capsicum frutescens* var. *longum* (Sendtn.) L.H. Bailey | Solanaceae |
| 14 | Jire Golbheda | Tomato (cherry) | *Lycopersicon cerasiforme* Dunal | solanaceae |
| 15 | Jire Khursani | Chili/Bird's eye | *Capsicum microcarpum* Cav. | Solanaceae |
| 16 | Kakadi/ Lamkakro | Cucumber (long) | *Cucumis melo* var. *utilissimus* (Roxb.) Duthie &Fuller | Cucurbitaceae |
| 17 | Kakro | Cucumber (field) | *Cucumis sativum* L. | Cucurbitaceae |
| 18 | Kharbujha | Melon (Musk) | *Cucumis melo* var. *reticulatus* Ser. | Cucurbitaceae |
| 19 | Kubhindo | Ash gourd | *Benincasa hispida* (Thunb.) Cogn. | Cucurbitaceae |
| 20 | Lamche Piro Khursani | Chili/Long pepper | *Capsicum frutescens* var. *fasciculatum* (Sturtev.) L.H.Bailey | Solanaceae |
| 21 | Lauka | Gourd (bottle) | *Lagenaria siceraria* (Molina) Standl. | Cucurbitaceae |
| 22 | Parawal | Gourd (pointed) | *Trichosanthes dioica* Roxb. | Cucurbitaceae |
| 23 | Pate Ghiraula | Gourd (ridge) | *Luffa acutangula* (L.) Roxb. | Cucurbitaceae |
| 24 | Pharsi | Pumpkin (Nepali) | *Cucurbita moschata* Duchesne | Cucurbitaceae |
| 25 | Phut Kakri | Snap melon | *Cucumis melo* var. *momordica* (Roxb.) Cogn. | Cucurbitaceae |
| 26 | Ramtoriya | Lady's finger/okra | *Abelmoschus esculentus* (L.) Moench | Malvaceae |
| 27 | Rukha Golbheda | Tomato (tree) | *Cyphomandra betacea* (Cav.) Sendtn. | Solanaceae |
| 28 | Silam | Perilla | *Perilla frutescens* (L.) Britton | Lamiaceae |
| 29 | Skwas Pharsi | Pumpkin (Squash) | *Cucurbita pepo* L. | Cucurbitaceae |
| 30 | Suryamukhi | Sun flower | *Helianthus annuus* L. | Asteraceae |
| 31 | Tarbhujha | Melon (water) | *Citrullus lanatus* (Thunb.) Matsum. & Nakai | Cucurbitaceae |
| 32 | Tinda | Gourd (round) | *Citrullus vulgaris* var. *fistulosus* Steward | Cucurbitaceae |
| 33 | Tite Karela | Gourd (bitter) | *Momordica charantia* L. | Cucurbitaceae |
| | | **Legume vegetables** | | |
| 1 | Bhatmas | Bean (soya) | *Glycine max* (L.) Merr. | Fabaceae |
| 2 | Bodi | Cow-pea (kattike) | *Vigna unguiculata* (L.) Walp. | Fabaceae |
| 3 | Gwar Simi | Bean (cluster) | *Cyamopsis tetragonoloba* L. | Fabaceae |
| 4 | Hiude/Tate Simi | Bean (Hyacinth) | *Dolichos lablab* L. | Fabaceae |
| 5 | Kause Simi | Bean (Velvet) | *Mucuna cochinchinensis* (Lour.) A.Chev. | Fabaceae |
| 6 | Kerau | Pea | *Pisum sativum* L. | Fabaceae |

| | | | | |
|---|---|---|---|---|
| 7 | Khude Simi | Bean (sword) | *Canavalia gladiata* (Jacq.) DC. | Fabaceae |
| 8 | Pakhate Simi | Bean (winged) | *Tetragonolobus purpureus* Moench | Fabaceae |
| 9 | Sajiwan | Drum stick | *Moringa oleifera* Lam. | Moringaceae |
| 10 | Tanebodi | Cow-pea (Tane) | *Vigna unguiculata* var. *sesquipedalis* (L.) Bertoni | Fabaceae |
| 11 | Tarbare Simi | Bean (sword) | *Canavalia ensiformis* (L.) DC. | Fabaceae |
| | | **Roots and tubers** | | |
| 1 | Aalu | Potato | *Solanum tuberosum* L. | Solanaceae |
| 2 | Chukandar | Beet root | *Beta vulgaris* L. | Chenopodiaceae |
| 3 | Gajar | Carrot | *Daucus carota* L. | Apiaceae |
| 4 | Ghar Tarul | Yam (white) | *Dioscorea alata* L. | Dioscoreaceae |
| 5 | Ghyampe Tarul | Yam (giant taro) | *Alocasia macrorrhizos* (L.) G.Don | Dioscoreaceae |
| 6 | Mula Seto | Radish (white) | *Raphanus sativus* var. *longipinnatus* L.H. Bailey | Brassicaceae |
| 7 | Pyuthane Mula | Radish (Pyuthane) | *Raphanus sativus* L. | Brassicaceae |
| 8 | Rutabaga | Rutabaga | *Brassica napus* var. *napobrassica* (L.) Rchb. | Brassicaceae |
| 9 | Simal Tarul | Cassava | *Manihot esculenta* Crantz | Euphorbiaceae |
| 10 | Tarul Suthani | Yam (Karenpotato) | *Dioscorea esculenta* (Lour.) Burkill | Dioscoreaceae |

## *Semi-domesticated Vegetables in Nepal*

Semi-domesticated plants are the species those are accustomed to regular disturbance of the people. Such species generally grow in and around the farmlands and disturbed habitats. These plants are sometime known as underutilized, minor or undomesticated species (KC et al., 2017; González-Insuasti et al., 2011). Semi-domesticated species are regarded to be in between wild plants and domesticated crops because these species are conserved in the marginal or in farmland for their use values and very little or no attention is given to manage them. Sometime confusion occurs when wild plants are documented as semi-domesticated or vice versa. This is mainly due to the difference in use pattern of a species in different areas (Meyer et al., 2012). KC et al. (2017) has reported 42 semi-domesticated species, which are distributed in different ecological zones of Nepal. Among 42 species, 22 (53%) are used as vegetables. The revised list of semi-domesticated vegetables with 56 species is given in Table 3.2.

**Table 3.2.** Semi-domesticated vegetables in Nepal.

| S. N. | Representing species/Family, Habit | Local name | Distribution (masl) |
|---|---|---|---|
| 1 | *Acmella calva* (DC.) R.K.Jansen/Asteraceae, Herb | Marauthi | WC (1,600) |
| 2 | *Acmella paniculata* (Wall. ex DC.) R.K. Jansen/Asteraceae, Herb | Marauthi | C (104) |
| 3 | *Amaranthus lividus* L./Amaranthaceae, Herb | Banlude | WC (1,500–2,300) |
| 4 | *Amaranthus spinosus* L./Amaranthaceae, Herb | Banlude | WCE (150–1,560) |
| 5 | *Amaranthus viridis* L./Amaranthaceae, Herb | Latte, Lunde | CE (150–1,200) |
| 6 | *Amorphophallus campanulatus* Blume/Araceae, Herb | Ol | WCE (1,000) |

| | | | |
|---|---|---|---|
| 7 | *Bauhinia purpurea* L./Fabaceae, Tree | Taki | WCE (300–1,600) |
| 8 | *Bauhinia variegata* L./Fabaceae, Tree | Koiralo | WCE (150–1,900) |
| 9 | *Canna chinensis* Willd./Cannaceae, Herb | Bhuinchapo | C |
| 10 | *Canna glauca* L./Cannaceae, Herb | - | - |
| 11 | *Canna indica* L./Cannaceae, Herb | Sarbada phool | CE (900) |
| 12 | *Cassia fistula* L./Fabaceae, Tree | Rajbriksha | WCE (150–1,400) |
| 13 | *Centella asiatica* (L) Urban/Apiaceae, Herb | Godtapre | WCE (500–2,100) |
| 14 | *Chenopodium album* subsp. *album* L./Chenopodiaceae, Herb | Bathu | WC (2,000–4,000) |
| 15 | *Chenopodium album* subsp. *amaranticolor* Coste & Reyn./Chenopodiaceae, Herb | Bethe, Rato latte | C (1,800–2,200) |
| 16 | *Chenopodium murale* L./Chenopodiaceae, Herb | Kalo bethe | WCE |
| 17 | *Cleome viscosa* L./Capparaceae, Herb | Tori Jhar | WCE (100–2,800) |
| 18 | *Corchorus aestuans* L./Tiliaceae, Shrub | Balu jhar | CE (100–1,200) |
| 19 | *Crateva unilocularis* Buch.-Ham./Capparaceae, Tree | Sipligan | WCE (250-1,500) |
| 20 | *Dendrocalamus giganteus* Munro/Poaceae, Bamboo | Bhalu bans | CE (200–1,300) |
| 21 | *Dioscorea bulbifera* L./Dioscoreaceae, Climber | Ban tarul | WCE (150–2,100) |
| 22 | *Dioscorea kamoonensis* Kunth/Dioscoreaceae, Climber | Bhyakur | WCE (1,600–2,200) |
| 23 | *Dioscorea pentaphylla* L./Dioscoreaceae, Climber | Bhyakur | WCE (190–1,500) |
| 24 | *Dysolobium grande* (Wall. ex Benth) Prain/Fabaceae, Herb | - | C |
| 25 | *Dysolobium pilosum* (Klein ex Willd.) Marechal/Fabaceae, Herb | - | E |
| 26 | *Eclipta prostrata* (L.) L./Asteraceae, Herb | Bhringiraj | WCE (500–1,500) |
| 27 | *Eichhornia crassipes* (Martius) Solms/Pontederiaceae, Herb | Teli phul | WCE (200–1,500) |
| 28 | *Emilia sonchiholia* (L.) DC. ex DC./Asteraceae, Herb | Chaulene jhar | WCE (1,700) |
| 29 | *Euphorbia hirta* L./Euphorbiaceae, Herb | Dudhe | WCE (1,800) |
| 30 | *Fagopyrum dibotrys* (D. Don) H. Hara/Polygonaceae, Herb | Salsale | WCE (1,500–3,400) |
| 31 | *Ficus hispida* L.f./Moraceae, Tree | Khasreto | WCE (450–1,100) |
| 32 | *Ficus lacor* Buch.-Ham./Moraceae, Tree | Kabro | C (500–1,400) |
| 33 | *Himalayacalamus fimbriatus* Stapleton/Poaceae, Bamboo | Tite nigalo | WE (1,100–1,800) |
| 34 | *Jatropha curcas* L./Euphorbiaceae, Shrub | Sajiwan, Sajyon | WCE (1,300) |
| 35 | *Justicia adhatoda* L./Acanthaceae, Shrub | Asuro | WCE (2,700) |

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|---|---|---|---|
| 36 | *Leucaena leucocephala* (Lam.) de Wit/Fabaceae, Tree | Epil | WC (1,400) |
| 37 | *Leucas cephalotes* (Roth) Spreng./Lamiaceae, Herb | Tauke jhar | WCE (2,400) |
| 38 | *Macropanax undulatus* (Wall. ex G. Don) Seem./Araliaceae, Tree | Chinde | E (2,200–2,900) |
| 39 | *Megacarpae polyandra* Bentham/Brassicaceae, Herb | Rubiko sag | WC (900–3,800) |
| 40 | *Melochia corchorifolia* L/Sterculiaceae, Herb | Ban pate | CE (1,300) |
| 41 | *Mirabilis jalapa* L/Nyctanginaceae, Herb | Malati | WCE (1,600) |
| 42 | *Monochoria hastata* (L) Solms/Pontederiaceae, Herb | Dhape jhar | CE (80–500) |
| 43 | *Oroxylum indicum* (L.) Kurz/Fabaceae, Tree | Tatelo | WCE (500–1,400) |
| 44 | *Phytolacca acinosa* Roxb./Phytolaccaceae, Herb | Jaringo sag | WC (2200–3200) |
| 45 | *Plantago erosa* Wallich/Plantaginaceae, Herb | Esabgol | WCE (2,000–4,600) |
| 46 | *Plantago lanceolata* L./Plantaginaceae, Herb | Isapgol | CE (1,700) |
| 47 | *Portulaca oleracea* L./Portulaceae, Herb | Nundhiki | WCE (1,600) |
| 48 | *Rumex hastatus* D. Don/Polygonaceae, Herb | Amili | WC (1,100–2,600) |
| 49 | *Rumex nepalensis* Spreng./Polygonaceae, Herb | Halhale | WCE (1,200–4,200) |
| 50 | *Senna floribunda* (Cav.) H.S. Irwin & Barneby/Fabaceae, Herb | Bhatte | WCE (700–2,200) |
| 51 | *Senna tora* (L.) Roxb./Fabaceae, Herb | Chhinchhine | WCE (400–1,500) |
| 52 | *Thysanolaena latifolia* (Roxb. Ex Hornem) Honda/Poaceae, Grass | Amriso | WCE (150–2,000) |
| 53 | *Trevesia palmats* (Roxb) Visiani/Araliaceae, Tree | Chuletro | CE (250–2,500) |
| 54 | *Trianthema portulacastrum* L./Aizoaceae, Herb | Gadapurina | WCE (150–300) |
| 55 | *Urtica dioica* L./Urticaceae, Herb | Sisnu | C (3,500–4,000) |
| 56 | *Urtica parviflora* Roxb./Urticaceae, Herb | Sisnu | WCE (600–4,100) |

masl = meter above sea level. W = west, C = central and E = east.

## *Wild Vegetables in Nepal*

Globally wild vegetables have noteworthy contribution by supplying diet with supplement protein, vitamins and other minerals necessary for rural people. Consumption of wild edible plants including vegetables is a traditional culinary practice in Nepal. Importance of wild vegetables is more pronounced during critical food shortage, particularly for the people who do not have enough land to grow foods that can feed them round the year (Manandhar, 2002; Uprety et al., 2012). Globally wild vegetables have offered alternate source of income for millions of low income rural people as well (Hickey et al., 2016; Oladele, 2011; You-kai et al., 2004). Many studies had documented food, livelihood, cultural and religious importance of wild vegetables in Nepalese communities inhabiting different parts of the country (Dangol et al., 2017; DMPN, 1982; Manandhar, 2002; Singh, 1968; Uprety et al., 2012). The revised list of wild vegetables comprising 143 species is given in Table 3.3.

**Table 3.3.** Wild vegetables consumed by different communities in Nepal. Botanical names are based on Fraser-Jenkins et al. (2015), Fraser-Jenkins and Kandel (2019), NPHL (2011, 2012), and Rajbhandari and Rai (2017, 2019).

| S. N. | Species/Family, Habit | Local name | Distribution (masl) |
|---|---|---|---|
| 1 | *Abrus precatorius* L./Fabaceae, Climber | Ratigedi | WCE (100–1,200) |
| 2 | *Aconogonon campanulatum* (Hook.f.) H. Hara/Polygonaceae, Herb | Rapre ghans | CE (2,100–4,000) |
| 3 | *Aconogonon molle* (D.Don) H. Hara/Polygonaceae, Herb | Thotne | CE (1,200–2,400) |
| 4 | *Aesculus indica* (Colebrooke ex Cambessedes) Hooker/Sapindaceae, Tree | Lekh pangro | WC (1,900–2,700) |
| 5 | *Allium wallichii* Kunth/Amaryllidaceae, Herb | Ban lasun | WCE (2,100–4,400) |
| 6 | *Alternanthera sessilis* (L.) de Candolle/Amaranthaceae, Herb | Bhiringi jhar | WCE (200–2,000) |
| 7 | *Anagallis arvensis* L./Primulaceae, Herb | Armale, Krishna nil | C (1,650) |
| 8 | *Arisaema tortuosum* (Wallich) Schott/Araceae. Herb | Bir banko | WCE (1,300–2,900) |
| 9 | *Arthromeris wallichiana* (Sprengel) Ching/Polypodiaceae, Fern | Niguro | - |
| 10 | *Asparagus filicinus* D. Don/Asparagaceae, Herb | Kurilo | WC (2,100–3,450) |
| 11 | *Asparagus racemosus* Willd./Asparagaceae, Herb | Kurilo | WCE (150–2,100) |
| 12 | *Barbarea intermedia* Boreau/Brassicaceae, Herb | Khole saag | WC (3,000–3,500) |
| 13 | *Basella alba* L./Basellaceae, Herb | Poi saag | WCE (500) |
| 14 | *Bidens bipinnata* L./Asteraceae, Herb | Kuro | WCE (700–2,000) |
| 15 | *Boehmeria ternifolia* D.Don/Urticaceae, Small tree | Kamle | WCE (900–2,300) |
| 16 | *Boerhavia diffusa* L./Nyctaginaceae, Herb | Punarnava | WCE (300–1,200) |
| 17 | *Bombax ceiba* L./Malvaceae, Tree | Simal | WCE (200–1,000) |
| 18 | *Botrychium lanuginosum* Wall.ex Hook. & Grev./Ophioglossaceae, Fern | Jaluko | WCE (1,600–3,000) |
| 19 | *Brachycorythis obcordata* (L) Summerhayes/Orchidaceae, Herb | Gamdol | WCE (1,000–2,600) |
| 20 | *Capparis spinosa* L./Capparaceae, Shrub | Bagh mukhe | WCE (2,000) |
| 21 | *Capsella bursa-pastoris* (L.) Medikus/ Brassicaceae, Herb | Chalne, Tori ghans | WCE (100–4,900) |
| 22 | *Caragana brevispina* Royle/Fabaceae, Shrub | Jyaure kanda | WC (2,500–3,100) |
| 23 | *Cardamine impatiens* L./Brassicaceae, Herb | Sim sag | WCE (100–400) |
| 24 | *Cardamine loxostemonoides* O.E. Schulz/Brassicaceae, Herb | Chamsure ghans | WCE (2,400–5,500) |
| 25 | *Cardamine violaceae* (D.Don) Wall. ex Hook.f. & Thomson/Brassicaceae, Herb | Tuki jhar | CE (1,800–4,000) |
| 26 | *Cardiospermum halicacabum* L./Sapindaceae, Climbing herb | Kesh lahara | WCE (500–1,500) |
| 27 | *Carum carvi* L./Apiaceae, Herb | Jangali jira | WC (2,500–4,500) |
| 28 | *Cautleya spicata* (Sm.) Baker/Zingiberaceae, Herb | Pani saro | WCE (1,800–2,800) |
| 29 | *Ceratopteros thalictroides* (L.) Brongn./Parkeriaceae, Fern | Pani dhaniya | WCE (450–1,000) |
| 30 | *Ceropegia pubescens* Wall./Asclepiadaceae, Climber | Mirke laharo | WCE (600–2,700) |
| 31 | *Cheilocostus speciosus* (J. Koenig) C.D. Specht/Costaceae, Herb | Betlauri | WC (400–1,500) |
| 32 | *Chlorophytum nepalense* (Lindl.) Baker/Asparagaceae, Herb | Ban pyaj | WCE (1,400–3,000) |
| 33 | *Clematic acuminata* DC./Ranunculaceae, Climbing shrub | Ransag | WCE (200–3,000) |
| 34 | *Clematis buchananiana* DC/Ranunculaceae, Climbing shrub | Junje lahara | WCE (900–3,900) |
| 35 | *Clerodendrum indicum* (L) Kuntze/Lamiaceae, Shrub | Ekle bir | WCE (200–1,400) |
| 36 | *Clerodendrum japonicum* (Thunberg) Sweet/Lamiaceae, Shrub | Dhago phool | CE (700–1,600) |

| | | | |
|---|---|---|---|
| 37 | *Clerodendrum viscosum* Ventenat/Lamiaceae, Shrub | Bhat | WCE (300–1,500) |
| 38 | *Clintonia udensis* Trautv. & C.A. Mey./Liliaceae, Herb | - | WCE (3,200–4,000) |
| 39 | *Clitoria ternatea* L./Fabaceae, Herb | Aparajita | WCE (100–200) |
| 40 | *Commelina paludosa* Blume/Commelinaceae, Herb | Buki | WCE (300–3,500) |
| 41 | *Commellina benghalensis* L./Commelinaceae, Herb | Kane jhar | WCE (300–2,100) |
| 42 | *Cordia dichotoma* Forster fil./Boraginaceae, Tree | Bori | CE (300–1,600) |
| 43 | *Cortia depressa* (D.Don) C.Norman/Apiaceae, Herb | Bhutkesh | WCE (3,300–4,500) |
| 44 | *Cycas pectinata* Buchanan-Hamilton/Cycadaceae, Shrub | Thulo nyauro | WCE (500–1,400) |
| 45 | *Cynanchum auriculatum* Wight/Asclepiadaceae, Climbing shrub | Latikoseli | WCE (1,800–3,300) |
| 46 | *Cypripedium cordigerum* D. Don/Orchidaceae, Herb | Jibre | WC (2,100–4,000) |
| 47 | *Dactylorhiza hatagirea* (D.Don) Soo/Orchidaceae, Herb | Panchaunle | WCE (2,800–4,000) |
| 48 | *Deeringia amaranthaoides* (Lam.) Merr./Amaranthaceae, Climbing shrub | - | WCE (600–1,500) |
| 49 | *Deparia boryana* (Willd.) M. Kato subsp. *boryana*/Athyriaceae, Fern | - | WC (1,400–3,000) |
| 50 | *Didymocarpus villosus* D.Don/Gesneriaceae, Herb | Kiya | CE (1,000–2,400) |
| 51 | *Dienia cylindrostachya* Lindl./Orchidaceae, Herb | - | WCE (2,600–3,500) |
| 52 | *Dillenia indica* L./Dilleniaceae, Tree | Ramphal | CE (300) |
| 53 | *Dillenia pentagyna* Roxb./Dilleniaceae, Tree | Tantari | CE (1,200) |
| 54 | *Diplazium esculentum* (Retz.) Sw./Athyriaceae, Fern | Masino niuro | WCE (100–2,200) |
| 55 | *Disporum cantoniense* (Loureiro) Merrill/Convallariaceae | Mahajari | WCE (1,100–2,900) |
| 56 | *Drymaria cordata* (L.) Willd. ex Schult./Caryophyllaceae, Herb | - | WCE (2,200–4,300) |
| 57 | *Drymaria villosa* Chamisso & Schlechtendal/Caryophyllaceae, Herb | Abhijalo | CE (1,000–1,900) |
| 58 | *Dryopteris cochleata* (D. Don) C.Chr./Dryopteridaceae, Fern | Niuro, Kuthurke | WC (1,600) |
| 59 | *Edgaria darjeelingensis* C.B.Clarke/Cucrubitaceae, Herbaceaous climber | - | CE (900–3,200) |
| 60 | *Elatostema platyphyllum* Wedd./Urticaceae, Herb | Sano gagaleto | C (1,100–2,200) |
| 61 | *Elatostema sessile* J.R.Forst. & G.Forst./Urticaceae, Herb | Gagaleto | WCE (500–3,000) |
| 62 | *Eryngium foetidum* L./Apiaceae, Herb | Barmeli dhaniya | E (1,000) |
| 63 | *Fritillaria cirrhosa* D.Don/Liliaceae, Herb | Kakoli | WCE (3,000–4,500) |
| 64 | *Galinsoga quadriradiata* Ruiz & Pavon/Asteraceae, Herb | Jhuse chitlange | WCE (2,500) |
| 65 | *Gentiana pedicellata* (D.Don) Grisebach/Gentianaceae, Herb | Tauke phool | WCE (800–3,800) |
| 66 | *Girardinia diversifolia* (Link) Friis/Urticaceae, Stout Herb | Chalne sisnu | WCE (1,700–3,300) |
| 67 | *Grangea maderaspatana* (L.) Poir./Asteraceae, Herb | Gobre jhar | WC (2,000) |
| 68 | *Habenaria furcifera* Lindley/Orchidaceae, Herb | Sankalo | WC (150–800) |
| 69 | *Habenaria intermedia* D. Don/Orchidaceae, Herb | Thunma | WC (1,800–3,000) |
| 70 | *Helminthostachys zeylanica* L./Ophioglossaceae, Fern | Kamraj | WCE (500) |
| 71 | *Holarrhena pubescens* Wall. ex G.Don/Apocynaceae, Small tree | Dudhe | WCE (1500) |
| 72 | *Houttuynia cordifolia* Thunb./Saururaceae, Herb | Kalancha | CE (1,300–2,500) |
| 73 | *Hydrolea zeylanica* (L) Vahl/Hydrophyllaceae, Herb | - | CE (1,200) |
| 74 | *Impatiens bicornuta* Wall./Balsaminaceae, Herb | - | WCE (1,900–2,600) |
| 75 | *Impatiens falcifer* Hook f./Balsaminaceae, Herb | - | CE (2,200–3,400) |
| 76 | *Indigofera cassioides* Rottler ex DC./Fabaceae, Herb | - | WCE (2,400–2,800) |
| 77 | *Indigofera pulchella* Roxb./Fabaceae, Herb | Phusre ghans | WCE (200–3,600) |
| 78 | *Launaea aspleniifolia* (Willdenow) Hook.f./Asteraceae, Herb | Dudhe jhar | WCE (390–1,500) |

| | | | |
|---|---|---|---|
| 79 | *Lecanthus peduncularis* (Wall. ex Royle) Wedd./Urticaceae, Herb | Gakaleti | WCE (1,200–3,700) |
| 80 | *Ligularia fischeri* (Ledeb.) Turcz./Asteraceae, Herb | - | WCE (2,200–4,600) |
| 81 | *Lilium nepalense* D.Don/Liliaceae, Herb | Ban lasun | WCE (1,500–3,400) |
| 82 | *Lygodium flexuosum* (L.) Sw./Lygodiaceae, Fern | Ankhle jhar | WCE (150–2,500) |
| 83 | *Lygodium japonicum* (Thunb.) Sw./Lygodiaceae, Fern | Bahune lahara | WCE (500–2,000) |
| 84 | *Macropanax dispermus* (Blume) Kuntze/Araliaceae, Tree | Chinde | CE (1,200–2,200) |
| 85 | *Maianthemum purpureum* (Wallich) LaFrankie/Convallariaceae, Shrub | Seto jara | WCE (2,600–4,200) |
| 86 | *Meeboldia achilleifolia* (DC.) P.K. Mukherjee & Constance/Apiaceae, Herb | Najo | WCE (1,200–3,200) |
| 87 | *Murdania nudiflora* (L) Brenan/Commelinaceae, Herb | Kane jhar | WCE (65–1,500) |
| 88 | *Ophioglossum parvifolium* Grev. & Hook./Ophiglossaceae. Fern | Ek patiya | WCE (1,800) |
| 89 | *Ophioglossum petiolatum* Hook./Ophiglossaceae, Fern | - | WCE (2,000–3,000) |
| 90 | *Ophioglossum reticulatum* L./Ophiglossaceae, Fern | Jibre sag | WCE (1,400) |
| 91 | *Oreocnide frutescens* (Thunb.) Miq./Urticaceae, Shrub | Chiple ghans | WCE (500–2,500) |
| 92 | *Osmunda claytoniana* L. subsp. *vestita* (Wall. ex Milde) A. Love & D. Love/Osmundaceae, Fern | Khuturke | WCE (1,400–3,300) |
| 93 | *Phlogacanthus thyrisiformis* (Roxburgh ex Hardwicke) Mabberley/Acanthaceae, Shrub | Tite | WE (200–1,700) |
| 94 | *Phoenix loureiroi* Kunth var. *pedunculata* (Griff.) Govaerts/Arecaceae, Shrub | Khajur, Thakal | WCE (150–900) |
| 95 | *Pilea glaberrima* (Blume) Blume/Urticaceae, Herb | Gageleto | CE (300–1,700) |
| 96 | *Pilea racemosa* (Royle) Tuyama/Urticaceae, Herb | Lede sag | WCE (2,000–4,000) |
| 97 | *Pilea symmeria* Weddell/Urticaceae, Herb | Kamle | WCE (1,700–3,300) |
| 98 | *Pilea umbrosa* Blume/Urticaceae, Herb | Chholyang | WCE (1,200–2,700) |
| 99 | *Polygonatum cirrhifolium* (Wall.) Royle/Asparagaceae, Herb | Khinraulaa | WCE (1,700–4,600) |
| 100 | *Polygonatum verticillatum* (L.) All./Asparagaceae, Herb | Khinraulaa | WCE (2,100–4,800) |
| 101 | *Polygonum plebeium* R. Br./Polygonaceae, Herb | Masino pirre | WCE (3,200) |
| 102 | *Polystichum squarrosum* (D.Don) Fée/Dryopteridaceae, Fern | - | WCE (1,000–3,000) |
| 103 | *Pouzolzia sanguinea* (Blume) Merr./Urticaceae, Shrub | Lipe | CE (1,000–3,000) |
| 104 | *Pteridium aquilinum* (L.) Kuhn/Dennstaedtiaceae, Fern | - | WC (1,200–3,400) |
| 105 | *Ranunculus diffusus* DC/Ranunculaceae, Herb | Sano saro | WCE (1,000–3,000) |
| 106 | *Ranunculus sceleratus* L./Ranunculaceae, Herb | Nagakor | WCE (200–2,800) |
| 107 | *Rotala rotundifolia* (Buch.-Ham ex Roxb.) Koehne/Lytharaceae, Herb | Sim jhar | WCE (300–3,000) |
| 108 | *Rungia pectinata* (L.) Nees/Acanthaceae, Herb | Ukuche jhar | WCE (200–2,000) |
| 109 | *Sambucus adnata* Wall. ex DC./Caprifoliaceae, Shrub | Chare bhango | WCE (2,000–3,700) |
| 110 | *Satyrium nepalense* D. Don/Orchidaceae, Herb | Gamdol | WC (600–4,600) |
| 111 | *Sauromatum brevipes* (Hooker fil.) N.E. Brown/Araceae, Herb | - | WC (2,300–2,800) |
| 112 | *Sauromatum diversifolium* (Wall. ex Schott) Cusimano & Hett./Araceae, Herb | - | WC (1,400–4,300) |
| 113 | *Scutellaria repens* Buch.-Ham. ex D. Don/Lamiaceae, Herb | Charpate | WCE (600–2,100) |
| 114 | *Selinum tenuifolium* Wallich ex C.B. Clarke/Apiaceae, Herb | Bhutkesh | WCE (2,500–4,800) |
| 115 | *Smilax aspera* L./Smilacaceae, Shrub | Kukurdaino | WCE (1,200–2,900) |
| 116 | *Smilax elegans* Wall. ex Kunth/Smilacaceae, Shrub | Kukurdaino | WCE (1,500–2,700) |
| 117 | *Smilax ferox* Wallich ex Kunth/Smilacaceae, Shrub | Kukurdaino | CE (1,100–2,700) |
| 118 | *Smilax lanceifolia* Roxb./Smilacaceae, Shrub | Kukurdaino | C (1,500–2,200) |
| 119 | *Smilax menispermoides* A.de Candolle/Smilacaceae, Climbing shrub | - | WCE (1,600–3,400) |

| | | | |
|---|---|---|---|
| 120 | *Smilax munita* S.C. Chen/Smilacaceae, Shrub | - | CE (2,100–2,900) |
| 121 | *Smilax perfoliata* L./Smilacaceae, Shrub | - | WCE (500–900) |
| 122 | *Spermadictyon suaveolens* Roxb./Rubiaceae, Shrub | Bhakhar pirre | WCE (600–2,300) |
| 123 | *Sphenoclea zeylanica* Gaertner/Sphenocleaceae, Herb | Dhansejuwa | CE (1,600) |
| 124 | *Stellaria media* (L) Villars/Caryophyllaceae, Herb | Armale jhar | WC (1,800–2,700) |
| 125 | *Stellaria monosperma* Buch.-Ham. ex D. Don/Caryophyllaceae, Herb | Sanhali sag | WC (2,200–3,200) |
| 126 | *Stellaria vestita* Kurz/Caryophyllaceae, Herb | Armane | WCE (1,500–2,500) |
| 127 | *Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre/Rubiaceae, Tree | Pidar | C (250) |
| 128 | *Taraxacum parvulum* Wall. ex DC./Asteraceae, Herb | Tuki phool | WCE (1,000–4,000) |
| 129 | *Tectaria coadunata* (J.Sm.) C. Chr./Tectariaceae, Fern | Kali neuro | WCE (1,000–2500) |
| 130 | *Telosma pallida* (Roxb) Craib/Asclepiadaceae, Twining shrub | Asare phul | WCE (300–1,200) |
| 131 | *Thamnocalamus spathiflorus* (Trin.) Munro/Poaceae, Bamboo | Nigalo | CE (2,800–3,500) |
| 132 | *Thelypteris auriculata* (J. Sm.) K. Iwats/Thelypteridaceae, Fern | Koche | WCE (1,500–2,800) |
| 133 | *Thelypteris nudata* (Roxb.) C.V. Morton/Thelypteridaceae, Fern | - | WCE (300–1,500) |
| 134 | *Thelypteris procera* (D. Don) Fraser-Jenk./Thelypteridaceae, Fern | - | WCE (500–2,400) |
| 135 | *Thlapsi arvensis* L/Brassicaceae, Herb | Tite | WC (2,000–5,200) |
| 136 | *Thunbergia coccinea* Wallich ex D. Don/Acanthaceae, Climber | Sigane lahara | WE (300–1,800) |
| 137 | *Typha angustifolia* L./Typhaceae, Herb | - | WCE (80–200) |
| 138 | *Typha elephantina* Roxb./Typhaceae, Herb | - | WE (80–300) |
| 139 | *Veronica baccabunga* L/Scrophulariaceae, Herb | Phuli jhar | W (2,200–3,100) |
| 140 | *Wallichia oblongifolia* Griff./Arecaceae, Shrubby palm | - | WCE (250–1,400) |
| 141 | *Woodwardia unigemmata* (Makino) Nakai/Blechnaceae, Fern | Danthe unyu | WCE (840–2,600) |
| 142 | *Youngia japonica* (L) de Candolle/Asteraceae, Herb | Chaulane, Dudhe | WCE (230–2,900) |
| 143 | *Yushania maling* (Gamble) R.B.Majumdar & Karthik./Poaceae, Tall herb | Malingo | E (2,000–3,000) |

masl = meter above sea level. W = west, C = central and E = east

## Genomics of Vegetables

### *How Did Modern Vegetables Develop?*

When our hunter and gatherer ancestors understood the dispersal mechanisms in different plant species, they then started to gather propagules of wild plants and planted them in the area with right amount of manure, sun and water (Rubatzky & Yamaguchi, 1997). However, it is difficult to get explicit records that clearly mention when our ancestors realized the importance of seeds and how they started planting them. During hunting and gathering, collection of propagules and their dispersal around caves or resting sites might have occurred unknowingly which later helped our forefathers to understand the mechanisms of plant propagation (Harlan, 1992; Hoyt, 1988; Vavilov, 1952).

Human involvement in plantation or growing plants over centuries has induced tremendous evolutionary changes in the species subject to regular farming since generations. Once cultivated, these planted species depend on human for their complete development from the seed to mature fruiting plants (Hoyt, 1988; Zhang et al., 2017). Human has been selecting plants with desired characters since historic time for their need of food, clothing, shelter and pleasure. Artificial selection thus is a practice of selecting

genetically better individuals of plants and animals. Number of improved varieties of several domestic plants and animals i.e. potatoes, tomatoes, corn, pigeons, pigs, horses, poultry, cows, sheep, etc. have been developed from their wild ancestors by artificial selection. Farming began about 7,000–10,000 years ago independently in different parts of the world (Harlan, 1992). Our ancestors might have gathered the seeds of wild plants, which later developed, to modern crops like barley, wheat, potatoes, maize, etc. These modern crops are the most reliable source of food now than their wild progenitors naturally growing in the native habitats centuries ago. Selection of useful traits in those cultivated species was a continuous process. Since ancient times, farmers are selecting relatively few traits in the crops related to overall yield, harvesting and edibility (Hua et al., 2015). Such types of strong selection usually resulted in a substantial reduction in genetic variation among cultivated species (Meyer et al., 2012) (Figure 3.2). More than half of the genetic variation was found reduced in some crops (e.g. soybean), while even more reductions can be observed in other crops (e.g. rice) (Xu et al., 2012; Zhou et al., 2015). Selection of targeted traits in domesticated crops can also results in a complete loss of closely linked loci related to dispersal or seed quality (selective sweep) (Zhang et al., 2017). Due to the process of narrowing down the genetic base through selective domestication, the cultivated species contain only a fraction of genetic diversity present in their wild relatives (WRs) (Guarino & Lobell, 2011). The reduced genetic diversity in domesticated plants can be retained from cross-pollination with their wild cousins. Moreover, artificial selection of desired traits on plants, during the past 10,000 years, has evolved the species with adaptive syndromes to human maintained ecology. They can no more survive independently in the wild as their progenitors. Cultivated crops grow in human-maintained ecology or agricultural niches with the help of human mediated sowing, manuring, irrigation and dissemination, but their wild relatives should develop capacity by their own to cope against drought and floods, pests and diseases, and other natural hazards (Harlan, 1992). Wild relatives are evolved with nature and changing climate, therefore, they show greater resilience toward various stresses. Wild species of tomato has retained more than 90% of genetic diversity than the cultivar growing in our garden (Tanksley & McCouch, 1997).

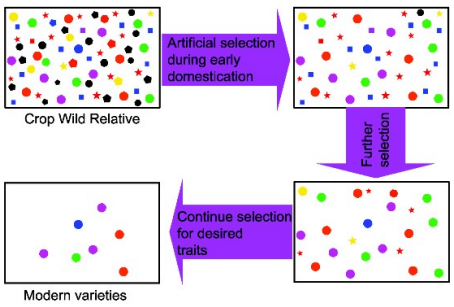



**Figure 3.2.** Schematic representation of gradual reduction in genetic variation in cultivated species.

## *Wild Cousins Are Relatives of Domesticated Plants*

Our ancestor started modifying some population of plants as crops for their use while remaining population of the same species left in wild are still surviving in the natural habitat. Human mediated artificial selection for desired traits has changed the phenotypic and genotypic characteristics of the cultivated crops but their other populations and relatives keep evolving in the natural habitats through natural selection. These left populations and phylogenetically close cousins surviving in the wild are known as "Wild cousins or Wild Relatives (WRs)" (Harlan & de Wet, 1971; Maxted et al., 2006; Singh, 2017). WRs possess strong genetic affinities with their related cultivated species. Many of these wild relatives are cross compatible with their cultivated relatives. Depending on genetic relatedness, cultivated and wild relatives exchange genes, and produce fertile offsprings. WR generally comprises wide variety of taxa ranging from immediate wild ancestor, congener and closely related taxon. Sometimes definition of WRs also incorporates various values as food, fodder, medicinal plants, spices, fiber yielding plants, etc., which can be improved through their use in the domesticated species. A broader concept of WRs presented by Singh (2017b) includes – *landraces*, which are genetically compatible wild, semi-cultivated and cultivated forms of domesticated species; *wild progenitors*, which are ancestral forms of cross-compatible wild species, sub-species or varieties to cultivated species; *wild/weedy relatives*, which are wild congeners but reproductively isolated to different degree with cultivated species; and finally *naturalized species*, these species are not the native species but show wider distribution range across region or continents through human mediated or other natural dispersal mechanisms.

Harlan and de Wet (1971) have defined wild relatives in the concept of gene pool (GP) based on the relative ease of gene exchange with cultivated crops. According to this definition WRs are classified into primary, secondary, tertiary and quaternary gene pools (GP-1, 2, 3, 4). Primary gene pools (GP-1) and secondary gene pools (GP-2) normally exchange genes through crossing and produce fertile hybrids; however, gene exchange between GP-1 and tertiary gene pool (GP-3) may not be always easy and possible. GP-3 gene pool comprises individuals from different species but from same genus. Exchange of gene pool between GP-1 and GP-2 is a common practice. There are cases where certain useful alleles from GP-3 are also used in the improvement of crops (Abedinia et al., 2000; Saintenac et al., 2013). Sophisticated techniques, such as embryo rescue, somatic fusion, grafting and bridge are adopted for gene transfer from the species of tertiary gene pool. Gp-4 species are distantly related belonging to different families, thus gene transfer possible only through genetic engineering. Smartt (1990) has extended the gene pools concept of Harlan and de Wet (1971) and further classified gene pools to six orders, which make distinction between domesticated and wild components in each gene pool.

Some plant taxonomists have different opinion on the definition of WRs (Miller & Khoury, 2018). They think that this concept has utilitarian value in crop science and plant breeding only, and it does not present any evolutionary or taxonomic relevance. Gene pool concept mainly focuses on level of interfertility between taxa. The pioneer of gene pool concept, Harlan and de Wet (1971) tried to reconcile gene pool concept with sub-

species of traditional taxonomic categories. While placing crop wild relatives (CWRs) into different tiers of gene pool, tremendous efforts are needed on extensive garden experiments (Plazas et al., 2016). Therefore, people are searching for alternative ways to assign crop WRs to gene pools. Maxted et al. (2006) proposed 'taxon group concept'. Taxon group concept can be used, as proxy for classification where different taxon groups equivalent to taxonomic classification can be categorized into different types of gene pools. Taxon group concept assumes that taxa within a taxonomic group are genetically related thus are more likely to cross easily. However, this method is still more subjective and less realistic because genetic relatedness differs even among same taxa. Such type of deviations are mainly due to uneven rate of speciation across lineages (Givnish, 2010). Detailed phylogenetic analysis and rigorous studies on patterns of interfertility would provide deeper understanding needed to assign species in an appropriate gene pool of CWRs (Wiersema & León, 2016). Rapid advances in genomic technologies are providing valuable data to elucidate evolutionary relationship among cultivated species and their wild relatives. Characters like species divergence, phylogenetic relationships, morphological and biogeographic differences and reproductive isolation in different species should be the primary focus to categorize CWRs across defined crop gene pools. Standardized and widely applicable system can be developed to evaluate potentially useful species as crop WRs (Vincent et al., 2013; Wiersema & León, 2016).

## *Global Distribution of Wild Relatives*

Wild relatives of crops are distributed naturally in all continents except Antartica; however, they are concentrated mainly on Vavilov centers of diversity viz. Mediterranean, the near east, western and southern Europe, south-east and east Asia, and South America (Vavilov et al., 1992). Vavilov's concept of 'Centers of Origin' of cultivated plants (Vavilov et al., 1992) has been later revised to 'Centers of Diversity' and this term is now widely used (Khoury et al., 2016; Zeven & Zhukovskiĭ, 1975). Centers of diversity are often not centers of origin. Species may have originated in some region but are domesticated extensively in different geographic areas. Dispersal of crops from center of diversity to different places are designated as 'Primary center of diversity' and 'Secondary center of diversity' (FAO, 2010; Zeven & Zhukovskiĭ, 1975). Primary regions of crop diversity are the geographic localities of the initial domestication of crops where species richness is relatively high (Khoury et al., 2016). Primary region of diversity of major vegetables, fruits and few crops is given in Figure 3.3.

Himalaya region, including Nepal, falls in and around three regions (central Asiatic region; Indian region and Chinese region) out of eight primary regions of crop diversity recognized by Vavilov. These regions are the oldest independent centers for vegetables like radish, cowpea, rajma, turnip, chickpea, pigeonpea, eggplant, cucumber, taro, yam, spinach, carrot, etc. Around 50,000–60,000 species of crops and wild relatives are estimated to be available for human use. Among the estimated number 10,739 species are listed useful for food security alone (Maxted & Kell, 2009). Distribution of crop and vegetable and their relatives worldwide are shown in Figures 3.3 and 3.4.




**Figure 3.3.** Global distribution of primary diversity areas of crops and vegetables (Map adopted from Khoury et al. (2016)). Underlined vegetables are found naturally growing in the wild/semi-wild habitat of Himalayan region including other places.

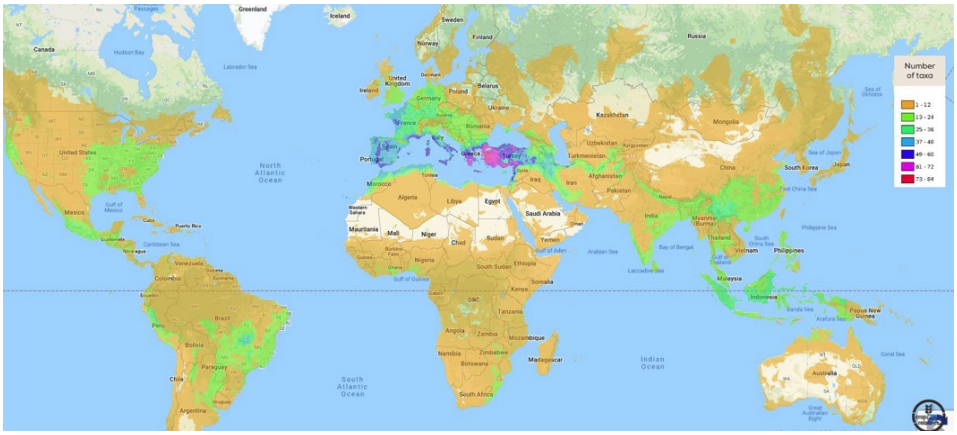



**Figure 3.4.** Distribution of CWRs (Source: Web, 1)

## *Wild Relatives of Cultivated Vegetables in Nepal*

Nepal is in the crossroads between several floristic regions. Nepalese flora shows close affinities to Sino Japanese flora to east, Irano-Turanian flora to west, The Central Asian flora to the north and Indian and Indo-Chinese flora to the south and south-east, respectively. Experts has estimated more than 6,500 species of flowering plants in Nepal,

of which 30% are restricted to Himalayas and 5% are endemic to Nepal (Miehe et al., 2015; Rajbhandari et al., 2017). This figure will increase substantially if extensive explorations are carried out from low lands to high alpine meadows. Despite occupying 0.1 percent of global area, Nepal harbour about three percent of world's known flora. Therefore, beta diversity is particularly high in Nepal. Diverse topographic conditions have also led to maximum diversity of agriculture crops that grow in tropical climate prevalent in the southern plain with as low as 60 m altitudes. In the northern hilly and mountainous belt, temperate-subalpine climate is prevalent where farming is done up to an altitude of 4,700 m (MoFE, 2018). Rice is planted up to two times in the plain areas with high rainfall, while potato is the main crop in higher altitudes. Agro-biodiversity of Nepal comprises about 790 food plant species in which 577 are cultivated species including forage species (Joshi, 2017b; Joshi, et al., 2017a). Among 577 cultivated species, around 84% species are indigenous. Having diverse geography, Nepal shows extreme variations on vegetation patterns and composition of biodiversity. This unique geographic and climatic setting has created suitable habitats for impressive diversities of CWRs. CWRs are wild relatives of cultivated food plants growing naturally in wild habitats or in the proximity of cultivated lands or in disturbed lands. Wild relatives are sometimes regarded as wild cousins of cultivated plants. WRs are mostly genetically related to the cultivated crops. Based on the genetic closeness and inter-mating capacities to exchange gene with cultivated relatives, naturally growing species are classified as primary gene pool, secondary gene pool and tertiary gene pool (Harlan & de Wet, 1971).

Many studies have documented several species of CWRs growing naturally in different ecological zones of Nepal. Regmi (1995) and Shrestha and Shrestha (1996) have reported 64 and 83 wild species of 43 and 36 agriculture crops respectively. Upadhaya and Joshi (2003) have reported about 157 species of food crops in which 56 species of 17 vegetables crops were wild relatives. FAO (2008), however, extended the list of wild relatives of food plants to 599. Out of 599, about 200 species were reported to be wild relatives of vegetable crops.

## *Primary Wild Vegetables (PWV) in Nepal*

Plants we are growing now were once wild. Through series of human mediated breeding and selection, several plants are evolved under domesticated crops. Many of the plants growing around us are either wild or some of them are gradually adapted to semi-domesticated habitats. Himalayan country Nepal is proximal to the primary and secondary sources of origin of many cultivated crops. There are about 15 species of cereals, 18 species of cultivated grain legume crops, 23 species of fruits crops and more than 100 species of vegetables crops growing in different parts of the country (Shrestha & Shrestha, 1999). Farming areas extended in different ecological zones of the country are rich in numerous local landraces and at the same time many of their primary wild relatives also exist in the surrounding natural vegetation. Nepal is one of the northern most country of rice origin where at least 5 wild species of rice and some their weedy varieties are present. Wild relatives of wheat have been reported from Jumla and Humla districts. Wild weedy species of *Hordeum*, *Fagopyrum* and *Eleusine* are reported from Nepal. Wild species of grain legumes belonging to *Atylosis*, *Cicer* and *Lathyrus* are locally used as ornamental plants, fodder and feed (Manandhar, 2002; Shrestha &

Shrestha, 1999). Some notable fruits and their wild relatives distributed in Nepal are *Prunus*, *Castanopsis*, *Malus*, *Morus*, *Pyrus* and *Mangifera*. They are found in tropical to temperate region of Nepal. Similarly, numerous wild relatives of Primary wild vegetables are widely distributed in tropical to subalpine zones of Nepal. About 37 species of crops, including vegetables and fruits of Nepal, fall in the primary gene pool concept suggested by Vavilov (1952) and Harlan and de Wet (1971). Among 37 species, primary gene pools of vegetables are represented by leguminous vegetables like beans, chickpea, cowpea, pigeon pea, egg plant and Swisschard (Joshi et al., 2017a). Diverse kinds of vegetables under genera *Amaranthus*, *Alocasia*, *Asparagus*, *Cajanus*, *Cicer*, *Chenopodium, Cucumis*, *Dioscorea*, *Dolichos*, *Ipomoea*, *Lactuca*, *Lathyrus, Momordica*, *Rumex*, *Solanum*, *Trichosanthes*, *Trigonella*, *Vicia* and *Vigna* are commonly found in disturbed and forested areas. Updated list of primary wild vegetables is presented in Table 3.4.

## *Updated Checklist of Vegetables Wild Relatives (VWRs) in Nepal*

A revised list of 68 wild relatives of 18 vegetables has been presented by Singh et al. (2017). In this paper, the list of vegetable wild relatives (VWR) in Nepal presented by Neupane et al. (2017) and Singh et al. (2017) has been further revised and updated. This revised list presents a total of 148 representing species under 55 genera comprising a broad range of green vegetables under categories fruity and flower; leafy; root, tuber and bulbous; and leguminous vegetables (Table 3.4). In terms of diversity, the presented list comprises a wide range of wild taxa found in Nepal as the primary, secondary and tertiary gene pools of wild relatives, those could be available to enhance and enrich quality of cultivated vegetables.

**Table 3.4.** Checklist of VWRs in Nepal. Number of wild species are based on NPHL (2011, 2012) and Rajbhandari and Rai (2017, 2019).

| S. N. | Genus/Number of species in Nepal | Representing species | Distribution range (altitude) | Chromosome number (2n)/ Genome size |
|---|---|---|---|---|
| 1 | *Abelmoschus* / 3 | *Abelmoschus crinitus* Wall.<br>*Abelmoschus manihot* subsp. *tetraphyllus* var. *pungens* (L.) Medik.<br>*Abelmoschus moschatus* Medik. | WC (150–1,000)<br>WCE (700–1,700)<br>WCE (600–1,100) | 56–144/1.6 Gb |
| 2 | *Allium* / 10 | *Allium carolinianum* DC.<br>*Allium fasciculatum* Rendle<br>*Allium hypsistum* Stearn<br>*Allium prattii* C. H. Wright apud Forbes & Hemsl.<br>*Allium przewalskianum* Regel<br>*Allium sikkimense* Baker<br>*Allium stracheyi* Baker<br>*Allium tuberosum* Rottler ex Spreng. | WC (3,300–5,100)<br>WCE (4,800–4,500)<br>C (5,500)<br>WCE (2,400–4,500)<br>WC (3,600–4,200)<br>C (3,000–5,100)<br>W (2,700–4,000)<br>WC (2,300–2,600) | 16–40/1C = 16.25 pg-31.45 |

| | | | | |
|---|---|---|---|---|
| 3 | *Alocasia* / 3 | *Alocasia fornicata* (Roxb.) Schott<br>*Alocasia macrorhizos* (L.) G. Don<br>*Alocasia navicularis* (K. Koch & Bouche) Koch & Bouche | E (250)<br>C (700–800)<br>E (450) | 28 |
| 4 | *Amaranthus* / 5 | *Amaranthus hybridus* subsp. *cruentus* (L.) Thell.<br>*Amaranthus hybridus* subsp. *hypochondriacus* (L.) Thell.<br>*Amaranthus quitensis* Kunth<br>*Amaranthus retroflexus* L.<br>*Amaranthus tricolor* L. | C (2,600)<br>CE (1,500–1,700)<br>W (200) | 32/466 mb |
| 5 | *Amorphopallus* / 3 | *Amorphophallus bulbifer* (Roxb.) Blume<br>*Amorphophallus napalensis* (Wall.) Bogner & Mayo<br>*Amorphophallus paeoniifolius* C. Y. Wu ex H. Li, Y. Shiao & S.L. Tseng | CE (300–900)<br>WCE (280–1,600)<br>- | 26, 28 |
| 6 | *Arisaema* / 17 | *Arisaema consanguineum* Schott<br>*Arisaema flavum* (Forsskal) Schott<br>*Arisaema jacquemontii* Blume<br>*Arisaema utile* Hooker fil. Ex Schott | CE (1,600–2,700)<br>WC (2,400–2,900)<br>WCE (2,700–4,400)<br>WCE (2,500–4,600) | |
| 7 | *Arundinaria* / 1 | *Arundinaria racemosa* Munro | E (3,000–3,600) | |
| 8 | *Asparagus* / 7 | *Asparagus curillus* Buch.-Ham. ex Roxb.<br>*Asparagus penicillatus* H. Hara, | WC (1,100–1,700)<br>W (2,000–2,400) | 20/720 mb |
| 9 | *Bambusa* / 3 | *Bambusa nepalensis* Stapleton<br>*Bambusa tulda* Roxb. | CE (500–1,700)<br>C (200–1,200) | |
| 10 | *Bauhinia* / 6 | *Bauhinia malabarica* Roxb.<br>*Bauhinia vahlii* Wight & Arn. | WCE (200–650)<br>WCE (200–1,300) | 28 |
| 11 | *Cajanus* / 4 | *Cajanus crassus* (Prain & King) Maesen<br>*Cajanus elongatus* (Benth.) Van der Maesen<br>*Cajanus mollis* Van der Maesen<br>*Cajanus scarabaeoides* (L.) houars | WC (200–1,000)<br>CE (1,200–2,000)<br>WCE (1,100–2,000)<br>WC (300–1,200) | 22/833 Mbp |
| 12 | *Celosia* / 1 | *Celosia argentea* L. | WCE (100–1,600) | |
| 13 | *Chenopodium* / 7 | *Chenopodium ambrosioides* L.<br>*Chenopodium botrys* L.<br>*Chenopodium ficifolium* Sm.<br>*Chenopodium foliosum* (Moench) Asch.<br>*Chenopodium opulifolium* Schrad. ex Koch & Ziz<br>*Chenopodium quinoa* Willd. | WCE (300–2,600)<br>C (4,000)<br>WC (1,100–2,100)<br>C (2,600–3,800)<br>CWE<br>- | 9, 36/145–150Gb |

| | | | | |
|---|---|---|---|---|
| 14 | *Cicer* / 1 | *Cicer microphyllum* Benth. | C (3,700–4,800) | 8, 16/738–931Mbp |
| 15 | *Coccinia* / 1 | *Coccinia grandis* (L.) Voigt | WCE (200–900) | 24, 28/719, 904Mb |
| 16 | *Colocasia* / 2 | *Colocasia affinis* Schott<br>*Colocasia fallax* Schott | C (1,100–2,000)<br>WCE (80–2,200) | 26, 28, 38, 42, and 56/3.29–12.51 pg/2C |
| 17 | *Crotalaria* / 16 | *Crotalaria spectabilis* Roth<br>*Crotalaria tetragona* Andrews | CE (200–300)<br>WCE (200–1,700) | 14, 16, 18 |
| 18 | *Cucumis* / 2 | *Cucumis maderaspatanus* L.<br>*Cucumis sativus* var. *hardwickii* (Royle) Kitam. | WCE (200–1,400)<br>C (1,300–1,700) | 14, 24/367–450Mbp |
| 19 | *Dendrocalamus* / 2 | *Dendrocalamus hamiltonii* Nees & Arn. ex Munro<br>*Dendrocalamus hamiltonii* Nees & Arn. ex Munro var. *undulatus* Stapleton | CE (1,000–2,000)<br>E (1,300–1,500) | 22, 24, 48, 72/2.075Gbp |
| 20 | *Descurainia* / 1 | *Descurainia sophia* (L) Webb ex Prantl | WC (2,200–4,200) | |
| 21 | *Dioscorea* / 11 | *Dioscorea belophylla* (Prain) Voigt ex Haines<br>*Dioscorea deltoidea* Wall. ex Griseb.<br>*Dioscorea glabra* Roxb.<br>*Dioscorea hamiltonii* Hook. f.<br>*Dioscorea hispida* Dennst.<br>*Dioscorea melanophyma* Prain & Burkill<br>*Dioscorea prazeri* Prain & Burkill<br>*Dioscorea pubera* Blume | WE (200–2,400)<br>WCE (500–3,100)<br>WCE (150–2,200)<br>WCE (1,200–1,700)<br>WCE (150–900)<br>WC (2,000–2,500)<br>CE (900–1,400)<br>WCE (150–1,100) | 4, 60, 80/454–562-594Mb |
| 22 | *Diplocyclos* / 1 | *Diplocyclos palmatus* (L.) C. Jeffrey | WCE (200–1,500) | |
| 23 | *Dolichos* / 2 | *Dolichos staintonii* H. Ohashi & Tateishi<br>*Dolichos tenuicaulis* (Baker) Craib | WC (1,000–3,000)<br>E (300–1,200) | 22/367Mbp |
| 24 | *Drepanostachyum* / 3 | *Drepanostachyum falcatum* (Nees) Keng f.<br>*Drepanostachyum intermedium* (Munro) Keng f.<br>*Drepanostachyum khasianum*(Munro) Keng f. | CE (1,000–2,200)<br>E (1,000–2,000)<br>C (1,950) | |
| 25 | *Ensete* / 1 | *Ensete glaucum* (Roxb.) Cheesman | C (1,200) | |
| 26 | *Erysimum* / 2 | *Erysimum hieraciifolium* L. | WCE (1,600–3,800) | |
| 27 | *Flemingia* / 4 | *Flemingia procumbens* Roxb. | WC (2,100–2,900) | 22 |
| 28 | *Herpetospermum*/3 | *Herpetospermum pedunculosum* (Seringe) Baillon | WCE (1,000–3,000) | |

| | | | | |
|---|---|---|---|---|
| 29 | *Himalayacalamus*/7 | *Himalayacalamus brevinodus* Stapleton<br>*Himalayacalamus falconeri* (Hooker fil ex Munro) Keng fil. | E (1,800–2,200)<br>CE (2,000–2,500) | |
| 30 | *Ipomoea* / 16 | *Ipomoea aquatica* Forsskal<br>*Ipomoea arachnosperma* Welw.<br>*Ipomoea cairica* (L.) Sweet<br>*Ipomoea turbinata* Lag. | WCE (500)<br>W (610)<br>E (200)<br>WC (900–1,400) | 15, 90/4.4Gb |
| 31 | *Lactuca* / 6 | *Lactuca dissecta* D. Don | WCE (500–3,100) | 18/2.7Gb |
| 32 | *Lathyrus* / 5 | *Lathyrus aphaca* L.<br>*Lathyrus laevigatus* subsp. *emodi* (Waldst. & Kit.) Gren.<br>*Lathyrus pratensis* L.<br>*Lathyrus sativus* L.<br>*Lathyrus sphaericus* Retz. | WCE (100–1,500)<br>W (2,100–3,100)<br>WC (2,300–3,000)<br>WCE (200–1,200)<br>W (1,300–1,600) | 14/6.3–8.2Gb |
| 33 | *Malva* / 4 | *Malva sylvestris* L.<br>*Malva verticillata* L. | C (2,400)<br>WC (2,500–3,550) | 42/1.87–3.82 pg |
| 34 | *Megacodon* / 1 | *Megacodon stylophorus* (C.B. Clarke) H. Smith | E (3,000–4,000) | |
| 35 | *Momordica* / 4 | *Momordica balsamina* L.<br>*Momordica dioica* Roxb. ex Willd. | W (600)<br>E (1,100) | 16, 22, 28, /339, 710.68–1141Mbp |
| 36 | *Mucuna* / 3 | *Mucuna macrocarpa* Wall.<br>*Mucuna nigricans* (Lour.) Steud.<br>*Mucuna pruriens* (L.) DC. | CE (1,200–2,200)<br>CE (300–1,200)<br>WCE (100–1,200) | 22/1281–1361Mbp |
| 37 | *Musa* / 1 | *Musa balbisiana* Colla | - | |
| 38 | *Nasturtium* / 1 | *Nasturtium officinale* R. Br. | WCE (900–3,800) | 16, 32, 64, 48/0.76–0.77 |
| 39 | *Natsiatum* / 1 | *Natsiatum herpeticum* Buch.-Ham. ex Arn. | WCE (250–1,400) | |
| 40 | *Nelumbo* / 1 | *Nelumbo nucifera* Gaertner | WCE (80–1,400) | |
| 41 | *Panax* /1 | *Panax pseudoginseng* Wall. | WCE (2,000–3,000) | |
| 42 | *Peperomia* / 3 | *Peperomia pellucida* (L.) Kunth | WCE (200–2,000) | |
| 43 | *Persicaria* / 29 | *Persicaria barbata* (L.) H. Hara<br>*Persicaria chinensis* (L.) H. Gross<br>*Persicaria microcephala* (D. Don) H. Gross<br>*Persicaria nepalensis* (Meisn.) H. Gross<br>*Persicaria perfoliata* (L) H. Gross<br>*Persicaria runcinata* (Buch.-Ham. ex D. Don) H. Gross | WCE (200–1,100)<br>WCE (1,200–2,900)<br>CE (1,200–2,700)<br>WCE (1,200–4,100)<br>CE (900–1,400)<br>CE (1,600–3,800) | 20, 24, 36, 40 |
| 44 | *Remusatia* / 3 | *Remusatia pumila* (D.Don) H.Li & A.Hay<br>*Remusatia vivipara* (Roxb.)Schott | WCE (1,200–2,400)<br>WCE (900–2,100) | |
| 45 | *Rhynchosia* / 7 | *Rhynchosia himalensis* Benth. ex Baker | WC (1,900–2,900) | |

| | | | | |
|---|---|---|---|---|
| 46 | *Rorippa* / 4 | *Rorippa benghalensis*(DC.) H. Hara<br>*Rorippa dubia* (Pers.) H. Hara<br>*Rorippa indica* (L). Hiern<br>*Rorippa palustris* (L.) Besser | E (200–300)<br>CE (1,200–2200)<br>WE (100–2,600)<br>CE (1,300–2,800) | 28 |
| 47 | *Rumex* / 5 | *Rumex acetosa* L.<br>*Rumex dentatus* subsp. *klotzschianus* L.<br>*Rumex patientia* subsp. *pamiricus* L.<br>*Rumex vesicarius* L. | WC (2,100–4,100)<br>C (1,400)<br><br>C (400)<br>E (200) | 14/7.04 |
| 48 | *Solanum* / 8 | *Solanum aculeatissimum* Jacq.<br>*Solanum alatum* Moench<br>*Solanum anguivi* Lam.<br>*Solanum erianthum* D. Don<br>*Solanum nigrum* L.<br>*Solanum surattense* Burm. f.<br>*Solanum torvum* Sw.<br>*Solanum viarum* Dunal | CE (1,600)<br>CE<br>WCE (250–2,300)<br>WCE (200–1,400)<br>WCE (900–2,900)<br>WCE (300–900)<br>CE (250–750)<br>CE (900–2,600) | 24, 48/727–844 Mbp; 798–931 Mb |
| 49 | *Solena* / 2 | *Solena heterophylla* Lour. | WCE (1,600–3,200) | 24 |
| 50 | *Sonchus* / 2 | *Sonchus asper* (L) Hill<br>*Sonchus oleraceus* L.<br>*Sonchus wightianus* de Candolle | CE (1,000–1,800)<br>WC (2,000–2,800)<br>WCE (600–2,500) | |
| 51 | *Thladiantha* / 1 | *Thladiantha cordifolia* (Blume) Cogn. | CE (400–2,500) | 18 |
| 52 | *Trichosanthes* / 6 | *Trichosanthe pilosa* Lour.<br>*Trichosanthes lepiniana* (Naudin) Cogn.<br>*Trichosanthes cordata* Roxb.<br>*Trichosanthes costata* Bl.<br>*Trichosanthes tricuspidata* Lour.<br>*Trichosanthes wallichiana* (Ser.) Wight | WCE (1,200–1,800)<br>WCE (1,500–1,900)<br><br>C (500)<br>WE (1,100–1,800)<br>WCE (700–2,300)<br>WCE (600–2,700) | 22, 44, 88 |
| 53 | *Trigonella* / 5 | *Trigonella corniculata* (L.) L.<br>*Trigonella emodii* Benth.<br>*Trigonella fimbriata* Royle ex Benth.<br>*Trigonella gracilis* Benth.<br>*Trigonella pubescens* Baker | C (3,700)<br>WC (1,300–4,900)<br>C (1,800–2,200)<br><br>WCE (2,200–3,400)<br>WC (2,200–3,600) | 14, 16, 18 |
| 54 | *Vicia* / 5 | *Vicia tetrasperma* (L.) Schreber<br>*Vicia bakeri* Ali<br>*Vicia hirsuta* (L.) Gray<br>*Vicia sativa* L. var. *angustifolia* (L.) Wahlenb.<br>*Vicia tenuifolia* Roth | C (1,500–1,600)<br>WC (2,700–3,200)<br>WCE (200–2,700)<br>WCE (200–4,000)<br><br>WC (1,600–2,200) | 10, 12, 14/~13 Gbp |
| 55 | *Vigna* / 12 | *Vigna nepalensis* Tateishi & Maxted<br>*Vigna radiate* (L.) R.Wilczek<br>*Vigna vexillata* (L.) A. Rich | E (300–1,700)<br>-<br>- | 22/416–1394Gb |

W = west, C = central and E = east

## *Hotspots for Wild Vegetables in Nepal*

Phytogeographically, Nepal is in the western edge of the eastern Himalayan biodiversity hotspot; however, almost all types of world climate exist in Nepal. Speciation of plants in this region happened during uplift of the Tibetan pleatue and evolution of regional climate (shift of temperature and precipitation) in different periods (Miehe et al., 2015). Midlands and sub-tropical evergreen broad-leaved forests are rich in plant species, as this zone lacks severe frosts, experiences high rainfall and moderately high temperatures (Kessler et al., 2011). Most of the vegetation types found in Nepal have wider range of distribution across Himalaya. Diverse vegetation types are not only habitats for varied species but also home for wild species that are genetically related to the cultivated crops including vegetables. Nepal is reputed for primary and secondary origin of crops like rice, wheat, buckwheat, fruits and several vegetables. Global analysis on 81 gene pools of wild relatives revealed that Nepal possess 22–36 taxa of CWRs (Crop Wild Relatives Occurrence Data Consortia, 2018). In the national study, wild relatives of wheat are reported from Jumla and Humla district of western Nepal (Joshi et al., 2006). Similarly, wild types of common buckwheat; *Fagopyrum cymosum* (Trevir.) Meisn., *Fagopyrum megacarpum* H. Hara and *Fagopyrum tataricum* ssp. *potanini* have also been reported in mid hills and high hills in western and far-western regions (Baniya, 2001; Joshi, 2008). FAO (2008) highlighted several indigenous species of cultivated vegetables and their wild relatives viz. *Allium*, *Amaranthus*, *Chenopodum*, *Colocasia*, *Curcuma*, *Dioscorea*, *Ipomoea*, *Mentha*, *Pisum*, *Rumex, Solanum* and *Trigonella*. These species are mainly distributed in terai and mid hills of Nepal. Majority of wild relatives of crops are distributed naturally in the tropical to temperate belt of Nepal.

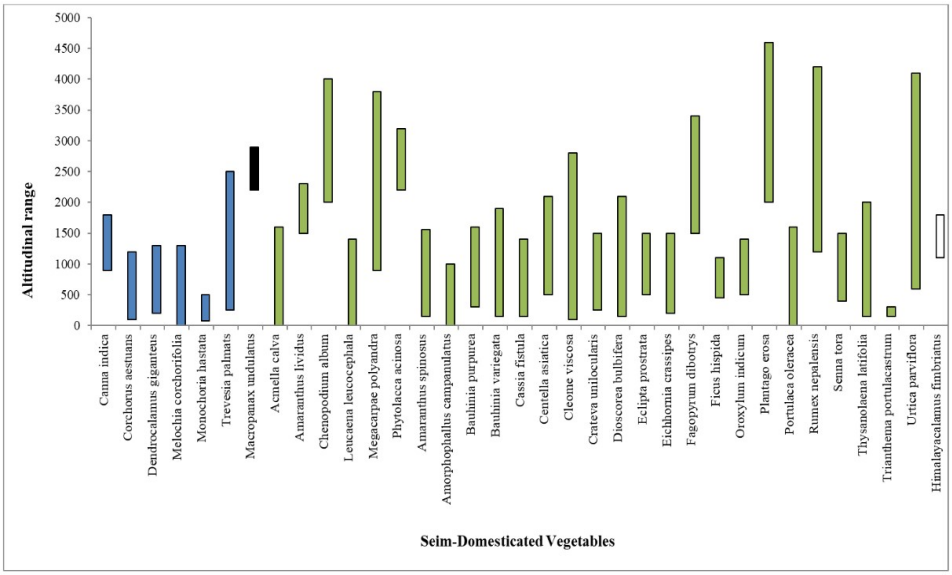



**Figure 3.5.** Semi-domesticated vegetables distributed in central-east Nepal (blue bars), west-cenral-east Nepal (green bars), and east Nepal (white bar).

Several semi-domesticated vegetable species can be seen growing along the edge of farm lands. Out of 56 species recorded here (see: Table 3.2), 31 species are distributed throughout Nepal (west, central and east) followed by 8 species in central-east Nepal, 7 species in west-central Nepal, 6 species in central Nepal, 2 species in east Nepal, and one in west and east Nepal (Figure 3.5).

As presented above, a total of 143 species of wild vegetables have been recorded (see: Table 3.3). Majority of them (93 species) are distributed throughout Nepal, followed by 21 species in cental-east Nepal and 19 species in west-central Nepal. A total of 4, 2 and 1 species are limited to central, east and west Nepal, respectively. Three species showed distribution in west and east. Among the total reported species, more than 72% species are found in the altitudinal range of 1000–3500 m. Distribution of a few commonly used species are shown in Figure 3.6.

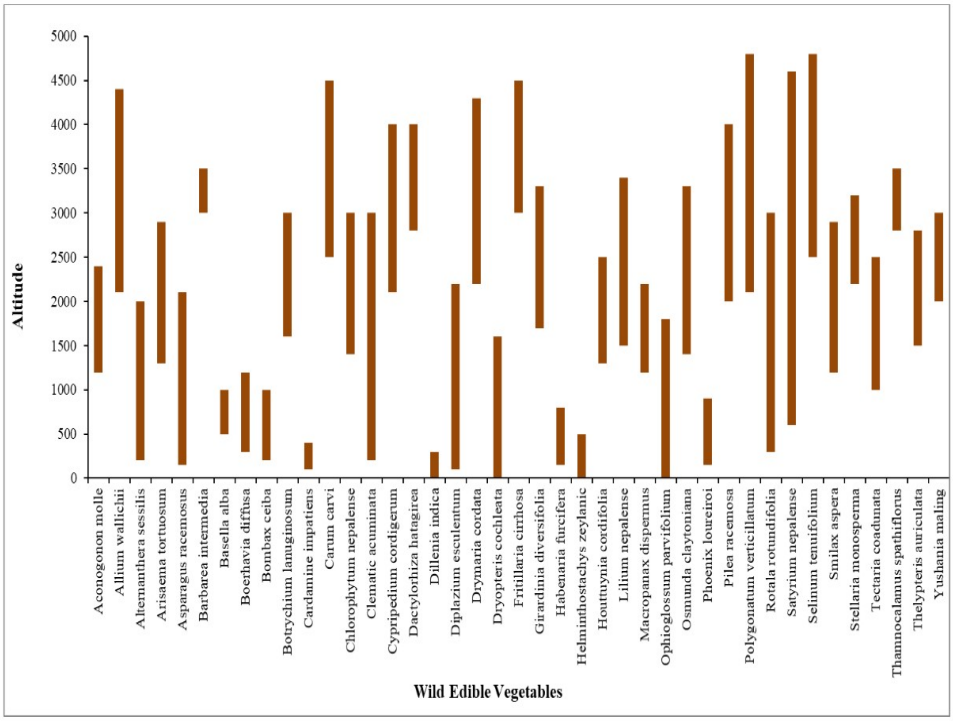



**Figure 3.6.** Wild vegetables that are distributed throughout (west-central-east) Nepal.

Similarly, out of a total of 148 species of VWRs presented in this paper (see: Table 3.4), 52 species are distributed from west-central to east Nepal followed by 27 species in west to central, and 24 species in central to east Nepal. Species found to be distributed only in west, central and east Nepal are 7, 19 and 16, respectively. Three species were reported from west and east Nepal (Figure 3.7).

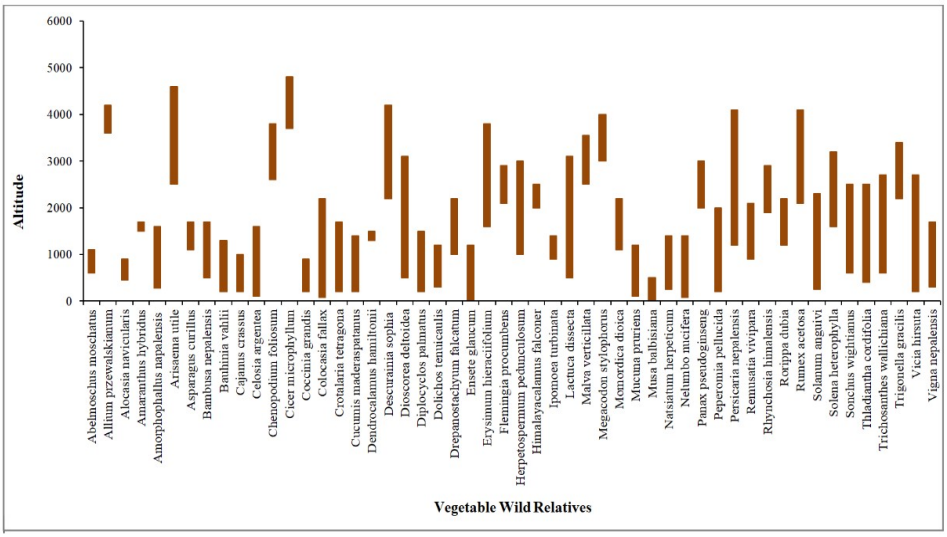



**Figure 3.7.** Distribution of VWRs in different altitudinal range of Nepal.

## Wild Vegetables to Enhance Domesticated Gene Pool

Wild relatives are the major source to improve genetic base of cultivated species. Over thousands of years of artificial selection for developing varieties of vegetables and other crops has led to the estimated loss of over 75% genetic diversity in crops (Singh, 2017). Continuous selections of thousands of years turned wild crops to very high yielding crops; however, they were separated from their wild progenitor very long ago and now loosed greater genetic versatility that helps to survive on much wider range of environment and associated climatic and edaphic stresses. Such qualities can be introduced back to cultivars from wild relatives (see: Table 3.5). Transferring desirable traits to cultivated progenitors sometimes become very challenging (Nair, 2019). Many traits in plants are closely linked with other traits. Among closely linked genes desirable gene sometimes could be linked with undesirable gene e.g. desired genes linked with traits which favour survival in wild rather than in human maintained ecosystem, that such linked gene should be excluded through repeated backcrossing or from genetic manipulations. Incorporation of wild gene diversity to the gene pool of cultivated species for better traits is being in practice in different vegetables. Enhancement of gene pool in cultivated vegetables is important for developing promising cultivars with higher yield and adaptabilities like disease resistance and biotic and abiotic tolerances. Utilization of wild gene pools depends on factors like cross compatibilities, genetic relatedness of available wild relatives, fertility of hybrid progeny and finally local need and availability of adequate financial support for the breeding program (Zhang et al., 2017). Major advances in broadening of the genetic base of vegetables using wild relative is well documented (Jansky, 2010; Kaur et al., 2018; Chittaranjan, 2011; Kunchge et al., 2012; Singh, 2017). Studies on utilizing wild gene pool in the improvement of selective vegetables are given in Table 3.5.

**Table 3.5.** Enriching traits on cultivated vegetables utilizing wild gene pools.

| S. N. | Vegetables | Wild relatives | Quality traits (References) |
|---|---|---|---|
| 1 | Tomato | *Solanum chilense*, *S. habrochaites*, *S. hirsutum*, *S. pennellii*, *S. pimpinellifolium* | Drought tolerance (Arms et al., 2015), leaf curl virus resistance (De Castro et al., 2007), pest resistance (Mirnezhad et al., 2010), enhance fruit quality (Wu et al., 2015), yield improvement trait (Haque et al., 2015) |
| 2 | Potato | *Solanum berthaultii*, *S. bulbocastanum*, *S. chacoense, S. commersonii*, *S. demissum, S. etuberosum, S. ruiz-zeballosii, S. stoloniferum*, *S. tarijense*, *S. torvum* | Late blight resistance (Bradshaw et al., 2006; Śliwka et al., 2012; Song et al., 2003), virus resistance (Duan et al., 2012), moth resistance (Horgan et al., 2007), pathogen resistance (Zuluaga et al., 2015), multiple traits improvement (Jansky, 2011) |
| 3 | Brinjal, eggplant | *Solanum linnaeanum*, *S. viarum* | Resistance to *Verticillium* wilt (Liu et al., 2015), resistance to *Leveillula taurica* (Bubici & Cirulli, 2008), resistance to shoot and fruit borer (Pugalendhi et al., 2010), resistance to bacterial wilt (Bainsla et al., 2016) |
| 4 | Cucumber | *Cucumis figarei*, *C. hardiwickii*, *C. hystrix* | Cucumber mosaic virus resistance, Downy mildew resistance, gummy stem blight resistance (Chen et al., 2008), green mottle mosaic virus resistance (Pan & More, 1996), resistance to powdery and downy mildew diseases (Pitchaimuthu et al., 2012), yield enhancing (Chen & Zhou, 2011) |
| 5 | Oakra | *Abelmoschus caillei*, *A. manihot*, *A. moschatus*, *A. tuberculatus* | Resistance to yellow vein mosaic virus, shoot and fruit borer, and leaf hopper (Gangopadhyay et al., 2017; Rana et al., 1991; Singh et al., 2007) |
| 6 | Pigeon pea | *Cajanus* spp. | Cytoplasmic male sterility (Mallikarjuna et al., 2012) |
| 7 | Chickpea | *Cicer reticulatum*, *C. echinospermum* | Yield enhancement related traits (Singh & Ocampo, 1997; Singh et al., 2008); resistance to *Ascochyta* blight (Singh et al., 2014), drought tolerance (Toker et al., 2007; Canci & Toker, 2009) |
| 8 | Garlic/Onion/Leek/shallots | *Allium roylei*, *A. ursinum*, *A. galanthum;* | Resistance to downy mildew and botrytis leaf blight (Kofoet et al., 1990), novel flavonoids introgressed into garlic (Simon & Jenderek, 2010), develop a male sterile line for shallot and bunching onion (Yamashita et al., 1999) |
| 9 | Amaranthus | *Amaranthus hybridus*, *A. Tuberculatus* | Transmission of herbicide resistance gene (Tranel et al., 2002), improving grain harvestability and grain shattering (Baltensperger et al., 1992; Brenner et al.,2010) |
| 10 | Asparagus | *Asparagus densiflorus*, *A. kiusianus*, *A. maritimus* | Leaf spot rust resistance, stem blight resistance (Falavigna et al., 2008; Iwato et al., 2014) |
| 11 | Lettuce | *Lactuca virosa* | Mirafiori lettuce big vein virus (MLBVV) resistance (Hayes & Ryder, 2007), lettuce aphid resistance (McCreight, 2008), drought resistance (Argyris et al., 2008), introgression of genes from wild (Davey et al., 2007) |
| 12 | Bitter gourd | *Momordica balsamina* | Resistance to leaf damage from Aulocophora and other diseases (Njoroge & van Luijk, 2004) |

## Advance Tools to Use Wild Vegetables (PWV and VWR) for Developing Quality Traits

The potential of wild relatives as a source of quality traits to bring in cultivated species has been realized as early as 20th century. However, the process of incorporating genetic diversity from wild into cultivars requires tremendous amount of time, money and dedicated human resources. In fact, this process involve a list of peoples having expertise on plant taxonomy, phytogeography, genebank curation, genetics, agronomy, pathology, breeding and finally mass farming (Dempewolf et al., 2017). In last two decades, substantial numbers of inbreeding programs have successfully transferred genes of interest from wild relatives to cultivated vegetables. Acceleration in gene transfer and improvement of cultivated crops is attributed to modern biotechnological approaches that have facilitated identifying genes or genomic region controlling complex traits (Varshney et al., 2005; Zhang et al., 2017). Widely used advanced methodologies for gene discovery in WRs are discussed below.

***Genomics:*** Genomic studies conducted using genetic analyzers produce tremendous amount of genomic data that helps in identification and evaluation of germplasm resources, heterosis prediction, linkage and association mapping and marker-assisted breeding (Zhang et al., 2017). High throughput next generation sequencing techniques has accelerated the use of wild crop relatives gene through efficiently identifying Single Neucleotide Polymorphisms (SNPs) associated with important traits. Next generation sequencing techniques offer low cost genotyping of thousands of WRs in a short period building libraries of their SNPs and phenotypic data. Such libraries are useful to validate previously identified genes and discover new genes of valuable agronomic traits through association mapping (Li et al., 2014; Zhang et al., 2017). Similarly, sequencing of heterozygous plants and segregating populations helps in the construction of high resolution linkage maps (Uitdewilligen et al., 2013). High throughput sequencing enables genotyping of all available cultivars and deposits them in public database or gene banks. Breeders can access those genomic data and work on core germplasm representing allelic richness of stored resources for the evaluation of desired traits. This approach of evaluating cultivars is highly effective and efficient in terms of saving both time and money.

***Quantification of functional molecules:*** Unlike genomics, analysis of functional molecules 'functional omics' focus on quantification of metabolites, proteins and transcriptomes, which are produced by the plant due to biotic and abiotic stresses. Omic scale technologies i.e. proteomics, transcriptomics and metabolomics approaches quantify regulatory genes, expressed proteins and metabolites candidates underlying important traits present in CWRs. In functional omic analysis, CWRs are grown under certain biotic or abiotic stresses and stress resistant genes thereby expressed in the form of transcriptomes, proteins and metabolites are quantified. Combining phenotypic data with genotypic data helps to fine map known genes and discover novel genes underlying valuable agronomic traits in wild relatives through association mapping (Zhou et al., 2015). Omics databases of different gene or gene family members are proved to be highly effective for novel gene identification within target Quantitative Trait Loci (QTL). Omics approaches helps to dissecting and characterizing complex traits in WRs under diverse

treatments like in wild tomato (Fischer et al., 2013). Such methods are successful to transfer identified quality traits related matabolic pathways from WRs into cultivated species (Bleeker et al., 2012; Paudel et al., 2019). Transcriptomics, proteomics and metabolomics are thus powerful tools to study gene functions at different levels; however, these approaches are relatively costly than other available methods. Genome wide metabolomics mapping in CWRs can be useful in plant breeding because wild species mostly subject to different types of stress during evolutionary process than their cultivated descendants. High density SNPs markers developed in Brassica, eggplant, tomato, capsicum (Aflitos et al., 2014; Cericola et al., 2014; Clarke et al., 2016; Taranto et al., 2016) will have tremendous benefits for metabolomics mapping which can be used in future for breeding programs in vegetables.

***Gene manipulation:*** Gene manipulation induces mutation to the existing gene of the crops which includes genome editing, cisgenesis, intragenesis, RNA-dependant DNA methylation, etc. Late blight resistant potatoes were developed through cisgenesis approach (Haverkort et al., 2009). Transfer of desired traits through induced mutation also reduces the time involved using traditional breeding techniques (Zhang et al. 2015).

## Global Potential of Nepalese Wild Vegetables

Studies have shown that nutritional values of numerous wild plants are comparable to cultivated ones (Bajracharya, 1980). In these regard, there are tremendous potentialities to tame several of the wild vegetables found in Nepal and diversify their use in a local and global scales (Uprety et al., 2012). Many wild vegetables can be used in breeding programs and develop high yielding, nutritious varieties that can contribute to global food security. As the effect of climate change is likely to increase in various parts of the world, many drought tolerant genes in WRs can be transferred to cultivated species. Therefore, number of wild, semi-domesticated species and local landraces has immense value for develping resistance/ tolerance to drought, diseases and pests in the cultivated species necessary to feed the global population.

## Conservation of VWRs and PWV in Nepal

Nepal is considered one of the rich countries in agricultural crops with about 484 indigenous crops and an estimated 30,000 native landraces (Joshi & Upadhaya, 2019). Native crop diversity has supported different aspects of livelihood of local people. Indigenous crops are the source of food, fibre, medicine, organic manure, pesticides, etc. Conservation and sustainable use of agriculture plant genetic resources including their WRs are emphasized following 20 different conservation methods and the same number of actions plans under four different conservation strategies (on-farm, ex-situ, in-situ and use for breeding) (Joshi et al., 2017a, 2017d). Different conservation methods are in practice so that each approach complement to another, which helps to maximize the efforts on sustainable use and conservation of cultivated and wild crop gene pools (Figure 3.8).

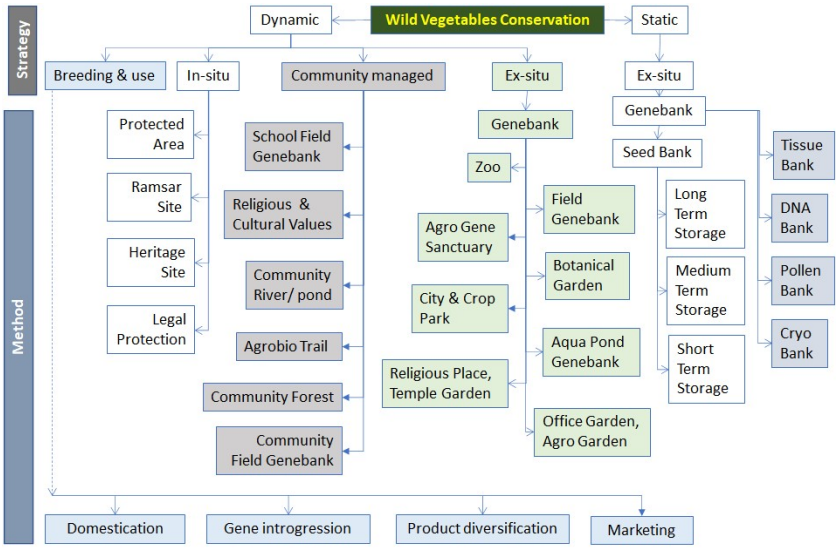



**Figure 3.8.** Strategies and methods for conservation of wild vegetables in Nepal (Source: Joshi et al 2020a).

## *In situ Conservation*

Crop diversities are being maintained for centuries by local communities on farm and around their surroundings (Joshi et al., 2017a, 2017b). There are 20 protected areas in Nepal. Out of 118 ecosystems of Nepal, about 80 are managed inside protected area systems. Networks of protected areas cover 23.39% of total land area of Nepal (DNPWC, 2018). In addition to protected areas, community managed forest (community forest, religious forest, leasehold forest, private forest, collaborative forest and protected forest) cover more than 18% of total land area (DoFSC, 2018). Therefore, in situ conservation of CWRs and other plant resources are being protected and managed within 43% of total land area. Agro-diversity in Nepal is high in all five levels of agro-biodiversity (agro-ecosystem, species, variety, genotype and allele). Moreover, there are 12 agro-ecosystems in Nepal and all of these agro-ecosystems and their surroundings are rich in semi-domesticated and WRs of crops (Joshi et al., 2020a, 2020b).

## *Ex situ Conservation*

The Agriculture Botany Division, Khumaltar, has started collection and preservation of indigenous crop landraces since 1984 (Joshi, 2017a, 2017b). Division has stored a collection of 10,781 accessions until 2010; however, most of them lost their viability due to lack of proper storage facility (Ghimire et al., 2017). National Agriculture Genetic Resource Centre (NAGRC) holds 11,200 accessions of 130 crops collected from 75 districts, among these accessions 8,410 accessions were collected from 67 districts, after the establishment of genebank in 2010 (Ghimire et al., 2017). Similarly, a total of 2,045 accessions are safely backed up in seven genebanks of different countries. More than 21 countries have conserved around 23,600 Nepalese accessions of different crops (Joshi et al., 2017a).

Conservation of seeds at community level as community seed bank and community field gene bank are another widely adopted practices in Nepal. The first community seed bank was established in Lalitpur district of Nepal. Now there are 120 community seed banks in operation by different organizations at local level. In addition to seed banks, Nepal has adopted other types of ex-situ conservation practices such as Botanical Garden, Cryo Bank, DNA Bank, Field Gene Bank, Farm and Parks, and Tissue Bank for recalcitrant seeds and vegetatively propagated crops. Farmers managed household and community seed banks, and gene banks are another effective method of on-farm conservation of landraces in Nepal.

### *Conservation through Uses*

Conservation of several domesticated, semi-domesticated and wild vegetable species is happening traditionally by farming communities in the forest and agro-ecosystems. On farm conservation is traditionally practiced as dynamic conservation. In this technique, farming community manages diverse set of vegetable populations in agro-ecosystem and store in community gene bank and field gene bank. Seed networks are also very effective approach of conservation in the farming communities of Nepal. Wild and semi-domesticated vegetables are conserved in community forests, culturally and religious important areas and along the periphery and margins of farm lands. Sustainable collection methods are adopted while harvesting seasonal vegetables from natural vegetations.

## Red Zoning and Red Listing of VWR and PWV

IUCN Red List is an important tool that helps to assess the conservation status of species, which then complements the setting of conservation priorities to that species. CWRs are also included on the Red List by IUCN. IUCN red listing further helps to scientifically access and communicate the conservation status of crop WRs of certain area and or region. IUCN conservation assessment has been done for animals and economically important medicinal and high value plants in Nepal (Jnawali et al., 2011; Shrestha & Joshi, 1996). Joshi et al. (2004) has emphasized the importance of red listing agriculture crop species, landraces and varieties in Nepal, and they have also proposed a slightly modified version of assessment criteria, which are appropriate for agricultural crop species. Following Joshi et al. (2004) red listing of crop landraces has been done and red list groups are identified for some crops as common, vulnerable, endangered, extinct and not evaluated. Red list groups are assessed through techniques like survey, distribution and population size analysis (commonly called five cell analysis), trait distribution analysis, red zoning farming areas and collection gap analysis (Joshi et al., 2004; Joshi & Gauchan, 2017). Schematic representations of distribution and population size analysis and trait distribution analysis are given in Figures 3.9 and 3.10. Rescue missions are conducted in different district by National Genebank to collect endangered landraces and to conserve ex-situ. Rescue missions also aware local communities to protect seeds in community seed bank at the same time encourage them to plant regularly so as to restore genetic diversity present in the crop. NAGRC has rescued 34 crop landraces in 2014 and 2016, that includes 13 landraces of vegetables (Joshi & Gauchan, 2017). An additional list of 36 crop landraces and 8 vegetable landraces have also been suggested for germplasm

rescue missions (Joshi, 2017a; Joshi et al., 2017c). An exhaustive list of native crop landraces was prepared and red listed from 10 districts severely affected from 7.5 rectscale earthquake that hit central Nepal in 2015. Red listed landraces were assessed as 104 landraces extinct, 26 landraces rare and 73 landraces endangered from earthquake, and an additional 185 landraces endangered due to other associated factors. This comprehensive list comprises 10 types of leguminous vegetables, 10 kinds of cucurbits and 8 different root and tuberous and fruity vegetables. This study was able to collect 921 accessions of 61 crops, which are conserved in National Genebank (Joshi et al., 2017c; Joshi & Gauchan, 2017). Red zonation of agriculture areas is considered effective approach in Nepal to identify vulnerable and endangered landraces. Endangered and vulnerable native landraces are collected through collection visits, requesting relevant farmers to collect, by organizing germplasm diversity fairs, participatory seed exchange program among communities and announcement from the mass media to collect endangered landraces from larger areas (Joshi & Gauchan, 2017).

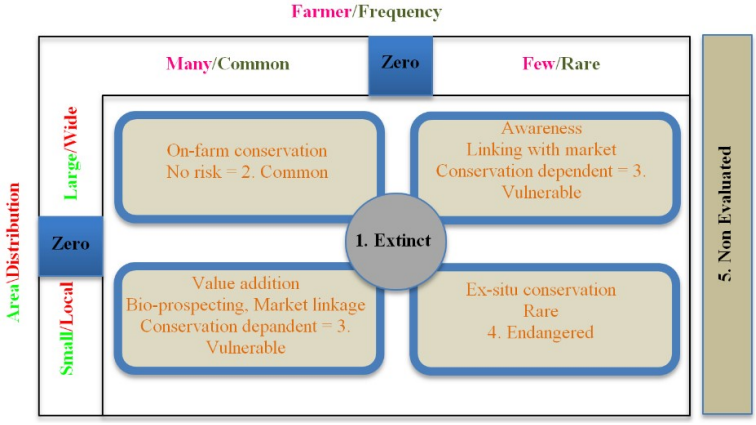



**Figure 3.9.** Categorization of crop landraces based on the distribution and population size (Source: Joshi & Gauchan, 2017; Joshi 2017a).

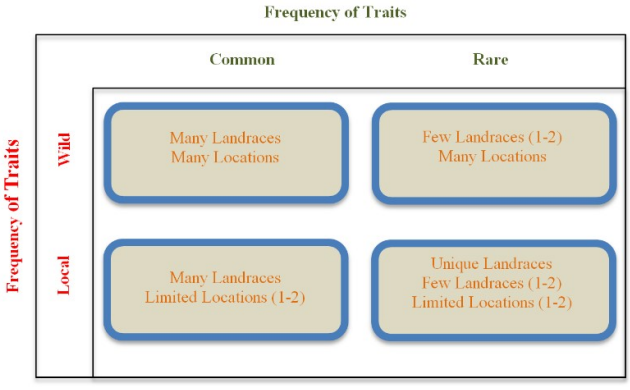



**Figure 3.10.** Categorrization of crop landraces based on the distribution of traits. (Source: Joshi & Gauchan, 2017; Joshi, 2017a).

In Europe, North America and North Africa, conservation status assessment of CWRs had been done following ICUN red list criterias. In Europe, a total of 572 species of CWRs were assessed. Among the total studied species, maximum 137 species were represented from Brassica complex. Other vegetables species included in the list were: onion, leek, garlic, etc. –115 species, legume forage – 89 species, lettuce – 27 species, asparagus – 19 species, grass pea – 19 species, carrot – 12 species, cultivated beets – 10 species, chicory – 3 species. Out of total assessed vegetable species, 50% species of cultivated beets were threatened followed by 26.3% species of asparagus, 18.2% species of Brassica complex, 11.1% species of lettuce, 7.9% species of legume forage, and 5.2% species of onion, leek, garlic, etc (Bilz et al., 2011). Similarly, 502 CWRs taxa identified as a priority for conservation in North Africa were assessed through IUCN red list from a checklist of 5,780 CWRs taxa. Approximately 119 (2%) taxa were assessed as threatened, 21 taxa as critically endangered, 53 as endangered and 45 as vulnerable. Major vegetables having centre of diversity in Africa viz. Brassica group, onion, garlic, lettuce, safflower, asparagus and peas were included in the study (Lala et al., 2018). Frances et al. (2018) reviewed conservation status and threat assessment for North American CWRs. This study has reviewed two methods Nature Serve and IUCN Red list conservation assessment followed for the conservation assessment or red listing of taxa. A total of 871 native species of China related to crop were enlisted and assessed for their red list status. These species included primarily rice, wheat, soybean, potato, sweet potato, millet and yam, which are predominantly related with food and economic security in China and other parts of the world (Kell et al., 2015).

## Threats to Domesticated and Wild Vegetables

### *a. Climate Change and Stresses*

Climate of the world is predicted to be warmer in the future (Hausfather et al., 2020). Climate is one of the key factors that determine the growth, reproduction and dispersal of plants. Vegetables we are farming since long in certain areas would have decreased performance in yield due to more variable rainfall and temperature patterns. In this context, we can either move crops in more favourable areas or modify the genetic makeup of current crops through advance biotechnologies. Due to continuous selections of hundreds of years, domesticated crops, like vegetables, lack adaptabilities needed for tolerance to heat, drought, pest, low manuring and several other stresses (Nair, 2019). Wild plants are evolved to survive in different and difficult climatic and edaphic conditions, including in the presence of pests and diseases. Climate change is projected to increase the spread of pests and diseases and the situation would become even worst in the days ahead. CWRs might have wide range of genetic diversities to combat climate change (Nair, 2019). Even though WRs of cultivated crops might have been evolved with greater genetic versality, they would also face series of unprecedented abiotic stresses due to abrupt climate changes. Furthermore, some CWRs that grow on disturbed habitats were found less resilient to climate change. Endemic or species with narrow range of distribution are especially vulnerable to climate change. Indirect impact of climate change will be changes in biotic interactions including increased competition among species and pressure from pest and diseases (Newton et al., 2008). WRs those having wide range of

climatic adaptabilities can migrate to higher altitude and higher latitude but for species with narrow distribution range, shrinkage in their population will be an ultimate fate (Menéndez et al., 2006). Migration of pests and epidemics of diseases are largely dependent on climatic conditions. Shift in climatic patterns contribute to increase pathogen and pest populations. Study conducted by Jarvis et al. (2008) showed that climate change will cause extinction of around 16–22% species of major crops (potato, peas and peanut) and most species lose over 50% of their current range size within 50 years.

### *b. Habitat Degradation*

In addition to climate change, CWRs are facing several other threats like habitat degradation, infrastructure development, pollution, forest fire, over grazing, invasive species enchroachment, logging, expansion of agriculture land into their habitat, forest clearance, desertification and urbanization (Hoyt, 1988). CWRs are more likely to be distributed in marginal forest areas where human activities are relatively more. These habitats are also not adequately conserved by protected areas; therefore, human activities are serious threats to CWRs. Loss of agricultural genetic resources has been estimated to around 40% in the country. In some areas, up to 100% loss of native landraces has also been recorded from many parts of Nepal (Joshi & Gauchan, 2017). Overgrazing, rampant collection of wild resources, deforestation and encroachment of natural forest, grasslands and fallows by moterable roads, settlements, water dams, powerhouses and agriculture lands have fragmented and shrank the population sizes of WRs.

### *c. Human Activities*

Genetic erosion in CWRs and native landraces due to anthropogenic activities is a very serious threat globally including in Nepal. Agriculture land expansion, overgrazing and introduction of invasive species have replaced many CWRs growing along the margin of farmlands. In addition to the human mediated habitat destruction and degradation, continuous replacement of indigenous landraces by modern varieties has led to the extinction of genetically rich native landraces of crops including many vegetables. Commercialization of agriculture and high market demand are also main reasons that have discouraged communities to grow native landraces with wild genotypes (Joshi et al., 2020a). In semi-urbanized area, excessive pressure on natural habitat, and uncontrolled and over harvesting of wild vegetables have been causing irreversible losses of wild germplasms that can withstand several biotic and abiotic stresses, contain high yield and nutritional quality and other desired traits.

## Utilization of VWRs and PWVs

Several species of vegetables are regularly consumed in villages and urbanized areas in Nepal. A large part of seasonal nutrition comes from both VWRs and PWVs collected from forest and nearby areas. Selective vegetable species representing *Asparagus*, *Bauhinia*, *Colocasia*, *Dioscorea*, *Dendrocalamus*, etc. have high market value in the town and city areas. Development of proper market plan and promotion of commercial activities through micro-enterprises can have remarkable impacts on sustainable utilization and conservation of semi-wild and wild vegetables of Nepal. Market promotion

of seasonal vegetables provides economic opportunities to rural farmers, village based traders and enterprenuers. Wild vegetables are also an important resources used in the treatment of diseaseas and various kinds of health aliments by rural, peri-urban and semi-urban communities of Nepal. Wild vegetables have contributed immensely to enhance food and livelihood security of rural people of Nepal. Beyond these benefits, the use of wild species as donor source of resistance, biotic and abiotic stresses and yield improvement in cultivated crops needs to be intensified (GoN/MoFSC, 2014; Joshi et al., 2020b; Neupane, 1999).

## Conclusion

Vegetables in general and their WRs are not considered cereal commodities; therefore, they get less attention. For nutrition and health reasons, these foods should get equal emphasis with other cereals. Because of high genetic values of WRs in the development of novel cultivar, there is urgency for their conservation. Conservation of WRs and wild edibles is even more urgent in the mounting scenario of biodiversity loss due to climate change and anthropogenic activities in their natural habitats. Nepal has adopted four different methods of conservation viz. on-farm, in-situ, ex-situ and conservation plant breeding. Conservation of wild vegetables (both VWRs and PWVs) can be possible only after getting information about their distribution and population status. Detailed maps that show distribution of vegetable WRs with their density and diversity are very helpful to conservationists and policy makers for prioritization of collection and conservation activities. Such information is crucial to plant breeders in the development of novel varieties. Moreover, germplasm rescue activities would become effective, if detailed maps of WRs are in place.

This paper has presented a revised list of wild and semi-wild vegetables including relatives of domesticated vegetables distributed along different climatic zones and ecosystems of Nepal. Further studies and inventories are necessary and those should be made in a systematic manner covering each municipalities/rural municipalities at districts and provincial levels. Indiscriminate use and over exploitation of wild vegetables should be controlled immediately. Inventory of vegetables WRs can be started in different phases based on the priorities set for different vegetable types like leafy, fruity, stem, roots and tuberous, and legumenous, etc. Guidelines for inventory and prioritizing species would depend on availability of technical, physical and skilled manpower in the country. Intensive, rigorous and regular organization of collection trips should be undertaken considering species and places where there are critical collection gaps and includes under red zones. Conservation efforts should be focused on inventory and collection of primary gene pools in the initial stage and later on secondary and tertiary gene pools can be managed subsequently. Although National Gene Bank has already collected and stored WRs of few vegetables; systematic collection and priority settings for collecting more species should be based on their overall significance. In addition to some important traits potentially present in certain species of WRs giving higher weightage to overall genetic variations, and adaptive value should be valued during the conservation of each wild gene pools.

Safe guarding WRs in their natural habitats warrants genetic variations and evolutionary processes, but seed conservation in national and local level gene banks and

seed banks are also very successful approaches in Nepal. However, different methods of conservation plant breeding need to be implemented extensively in different agro- and eco- climatic zones of the country. In this context, there is an increasing need of collaboration and co-operations among plant breeders, ecologist, botanist and population geneticists for the long term conservation and sustainable utilization of WRs and indigenous landraces of vegetables.

Along with the inventory and collection of WRs, their adaptive ability to different biotic and abiotic stresses including enhanced productivity is necessary to be evaluated and documented. Advanced biotechnological tools available thus far are largely useful and effective to exploit wild germplasm for incorporating desired traits in cultivated vegetables. The local, provincial and central governments should implement national conservation actions devised by NAGRC with high priority. Such programmes entail international supports and cooperation to assure long term survival of indigenous landraces and wild germplasm of Nepal which eventually will strengthen and enhance our capacity to tackle increasing challenge of food security and malnutrition prevalent in the national, regional and global scale.

**Abbreviations:** CWRs = Crop Wild Relatives; FAO = Food and Agriculture Organization; IUCN = International Union for Conservation of Nature; NAGRC = National Agriculture Genetic Resource Centre; PWV = Primary Wild Vegetables; VWRs = Vegetable Wild Relatives; WRs = Wild Relatives.

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## Author's Biography



Dr. Ram Chandra Poudel is a Senior Scientific Officer at Nepal Academy of Science and Technology. Plants and more recently animals naturally distributed along the Himalayan region have been focus of his research. His landmark work is the Conservation Genetics of the three species of Yews distributed along Hindu Kush Himalaya Region. He has published more than two dozens articles in the peer reviewed international journals. Trained in molecular phylogeny, his diverse research areas include DNA barcoding, conservation genetics and Himalayan biogeography. He has received Third World Academy Award.



Dr. Bal Krishna Joshi, a Senior Scientist in Nepal Agricultural Research Council, did Ph.D. in plant breeding and genetics, with minor in statistics. Dr. Joshi is focusing on conservation and sustainable utilization of Nepalese agrobiodiversity through 80 different methods/approaches/good practices. He has applied/developed many new concepts for the management of agrobiodiversity. He is serving as an Editor-in-Chief of Journal of Nepal Agricultural Research Council since 2018. He has also involved on teaching plant breeding, genetics, biotechnology and statistics in different universities. He has published more than 300 articles and edited 20 books and proceedings. Dr. Joshi had received 12 different awards including National Technology Award, and Science and Technology Youth Award (Email: joshibalak@yahoo.com).

# Chapter 4

## Roles of Vegetables in Improving Nutrition

**Atul Upadhyay[1]* and Nirat Katuwal[2]**
[1]*Nutrition and Dietitian Association of Nepal, Baliyo Nepal Nutrition Initiative, Nepal*
[2]*Food Technology and Quality Control Office, Biratnagar, Nepal*
*Email: atul616@yahoo.com

*Vegetables have very important role in human nutrition. Dietary guidelines, from around the world, recommend consumption of variety of vegetables every day in sufficient quantities to maintain healthy life. It is an important component of a balanced diet. Apart from providing nutrients such as carbohydrates, vitamins and minerals, vegetables have role in protection from chronic diseases. In this chapter, role of vegetables in human nutrition, phytonutrients in vegetables and role in disease prevention have been discussed briefly.*

**Keywords:** Disease prevention; nutrition; phytochemicals; vegetables.

## Introduction

Vegetables are edible horticultural crops with certain portions of it consumed with staples as main course or as supplementary food in raw or cooked form (Hui, 2006; Ülger et al., 2018). Diets high in vegetables are widely recommended for their health-promoting properties. They have been included in dietary guidance because of their high contents of vitamins, especially vitamins C and pro-vitamin A, minerals, especially electrolytes and phytochemicals, and antioxidants. Moreover, fruits and vegetables are recommended as a source of dietary fibre (Slavin & Lloyd, 2012).

Dietary guidelines across the world recommends consumption of vegetables (Slavin & Lloyd, 2012). Government of Nepal (GoN) has released a *National Food-based Dietary Guidelines* which emphasizes consumption of plenty of vegetables and fruits, especially green leafy vegetables (GoN, 2015). Although the overall consumption of vegetables (215 g/day/moderate working person) meets the recommended dietary allowance (RDA), which is 200 g/day/moderate working person; the consumption of green leafy vegetables is concerning, as half of the vegetables consumed should be from the green leafy vegetables (GoN, 2015). The World Health Organizations of the United Nations (WHO) has recommended to always include vegetables in meals and having at least 400 g of fruits and vegetables to reduce the risk of non-communicable diseases and

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to ensure adequate daily intake of dietary fibre (WHO, 2003). A comparison of dietary guidelines regarding vegetables for few countries is shown in Table 4.1.

**Table 4.1.** Comparison of dietary guidelines of some countries

| Country | Name of guideline | Key messages |
|---|---|---|
| Canada | Canada's Food Guide | 1. Eat at least one dark green and one orange vegetable each day.<br>2. Enjoy vegetables and fruit prepared with little or no added fat, sugar, or salt.<br>3. Have vegetables and fruit more often than juice |
| United Kingdom | Eat Well Plate | Try to eat plenty of fruits and vegetables |
| USA | My plate | 1. Increase vegetables and fruit intake<br>2. Eat a variety of vegetables, especially dark-green vegetables and beans and peas |
| Nepal | National Food-Based Dietary Guidelines | Eat plenty of fruits and vegetables everyday |

Adapted from: (Slavin & Lloyd, 2012)

## Classification of Vegetables

Several species of plants are being consumed as vegetables. These species of vegetables can be classified into different groups based on composition of nutrients present. Nutritionally, it is important to incorporate vegetables from all the groups to sufficiently fulfill the daily requirements of nutrients. The major groups of vegetable with nutritional significance include coloured vegetables (dark green, red or orange), beans and peas, starchy, and others. These vegetables provide an array of micronutrients such as vitamins, minerals, and fibre.

***Dark green vegetables:*** This group includes broccoli, spinach, romaine, collard greens, mustard greens, etc. They are great sources of β-carotene (precursor of vitamin A), as well as vitamin C, folate, calcium, magnesium and potassium. They are also an important source of dietary fibre (Duyff, 2006).

***Red and orange vegetables:*** Deep-orange vegetables, such as sweet potatoes and carrots, supply β-carotene. Others, such as brussels sprouts, bell pepper and tomato, have more vitamin C. Many are rich in folate (Duyff, 2006).

***Beans and peas:*** Examples under this group include kidney beans, black beans, chickpeas, split peas, lentils, etc. They provide protein, as well as thiamin, folate, iron, magnesium, phosphorus, zinc, potassium and fibre (Duyff, 2006).

***Starchy vegetables:*** Potatoes, corn, green peas, etc. are examples of this group. Besides their complex carbohydrates, starchy vegetables supply niacin, vitamin B6, zinc, potassium, etc. (Duyff, 2006).

***Other vegetables:*** This group includes vegetables such as mushroom, summer squash, iceberg lettuce, etc. They are good source of protein and minerals such as potassium and phosphorus.

## Phytochemicals in Vegetables

Perhaps, one of the most significance benefits of vegetable consumption are due to the presence of large amount of phytochemicals besides the nutrients. Phytochemicals are

non-nutritive components in the plant-based diet and have been linked to reductions in the risk of major chronic diseases (Liu, 2003; Surh, 2003). Various types of health promoting phytochemicals have been described in vegetables (Alarcón-Flores et al., 2013; De la Rosa et al., 2010; Watson, 2000). Major phytochemicals present in vegetables include polyphenols, sterols, terpenoids, carotenoids, chlorophylls and organo-sulphur compounds.

## *Polyphenols*

Polyphenols are the most abundant antioxidants in human diets. They are secondary metabolites of plants. These compounds are designed with an aromatic ring carrying one or more hydroxyl moieties. There are several classes of polyphenols which include flavonoids and non-flavonoids. Flavonoids group includes flavanones, flavones, dihydroflavonols, flavonols, flavan-3-ols, anthocyanidins, isoflavones and proanthocyanidins. The non-flavonoids group include simple phenols, benzoic acids, hydrolyzable tannins, acetophenones and phenylacetic acids, cinnamic acids, coumarins, benzophenones, xanthones, stilbenes, chalcones, lignans, and secoiridoids (De la Rosa et al., 2010). Some structures of polyphenolic compounds are shown in Figure 4.1.

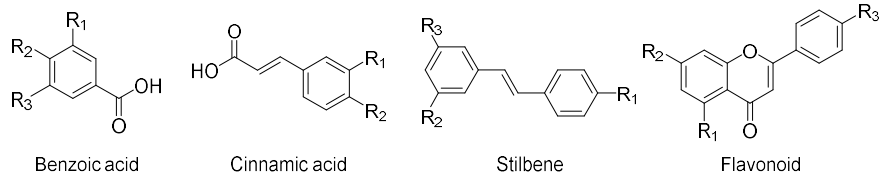



**Figure 4.1.** Major polyphenol classes and their structures (R = OH, H, etc.).

In food, polyphenols may contribute to the bitterness, astringency, colour, flavour, odour and oxidative stability. Epidemiological studies strongly suggested that long term consumption of diets, rich in plant polyphenols, offered some protection against development of cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases (Arts & Hollman, 2005; Graf et al., 2005). Moreover, polyphenols are reported to have antioxidative property (Pandey & Rizvi, 2009; Upadhyay et al., 2013; Vitaglione et al., 2004). Along with fruits, vegetables also contribute to dietary sources of polyphenols (Scalbert & Williamson, 2000). Table 4.2 shows sources of some major polyphenols.

**Table 4.2.** Sources of some polyphenols

| Sub-class of polyphenol | Name of polyphenol | Sources |
|---|---|---|
| Flavonols | Quercetin | Onions, asparagus, lettuce |
| | Kaempferol | Kale, spinach |
| | Myricetin | Red cabbage |
| | Isorhamnetin | Onion |
| Flavones | Apigenin | Artichokes, celery, red onion, lettuce |
| | Luteolin | Pepper, artichokes |
| Flavonones | Naringenin | Artichokes (raw), ripe tomatoes (raw) |
| Isoflavones | Genistein, daidzein, glycitein | Soya bean, Tofu |
| Anthocyanindins | Cyanidin | Red cabbage |
| | Pelargonidin | Radish |

Source: (De la Rosa et al., 2010)

## *Carotenoids*

Carotenoid pigments are responsible for most of the yellow and orange colours of fruits and vegetables. Chemically, carotenoids are classified as terpenoids (Coultate, 2009). Many carotenoids have the ability to quench singlet oxygen and thus function as antioxidants. Moreover, some carotenoids also serve as precursor of vitamin A (Watson, 2000). Ziegler et al., 1986 reported that increased consumption of β-carotene enriched foods and higher levels of β-carotene in blood is associated with reduced risk of lung cancer. Perera and Yen (2007) reviewed functional properties of carotenoids in human health. This review suggested that lycopene (carotenoid from tomato) and other carotenoid-rich vegetables and fruits reduce the incidence of several diseases such as cancers, cardiovascular diseases, agerelated macular degeneration, cataracts, diseases related to low immune function and otherdegenerative diseases.

## *Chlorophylls*

The chlorophylls are green pigments responsible for the colour of leafy vegetables and some fruits. The chlorophylls are tetrapyrrole pigments in which the porphyrin ring is in the dihydro form and the central metal atom is magnesium. There are two chlorophylls, a and b, which occur together in a ratio of about 1:25. Due to different processing or conditions, chlorophyll gets converted into several derivatives (DeMan et al., 2018). Ferruzzi and Blakeslee (2007) described anticancer activity of chlorophyll and its derivatives along with antioxidant and antimutagenic activities; and mutagen trapping, xenobiotic metabolism modulation and apoptosis inducing properties.

## *Organosulphur Compounds from Allium Vegetables*

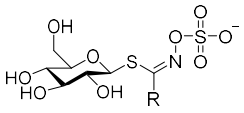
Role of organosulphur compounds on cardiovascular disease have been reviewed by Vazquez-Prieto and Miatello (2010). This review suggests that the consumption of organosulphur compounds is beneficial in prevention of cardiovascular diseases. Moreover, organosulphides have the ability to prevent reactive oxygen species (ROS) production, increase antioxidant status, prevent vascular inflammation, reduce lipid content and inhibit platelet aggregation. Organosulphur compounds are found in *Allium* vegetables such as garlic and onion. These compounds have been attributed to health promoting properties of *Allium* vegetables (Bianchini & Vainio, 2001; Vazquez-Prieto & Miatello, 2010).

## *Glucosinolates from Brassicaceae*

The glucosinolates are sulphur-containing glucosides prevalent in vegetables of Brassicaceae family (Rodriguez et al., 2015; Verkerk et al., 2009). These molecules are made up of a β-thioglucose moiety, sulphonated oxime moiety and a variable side chain derived from methionine, tryptophan, phenylalanine or branched chain amino acids (Rodriguez et al., 2015; Traka, 2016). Based on amino acids from which they are derived, the glucosinolates are generally classed into following three groups: (i) aliphatic glucosinolates derived from methionine, (ii) aromatic glucosinolates derived from phenylalanine, and (iii) indolyl glucosinolates derived from tryptophan (Traka, 2016).

Glucosinolates themselves are biologically inactive but when the plant tissue is damaged, such as in food preparation, they are hydrolysed by plant enzyme (myrosinase) to yield biologically active isothiocyantes, nitriles and thiocyanates (Rodriguez et al., 2015; Traka, 2016). Side chain structures for some glucosinolates/isothiocyantes are shown in Table 4.3.

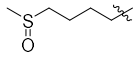
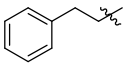
**Table 4.3.** Side chains of some glucosinolates/isothiocyanates




Glucosinolates




Isothiocyantes

| Side chain (R) | Common name of glucosinolates/isothiocyanates | Vegetables |
|---|---|---|
|  4-Methlsulphinylbutyl- | Glucoraphanin/sulforaphane | Broccoli |
|  4-Methylthiobutyl- | Glucoerucin/erucin | Rockets |
|  2-Propenyl- | Sinigrin/allyl-isothiocyanate | Mustards, cabbages, some brussels sprouts |
|  Benzyl- | Glucotropaeolin/benzyl-isothiocyanate | Lepidium cress |
|  Phenylethyl- | Gluconasturtiin/phenylethylisothiocyanate | Water cress, radish, turnip |

Review by Rodriguez et al., 2015 suggests that isothiocyanates have anticancer property, in that, they can modulate detoxifying enzymes of phase I and II of cancer development, induce phase II enzymes by functioning as antioxidant, and modulate cell signaling, inducing apoptosis. Moreover, they can also reduce *Helicobacter* infections. Their review also suggested that glucosinolates/isothiocyanates has antinutritional and toxic effects, most importantly goitrogenic effects in higher animals. However, the epidemiological evidence of this goitrogenic effect resulting in disease in human is unavailable or very scarce.

## *Cucurbitacins*

Cucurbitacins are a group of triterpenoid compounds characterized well by their bitterness. They found in many Cucurbitaceae species (Yasuda et al., 2010) such as cucumber, gourd, loofah, etc. Structurally, they are characterized by the tetracyclic cucurbitane nucleus skeleton, namely, 19-(10→9β)-abeo-10α-lanost-5-ene (also known as 9β-methyl-19-norlanosta-5-ene), with a variety of oxygen substitutions at different positions (Chen et al., 2005). Basic structure of cucurbitane and structure of common categories of cucurbitacins is shown in Figure 4.2

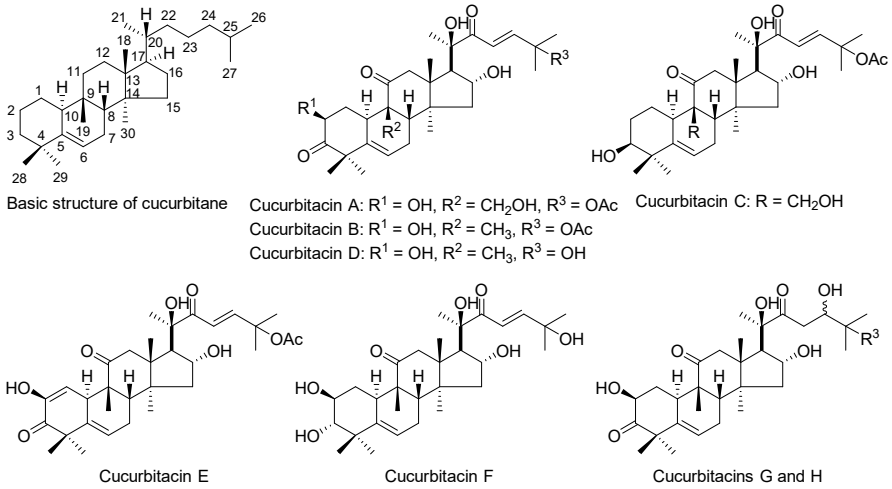



**Figure 4.2.** Basic structure of cucurbitane and cucurbitacins.

Medicinal properties of cucurbitacins have been reviewed by Kaushik et al., 2015. The review suggests that cucurbitacins are reported to inhibit mediators of inflammation such as Tumor necrosis factor (TNF)-α, nitric-oxidase synthase-2 and cyclooxygenase-2. Moreover, they have anti-tumour activity, anti-artherosclerotic activity, hepatoprotective and antidiabetic effects, etc.

## Roles of Vegetables in Intestinal Immunity

Veldhoen and Brucklacher-Waldert (2012) reviewed influence of diet in intestinal immunity. Their work highlighted the epidemiological studies which suggested rapid incidence of inflammatory disorders associated with consumption of higher amounts of processed foods and low contents of vegetables and fruits. Moreover, the work suggested that there is shared molecular pathways between nutrients- and pathogen-sensing systems that provide a potential molecular link between diet and disease. Targets at the intersection of metabolic and inflammatory responses are ligand-activated nuclear receptors and G protein-coupled receptors. Vitamins A and D (both acting through nuclear receptors) alter lymphocyte migration and activation, thereby contributing to intestinal immune homeostasis, which is characterized by a state of tolerance towards innocuous antigens. Furthermore, plants of the *Brassica* genus, which includes cruciferous vegetables, such as green cabbage and broccoli, contain ligands for the nuclear receptor aryl hydrocarbon receptor (AHR). AHR activity is required for the maintenance of intraepithelial lymphocytes and the proliferative capacity of postnatally developed ROR$\gamma t^{+}$ innate lymphoid cells in the intestine. Thus a consumption of vegetables has a role in immune homeostasis and preventing abnormal immunity and pathology.

## Vegetables in Disease Prevention

Ülger et al., 2018 summarized roles of vegetables in diseases prevention. This work reviewed that vegetables are protective against cardiovascular disease due to their low contents of

saturated fat, trans fat and cholesterol, and higher contents of bioactive compounds such as flavonoids, phytoestrogens (lignans, coumestran, isoflavones, resveratrol, and lycopene), organosulphur compounds, soluble dietary fibres (β-glucan, pectin and psyllium), isothiocyanates, monoterpenes and sterols (sitostanol, stigmasterol and campesterol). Moreover, phytochemicals from these vegetables are reported protective against cancers.

In addition to bioactive phytochemicals, vegetables are a good source of dietary fibres. Dietary fibres are components in food that are not digestible by human digestive enzymes. Studies has suggested that dietary fibre has role in preventing diseases such as cardiovascular diseases, type 2 diabetes, colorectal cancer, breast cancer, stomach cancer, kidney cancer esophageal cancer and other cancer (Park, 2016). An overview of roles of nutrients from vegetables on health promotion or disease prevention and their underlying mechanisms is presented in Table 4.4.

**Table 4.4.** Effects of nutrients from vegetables on health promotion/disease prevention and their putative underlying mechanisms

| S. N. | Nutrients/components of vegetables | Effects on health/disease prevention | Mechanism |
|---|---|---|---|
| 1 | K, Mg, vitamin C | Preservation of bone mass | Sufficient supply of nutrients |
| 2 | Folate | Prevention of hyperhomocysteinemia and low hemoglobin concentration | |
| 3 | Other micronutrients | Improved nutritional status | |
| 4 | Antioxidant phytochemicals | Protection from oxidative stress and damage | Scavenging of free radicals |
| | | Detoxification of carcinogens, inhibition of procarcinogen activation | Regulation of xenometabolic enzymes (phase 1 and phase 2) |
| | | Activation of antistress defense mechanisms | Hormetic stimulation of antioxidant enzymes and antistress genes |
| | | Preservation of bone mass | Stimulation of bone anabolism |
| 5 | Dietary fibre | Prevention of constipation | Incresing bowel function |
| | | Prevention of inflammatory bowel disease | Improvement of gut flora |
| | | Promotion of endothelial function | Fermentation to short-chain fatty acids |
| | | Better nutrient absorption | |
| | | Anti-inflammatory effects | |
| | | Prevention of hypercholesterolemia | Binding of cholesterol and bile acids |
| | | Improved glucose tolerance | Delayed carbohydrates absorption |
| 6 | Water | Prevention of dehydration | Contribution to fluid/water intake |

Adapted from: (Elmadfa & Meyer, 2016)

## Vegetables in Ayurveda

Ayurveda describes diet (*Ahara*) as the best preventive medicine and mentioned its role for the prevention and management of many diseases. *Shakavarga*, a category under Ayurvedic diet, enlisted different vegetables with their properties and indications in different disease conditions (Naik et al., 2015a). For example, garlic (*Allium sativum*) has been described in Ayurvedic management and treatment of dermatological diseases (Naik et al., 2016a), gastrointestinal tract diseases (Naik et al., 2016b), diabetes mellitus (Naik et al., 2015a) and cardiovascular diseases (Naik et al., 2015b).

## Effects of Preparing and Cooking Vegetable on Nutrients

Preparation of vegetables includes operations such as washing, peeling, cutting, soaking, etc. These operations expose vegetables to water, light, air and other conditions which can affect composition of nutrients in vegetables. Washing with water can reduce water soluble nutrients such as vitamin C and some phytochemicals. Similarly cutting can expose vegetable tissues to air causing oxidation of phytochemicals such as polyphenolic compounds and other pigments (DeMan et al., 2018). Loss of water soluble minerals could occur during preparation in an operation such as soaking (Ülger et al., 2018). Similarly, vegetables are heated during cooking to impart desirable texture, increase digestibility and palatability. However, cooking results in reduction of nutrients such as vitamins and phytonutrients to significant level (DeMan et al., 2018). Thus the knowledge of effects of preparing and cooking vegetables on nutrient profile is necessary to consume optimal levels of nutrients from vegetables.

## COVID-19 Infection and Roles of Vegetables

The outbreak of novel corona virus disease (COVID-19) is a leading global health challenge and it is very essential for an individual to maintain good nutritional status through optimal diet and nutrition intake. The appropriate nutrition will have a significant impact on the immune system. Researchers have recommended to take fresh vegetables (green bell peppers, garlic, ginger, kale, lime, coriander, broccoli, green chili pepper, etc.) along with other important nutrients (Aman & Masood, 2020). The WHO recommends consuming a minimum of 400 g of fruits and vegetables per day including both root and other vegetables (WHO, 2020). The Ministry of Health and Populations (MoHP) released *Nutrition Guidelines for COVID-19 Infected Patients* which also highlights the importance of vegetable consumption (MoHP, 2020). A recent molecular docking study have also shown that vegetables such as onion, garlic, etc. might be used as precautionary home remedy against COVID-19 (Sen et al., 2020). All these recommendation and studies have clearly highlighted the importance of vegetable consumption during the ongoing COVID-19 pandemic.

## Conclusion

Vegetables play a wide role in improving nutritional status as well as in preventing diseases. Nutrients in vegetables, such as dietary fibres, vitamins, minerals and phytochemicals, play major roles in preventing diseases. In Nepal, although the consumption of vegetable is significant, the consumption of green leafy vegetables has been of concerned. The National Food Based Dietary Guidelines, National Nutrition Guidelines, WHO recommendations, etc. emphasizes the importance of consumption of vegetables, particularly, green leafy vegetables, not only to maintain the nutritional status, but also during the COVID-19 outbreak. It is therefore essential to include vegetables in all meals to improve the nutritional status of people.

**Abbreviations:** GoN = Government of Nepal; MoHP = Ministry of Health and Populations; WHO = World Health Organizations of the United Nations.

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# Author's Biography



Dr. Atul Upadhyay holds PhD degree in Agriculture Science from Kagosima University, Japan. He was involved in post-doctoral research in Natural Product Chemistry & Pharamcognosy from University of Antwerp, Belgium. He has more than 30 peer reviewed publicaitons and several book chapters, mainly in the field of food and nutrition science, and natural product chemistry and pharmacognosy. Currently, Dr. Upadhyay is President of Nutritionist and Dietitian Association of Nepal (NUDAN) and CEO of Baliyo Nepal Nutrition Initiative (BNNI). He served as a Food Research Officer at Department of Food Technology and Quality Control (DFTQC) under Ministry of Agriculture and Livestock Development (MOALD) of Government of Nepal for nearly a decade. He is also a member of National Codex Committee of Government of Nepal. He is continually working for improving the quality of life through understanding and implementation of food and nutritional sciences.



Mr. Nirat Katuwal completed his B. Tech and M. Tech degrees in Food Technology from Tribhuvan University, Nepal. Currently, he is a Food Research Officer at Department of Food Technology and Quality Control (DFTQC) under Ministry of Agriculture and Livestock Development (MOALD) of the Government of Nepal. In the current role, he is involved in analysis of food samples, providing food safety, nutrition and processing trainings, providing consultation services to solve the problems of small scale food industries and conducting research works. He is also involved in teaching food processing, food chemistry and related subjects to undergraduate students. He has co-authored several research articles in the area of food science.

# Chapter 5

## Nutritional Importance of Nepalese Vegetables

**Purna Chandra Wasti**
*Department of Food Technology and Quality Control*
*Babarmahal, Kathmandu, Nepal*
Email: pcwasti@gmail.com

*Nutritional values of vegetables consumed in Nepal are reviewed in this chapter. Vegetables were found to contain low fat, low calorie, significant amount of protein and a very high amount of mineral content. The leafy vegetables were found to contain mineral content up to 4.2 g/100 g in stinging nettle leaves (sisnu) and camel's foot tree leaves (tanki), fiber up to 5.5 g/100 g in camel's foot tree flowers (koiralo), calcium content up to 981 mg/100 g (in stinging nettle leaves), phosphorus upto 530 mg/100 g (in carrot), β-carotene content up to 12,000 mg/100 g (in coloccasia leaves, dark variety) and vitamin C up to 315.69 mg/100 g (in spiny gourd). Vegetables are considered ideal foods for all age groups due to high in micronutrients (vitamins and minerals), fiber and phytochemicals, and low in calorie. Vegetables are also very good source of antioxidants, which make them ideal food for fighting against cardiovascular diseases, diabetes, cancer and metabolic syndroms. The adult population, who are very prone to lifestyle related diseases, get benefit from the vegetables. Vegetables could be a very good source of fighting micronutrient malnutrition such as iron deficiency anemia, vitamin A deficiency and calcium deficiency. In Nepal, production and consumption of vegetables have increased significantly in the recent years. However, consumption varies among different population groups. It is recommended that the nutritional importance of vegetables need to be highlighted and the consumption of vegetables need to be promoted in the days to come for fighting micronutrient deficiency and lifestyle related chronic diseases.*

**Keywords:** Green leafy vegetables; lifestyle related diseases; micronutrient deficiency; micronutrients; vegetables.

## Introduction

Vegetables play an important role in our diet. They also provide essential micronutrients for the regular functioning of human body. They are rich in not only vitamins and minerals but also phytochemicals and dietary fiber. Chronic diseases such as diabetes,

*Comprehensive Insights in Vegetables of Nepal*
Sajan Lal Shyaula, Gan B. Bajracharya, Gopal K.C., Shanta Man Shakya and Dilip Subba (Editors)
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cancers, obesity, metabolic syndrome, cardiovascular diseases, etc. can be prevented by adequate consumption of vegetables (Ülger et al., 2018).

Consumption of vegetables and fruits is associated with the lower risk of cardiovascular dieaseases, obesity and other diseaseas (Boeing et al., 2012). Studies show that vegetables are good sources of phytochemicals which are beneficial for fighting against cardiovascular diseases, cancers and obesity. Several studies have shown the antioxidant properties of vegetables. In one study, the common vegetables were studied for their antioxidant and anti-proliferative activities (Chu et al., 2002). The study revealed that red pepper had the highest antioxidant properties followed by broccoli, carrot, spinach, cabbage, yellow onion, celery, potato, lettuce and cucumber. In the same study, spinach was found to have the highest inhibitory effect followed by cabbage, red pepper, onion and broccoli.

Vegetable consumption in Nepal has increased significantly in the last fifteen years. Average per capita consumption of vegetables has doubled in the last fifteen years. The global consumption of vegetables in the year 2002 was 68 kg/capita/year and it has almost doubled to 128 kg/capita/year in the year 2017 (Ritchie & Roser 2020). While we compare the recommended daily consumption of vegetables, Nepal has an average consumption of 350 g/capita/day is higher than the recommended quantity of 250 g/capita/day. Similarly, an analysis based on the Nepal Living Standard Surveys reveals that the vegetable consumption has increased by about 200 percent in the period of 1995/96–2003/04 and by more than 300 percent between the period of 1995/96 and 2010/11 (CBS 2013). However, there is a difference of consumption by geography and wealth status of the population. The population in the rural areas tend to consume less vegetables than the population in the urban areas, whereas the poor households have less consumption of vegetables than the richer households (CBS 2018).

## Nutritional Composition of Vegetables

Food composition table was first published in Nepal, in the year 1988, as nutrient contents of Nepalese foods. It was updated with the addition of some food items in 2012. *Nepalese Food Composition Table 2017* is the latest version of food composition table in Nepal (DFTQC 2017). This includes the nutrient composition of local food items from the Karnali region of Nepal.

## 1. Proximate Composition of Green Leafy Vegetables

As given in Table 5.1, in general, vegetables are low in fat, carbohydrate, protein and calorie but high in crude fiber and mineral content (DFTQC 2017). In green leafy vegetables, protein is found in the range of 1.15–6.9 g/100g, fat is found in the range of 0.1–1 g/100 g, carbohydrate is found in the range of 1.5–44.2 g/100 g, minerals are found in the range of 0.6–4.2 g/100 g, fiber is found in the range of 0.5–3 g/100 g, and the energy content is found in the range of 11–192 Kcal/100 g of the fresh vegetables.

**Table 5.1.** Proximate composition of green leafy vegetables (per 100 g)

| S.N. | Name | Protein (g) | Fat (g) | Carbohydrate (g) | Mineral (g) | Fiber (g) | Energy (Kcal) |
|---|---|---|---|---|---|---|---|
| 1 | Amaranth (tender) | 4 | 0.5 | 6.1 | 2.7 | 1 | 45 |
| 2 | Amaranth (spined) | 3 | 0.3 | 7 | 3.6 | 1.1 | 43 |
| 3 | Asparagus | 3.3 | 0.1 | 2.7 | 0.6 | 0.8 | 25 |
| 4 | Buckwheat leaf | 3.9 | 0.1 | 3.8 | 1.86 | 0.87 | 31 |
| 5 | Cabbage green | 1.8 | 0.1 | 4.6 | 0.6 | 1 | 27 |
| 6 | Cabbage purple | 1.9 | 0.2 | 3.5 | 0.6 | 2.2 | 11 |
| 7 | Camel's foot tree flower (*Koiralo*) | 3.6 | 1 | 9.7 | 2.1 | 5.5 | 62 |
| 8 | Camel's foot tree leaves (*Tanki* ) | 1.3 | 0.8 | 44.2 | 4.2 | 3.7 | 190 |
| 9 | Cauliflower green | 5.9 | 1.3 | 7.6 | 3.2 | 2 | 66 |
| 10 | Chayote leaf | 3.01 | 0.21 | 3.2 | 1.19 | 1.01 | 27 |
| 11 | Colocasia leaf (green) | 3.9 | 1.5 | 6.8 | 2.2 | 2.9 | 56 |
| 12 | Colocasia leaf (black) | 6.8 | 2 | 8.1 | 2.5 | 1.8 | 77 |
| 13 | Coriander leaf | 3.3 | 0.6 | 6.3 | 2.3 | 1.2 | 44 |
| 14 | Drumstick leaf | 6.7 | 1.7 | 12.5 | 2.3 | 0.9 | 92 |
| 15 | Fenugreek leaf | 4.4 | 0.9 | 6 | 1.5 | 1.1 | 49 |
| 16 | Fiddlehead (*Niguro*) | 1.15 | 0.15 | 3.4 | – | 0.99 | 19 |
| 17 | Garden cress | 5.8 | 1 | 8.7 | 2.2 | – | 67 |
| 18 | *Jaluko* (*Botrychium lanuginosum)* | 2.4 | 0.43 | 5.5 | 1.66 | 3.0 | 35 |
| 19 | Khesari leaf | 6.1 | 1 | 5.5 | 1.1 | 2.1 | 55 |
| 20 | Lamb's quarter (*Bethe* ) | 3.7 | 0.4 | 2.9 | 2.6 | 0.8 | 30 |
| 21 | Lettuce | 2.1 | 0.3 | 2.5 | 1.2 | 0.5 | 21 |
| 22 | Mustard leaf | 4 | 0.6 | 3.2 | 1.6 | 0.8 | 34 |
| 23 | Pumpkin leaf | 4.6 | 0.8 | 6.9 | 3.7 | 2.1 | 53 |
| 24 | Radish leaf | 3.8 | 0.4 | 2.4 | 1.6 | 1 | 28 |
| 25 | Rape leaf | 5.1 | 0.4 | 5.9 | 2.5 | 1.2 | 48 |
| 26 | Spinach | 2 | 0.7 | 2.9 | 1.7 | 0.6 | 26 |
| 27 | Stinging nettle leaf | 6.9 | 0.2 | 5 | 4.2 | 1.8 | 53 |
| 28 | Thai spinach | 2.3 | 0.3 | 6.1 | 1.4 | 0.8 | 36 |
| 29 | Water cress (*Sim saag*) | 2.4 | 0.44 | 1.5 | 1.23 | 0.67 | 20 |

## 2. Proximate Composition of Other Vegetables

As given in the Table 5.2, in vegetables other than green leafy vegetables, protein is found in the range of 0.2–14.9 g/100 g, fat is found in the range of 0.1–3.4 g/100 g, carbohydrate is found in the range of 1.9–22.7 g/100 g, minerals are found in the range of 0.3–2 g/100 g, fiber is found in the range of 0.4 to 9.6 g/100 g, and the energy content is found in the range of 10–107 Kcal/100 g (DFTQC 2017).

**Table 5.2.** Proximate composition of other vegetables (per 100 g)

| S.N. | Name | Protein (g) | Fat (g) | Carbohydrate (g) | Mineral (g) | Fiber (g) | Energy (Kcal) |
|---|---|---|---|---|---|---|---|
| 1 | Ash gourd | 0.4 | 0.1 | 1.9 | 0.3 | 0.8 | 10 |
| 2 | Balsam apple (*Barela*) | 0.99 | 0.26 | 6.7 | 0.81 | 0.79 | 33 |
| 3 | Bamboo (young shoot) | 3.9 | 0.5 | 5.7 | 1.1 | – | 43 |
| 4 | Bitter gourd | 1.6 | 0.2 | 4.2 | 0.8 | 0.8 | 25 |
| 5 | Bottle gourd | 0.2 | 0.1 | 2.5 | 0.5 | 0.6 | 12 |
| 6 | Brinjal | 1.4 | 0.3 | 4 | 0.3 | 1.3 | 24 |
| 7 | Broad beans | 4.5 | 0.1 | 7.2 | 0.8 | 2 | 48 |
| 8 | Broccoli | 4.99 | 0.2 | 7.1 | 1.12 | 0.94 | 50 |
| 9 | Button mushroom | 4.6 | 0.8 | 4.3 | 1.4 | 0.4 | 43 |
| 10 | Capsicum | 0.9 | 0.11 | 2.5 | 0.52 | 0.7 | 13 |
| 11 | Carrot | 0.9 | 0.2 | 10.6 | 1.1 | 1.2 | 47.8 |
| 12 | Cauliflower | 2.6 | – | 4 | 1 | 1.2 | 30 |
| 13 | Chayote | 0.7 | 0.1 | 5.7 | 0.4 | 0.6 | 27 |
| 14 | Cluster beans | 3.2 | 0.4 | 10.8 | 1.4 | 3.2 | 59.6 |
| 15 | Colocasia stem | 0.3 | 0.3 | 3.6 | 1.2 | 0.6 | 18 |
| 16 | Cowpea pods | 3.5 | 0.2 | 8.1 | 0.9 | 2 | 48 |
| 17 | Cucumber | 0.4 | 0.1 | 2.5 | 0.3 | 0.4 | 13 |
| 18 | Double bean | 8.3 | 0.3 | 12.3 | 1 | 4.3 | 85 |
| 19 | Drumstick | 2.5 | 0.1 | 3.7 | 2 | 4.8 | 26 |
| 20 | Field bean | 3.8 | 0.7 | 6.7 | 0.9 | 1.8 | 48 |
| 21 | French bean (tender) | 1.7 | 0.1 | 4.5 | 0.5 | 1.8 | 26 |
| 22 | Jackfruit (young fruit) | 2.6 | 0.3 | 9.4 | 0.9 | 2.8 | 51 |
| 23 | Ladies finger | 1.9 | 0.2 | 6.4 | 0.7 | 1.2 | 35 |
| 24 | Onion | 1.2 | 0.1 | 10.4 | 0.4 | 1.3 | 47 |
| 25 | Oyster mushroom | 3 | 0.2 | 5.8 | 1.3 | 0.9 | 37 |
| 26 | Peas | 7.2 | 0.1 | 15.9 | 0.8 | 4 | 93 |
| 27 | Pink beans | 3.1 | 0.4 | 7 | 0.6 | 2.1 | 44 |
| 28 | Pointed gourd | 2 | 0.3 | 2.2 | 0.5 | 3 | 20 |
| 29 | Pumpkin | 1.4 | 0.1 | 4.6 | 0.6 | 0.7 | 25 |
| 30 | Raddish | 0.7 | 0.1 | 22.7 | 0.6 | 9.6 | 101 |
| 31 | Red beans | 3.1 | 0.1 | 5.2 | 0.6 | 2.5 | 34 |
| 32 | Red cowpea | 3.1 | 0.1 | 5.2 | 0.6 | 2.5 | 34 |
| 33 | Red gram (tender) | 9.8 | 1 | 16.9 | 1 | 6.2 | 116 |
| 34 | Snake gourd | 0.5 | 0.3 | 3.3 | 0.5 | 0.8 | 18 |
| 35 | Soybean (tender) | 14.9 | 2.9 | 15.1 | 2.1 | 3.7 | 146 |
| 36 | Spiny gourd(*Chattel*) | 2.04 | 0.18 | 6.1 | 0.78 | 1.2 | 34 |
| 37 | Sponge gourd | 1.03 | 0.11 | 5 | 0.35 | 0.39 | 26.4 |
| 38 | Spotted beans | 3.34 | 0.75 | 21.8 | 1.24 | 2.12 | 107 |
| 39 | Sword beans | 2.7 | 0.2 | 7.8 | 0.6 | 1.5 | 44 |
| 40 | Tomato | 1.3 | 0.1 | 3.9 | 0.7 | 0.5 | 21 |
| 41 | Tree tomato | 1.5 | 0.2 | 6.7 | 1.2 | 4.2 | 35 |
| 42 | Winged bean (tender) | 2.66 | 3.4 | 7.9 | 0.76 | 1.79 | 45.1 |

## 3. Vitamin and Mineral Composition of Green Leafy Vegetables

As given in Table 5.3, in green leafy vegetables, calcium is found in the range of 22.7–981 mg/100 g, phosphorus is found in the range of 0.1–1 g/100 g, iron is found in the range of 0.8–6.1 mg /100 g, carotene content is in the range of 120–12,000 µg/100 g, vitamin C is in the range of 5.5–220 µg/100 g, thiamin is in the range of 0–0.22 mg/100 g, riboflavin is in the range of 0–0.26 mg/100 g and niacin is in the range of 0.5–1.9 mg/100 g (DFTQC 2017).

**Table 5.3.** Vitamin and mineral composition of green leafy vegetables (per 100 g)

| S.N. | Name | Ca (mg) | P (mg) | Fe (mg) | Carotene (µg) | Vit. C (mg) | Thiamin (mg) | Riboflavin (mg) | Niacin (mg) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Amaranth (tender) | 397 | 83 | 3.5 | 5,520 | 99 | 0.03 | 0.3 | 1.2 |
| 2 | Amaranth (spined) | 800 | 50 | 2.9 | 3,504 | 33 | 0 | – | – |
| 3 | Asparagus | 30.6 | 45.5 | 1.3 | – | 12.8 | – | – | – |
| 4 | Buckwheat leaf | – | – | – | 1,846.6 | 81.8 | – | – | – |
| 5 | Cabbage green | 39 | 44 | 0.8 | 120 | 124 | 0.06 | 0.09 | 0.4 |
| 6 | Cabbage purple | 22.7 | 50.4 | 1.1 | – | – | – | – | – |
| 7 | Camel's foot tree (*Tanki saag*) | 361 | – | 6.1 | – | 9.5 | – | – | – |
| 8 | Camel's foot tree flower (*Koiralo*) | 312 | 92 | – | – | – | – | – | – |
| 9 | Cauliflower green | 626 | 107 | 4.0 | – | – | – | – | – |
| 10 | Chayote leaf | 42.5 | 76.38 | 2.26 | 1,042.7 | 11.9 | – | – | – |
| 11 | Colocasia leaf (green) | 227 | 82 | 10 | 1,0278 | 12 | 0.22 | 0.26 | 1.1 |
| 12 | Colocasia leaf (black) | 460 | 125 | 0.98 | 1,2000 | 63 | 0.06 | 0.45 | 1.9 |
| 13 | Coriander leaf | 184 | 71 | 1.42 | 6,918 | 135 | 0.05 | 0.06 | 0.8 |
| 14 | Drumstick leaf | 440 | 70 | 0.85 | 6,780 | 220 | 0.06 | 0.05 | 0.8 |
| 15 | Fenugreek leaf | 395 | 51 | 1.93 | 2,340 | 52 | 0.04 | 0.31 | 0.8 |
| 16 | Fiddlehead green (*Niguro*) | – | 117 | 1.0 | – | 6.2 | 0.03 | 0 | 1.5 |
| 17 | Garden cress | 360 | 110 | 2.8 | – | – | 0.15 | – | – |
| 18 | Grass pea leaf (*Khesari*) | 160 | 100 | 7.3 | 3,000 | 41 | 0.01 | 0.03 | – |
| 19 | *Jaluko* (*Botrychium lanuginosum)* | 254.4 | 49 | 3.6 | – | 3.25 | – | – | – |
| 20 | Lamb's quarter (*Bethe* ) | 150 | 80 | 4.2 | 1,740 | 35 | 0.01 | 0.14 | 0.6 |
| 21 | Lettuce | 50 | 28 | 2.4 | 990 | 10 | 0.09 | 0.13 | 0.5 |
| 22 | Mustard leaf | 155 | 26 | 1.6 | 2,622 | 33 | 0.03 | – | – |
| 23 | Pumpkin leaf | 392 | 112 | – | 497.9 | – | – | – | – |
| 24 | Radish leaf | 265 | 59 | 0.9 | 1,300 | 81 | 0.18 | 0.47 | 0.8 |
| 25 | Rape leaf | 370 | 110 | 1.2 | 130 | 65 | 0.01 | 0.03 | 0.9 |
| 26 | Spinach | 73 | 21 | 1.14 | 3,049 | 28 | 0.03 | 0.26 | 0.5 |
| 27 | Stingy nettle leaf | 981 | – | – | – | 5.5 | – | – | – |
| 28 | Thai spinach | 79.5 | 64.8 | 2.4 | – | 10 | – | – | – |
| 29 | Water cress (*Sim saag*) | 127 | 52.7 | 3.2 | 2,685 | – | – | – | – |

## 4. Vitamin and Mineral Composition of Other Vegetables

As given in Table 5.4, in vegetables other than green leafy vegetables, calcium is found in the range of 6–143.6 mg/100 g, phosphorus is found in the range of 10–258 mg/100 g, iron is found in the range of 0.1–4.9 mg/100 g, carotene content is in the range of 0–4275 µg/100 g, vitamin C is in the range of 0–317 mg/100 g, thiamin is in the range of 0–0.32 mg/100 g, riboflavin is in the range of 0–0.33 mg/100 g, and niacin is in the range of 0.1–1 mg/100 g (DFTQC 2017).

**Table 5.4.** Mineral and vitamin composition of other vegetables (per 100g)

| S. N. | Name | Ca (mg) | P (mg) | Fe (mg) | Carotene (µg) | Vit. C (mg) | Thiam-in (mg) | Riboflavin (mg) | Niacin (mg) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ash gourd | 30 | 20 | 0.8 | 0 | 1 | 0.06 | 0.01 | 0.4 |
| 2 | Balsam apple (*Barela*) | 143.6 | 51 | 2 | – | 6.9 | – | – | – |
| 3 | Bamboo (young shoot) | 20 | 65 | 0.1 | 0 | 5 | 0.08 | 0.19 | 0.2 |
| 4 | Bitter gourd | 20 | 70 | 0.61 | 126 | 88 | 0.07 | 0.09 | 0.5 |
| 5 | Bottle gourd | 20 | 10 | 0.46 | 0 | 0 | 0.03 | 0.01 | 0.2 |
| 6 | Brinjal | 18 | 47 | 0.37 | 74 | 12 | 0.04 | 0.11 | 0.9 |
| 7 | Broad beans | 50 | 64 | 1.4 | 9 | 12 | 0.08 | – | 0.8 |
| 8 | Broccoli | 44.9 | 109 | 1.52 | 630 | – | – | – | – |
| 9 | Button mushroom | 6 | 110 | 1.5 | – | – | – | – | – |
| 10 | Capsicum | 25.1 | 32.6 | – | – | 48 | – | – | – |
| 11 | Carrot | 80 | 530 | 1.03 | 4,275 | 3 | 0.04 | 0.02 | 0.6 |
| 12 | Cauliflower | 33 | 57 | 1.23 | 30 | 56 | 0.04 | 0.1 | 1 |
| 13 | Chayote | 140 | 30 | 0.6 | 0 | 4 | 0 | 0.04 | 0.4 |
| 14 | Cluster beans | 130 | 57 | 1.08 | 198 | 49 | 0.09 | 0.03 | 0.6 |
| 15 | Colocasia stem | 60 | 20 | 0.5 | 104 | 3 | 0.07 | 0.07 | 0.1 |
| 16 | Cowpea pods | 72 | 59 | 2.5 | 564 | 14 | 0.07 | 0.09 | 0.9 |
| 17 | Cucumber | 10 | 25 | 0.6 | 0 | 7 | 0.03 | 0 | 0.2 |
| 18 | Double bean | 40 | 140 | 2.3 | – | 22 | – | – | – |
| 19 | Drumstick | 30 | 110 | 0.18 | 110 | 120 | 0.05 | 0.07 | 0.2 |
| 20 | Field bean (tender) | 210 | 68 | 0.83 | 187 | 9 | 0.1 | 0.06 | 0.7 |
| 21 | French bean | 50 | 28 | 0.61 | 132 | 24 | 0.08 | 0.06 | 0.3 |
| 22 | Jackfruit (young fruit) | 30 | 40 | 1.7 | 0 | 14 | 0.05 | 0.4 | 85 |
| 23 | Ladies finger | 66 | 56 | 0.35 | 52 | 13 | 0.07 | 0.1 | 0.6 |
| 24 | Onion | 47 | 50 | 0.6 | 0 | 11 | 0.08 | 0.01 | 0.4 |
| 25 | Oyster mushroom | – | – | 1.5 | – | – | – | – | – |
| 26 | Peas | 20 | 139 | 1.5 | 83 | 9 | 0.25 | 0.01 | 0.8 |
| 27 | Pink beans | 54 | 70 | 1.5 | 453 | 12 | 0.06 | 0.02 | 0.6 |
| 28 | Pointed gourd | 30 | 40 | 1.7 | 153 | 29 | 0.05 | 0.06 | 0.5 |
| 29 | Pumpkin | 10 | 30 | 0.44 | 50 | 2 | – | – | – |
| 30 | Raddish | 24.7 | – | 0.4 | 3 | 15 | 0.06 | 0.02 | 0.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 31 | Red beans | 33 | 258 | 5 | – | 7.8 | – | – | – |
| 32 | Red cowpea | 18.1 | 254 | 4.9 | – | – | – | – | – |
| 33 | Red gram (tender) | 57 | 164 | 1.1 | 469 | 25 | 0.32 | 0.33 | 3 |
| 34 | Snake gourd | 26 | 20 | 1.51 | 96 | 0 | 0.04 | 0.06 | 0.3 |
| 35 | Soybean (tender) | 89.7 | 206.7 | 3.7 | – | 4.55 | – | – | – |
| 36 | Spiny gourd (*Chattel*) | 70.1 | 45.8 | 0.92 | – | 317.7 | – | – | – |
| 37 | Sponge gourd | 28.2 | 30.07 | 1.18 | – | 4.55 | – | – | – |
| 38 | Sword beans | 60 | 40 | 2 | 12 | 0.08 | 0.08 | 0.5 | – |
| 39 | Tomato | 15 | 27 | 0.7 | 424 | 23 | – | – | – |
| 40 | Tree tomato | 12 | 46 | 1 | 324 | 0 | – | – | – |
| 41 | Winged bean (tender) | 26.3 | 51 | – | – | 3.4 | – | – | – |

In general, vegetables are low in protein content. However, the result shows that some vegetables especially the green beans, peas and some green leafy vegetables such as grass pea leaves (*Khesari*), cauliflower greens and stinging nettle are good sources of protein. All of the vegetables are very low in fat content. Most of the vegetables contain less than 1 g/100 g fat.

Generally, vegetables are not rich in carbohydrate but some vegetables are good sources of carbohydrate. Camel's foot tree leaves (*Tanki saag*), drumstick leaves, colocasia leaves, pumpkin leaves, etc. are very good sources of carbohydrate, and most of which are complex carbohydrates. Similarly, vegetables, especially, green leafy vegetables were found to contain a good amount of minerals. Amaranth leaves, pumpkin leaves, cauliflower greens and stinging nettle leaves contain the highest amount of minerals.

Likewise, vegetables are good sources of roughage or fiber. Camel's foot tree (*Tanki* and *Koiralo*) and *Jaluko* (*Botrychium lanuginosum*) among green leafy vegetables, and beans, peas, radish and jackfruit (tender) are found to contain significantly a high amount of fiber. Vegetables contribute very less amount of calorie since most of the vegetables contain less than 100 Kcal/100 g; therefore, their consumption helps to control obesity.

Green leafy vegetables, peas and beans are found to have very good amounts of iron, while dark green leafy vegetables contained good amounts of β-carotene, precursor of vitamin A. Amaranth leaves, colocasia leaves, lamb's quarter leaves (*Bethe*), garden cress and others are found to be packed with minerals such as iron and calcium as well as vitamins and carotene.

## Effects of Vegetables on Diseases

Effects of vegetables on various lifestyle diseases such as diabetes, cardiovascular diseases, cancer and others are a widely studied area in the recent years. Most of the vegetables are good source of antioxidants, vitamins and phytochemicals which are beneficial for certain diseases. Although there are very nominal researches conducted on the chemical constituents of Nepalese vegetables, the researches conducted elsewhere can be used to project the health benefits of the vegetables found in Nepal. Table 5.5 provides a summary of the effects of vegetables on various diseases.

**Table 5.5.** Effect of vegetables on diseases

| S.N. | Vegetables | Nutrients/Bioactive compounds | Beneficial for | References |
|---|---|---|---|---|
| 1 | Broccoli | Glucosinolates, indole-3-carbinol | Diabetes, obesity, cancer | (Ülger *et al.* 2018) |
| 2 | Carrot | Flavonoids, polyacetylenes, vitamins, minerals, carotenes | Cancer | (Ülger *et al.* 2018) |
| 3 | Cauliflower | Glucosinolates, indole-3-carbinol | Diabetes, obesity | (Ülger *et al.* 2018) |
| 4 | Garlic | Volatile oils, organosulphur compounds, flavonoids | Diabetes, obesity, cardiovascular diseases, cancer | (Ülger *et al.* 2018) |
| 5 | Green leafy | Antioxidants phytochemicals, vitamin C, vitamin E, vitamin K, vitamin A | Diabetes, cardiovascular diseases, cancer | (Heber 2004; Tang *et al.* 2017; Ülger *et al.* 2018) |
| 6 | Onion | Volatile oils, organosulphur compounds, flavonoids | Diabetes, obesity, cardiovascular diseases, cancer | (Heber 2004; Tang *et al.* 2017; Ülger *et al.* 2018) |
| 7 | Peas | β-Sitosterol, campesterol, stigmasterol, linoleic acid | Diabetes, obesity | (Ülger *et al.* 2018) |
| 8 | Soybeans | β-Sitosterol, campesterol, stigmasterol, linoleic acid | Diabetes, obesity | (Tang *et al.* 2017; Ülger *et al.* 2018) |
| 9 | Spinach | Vitamin A, vitamin C, vitamin E, β-carotene, lutein, flavones, flavonoids | Cancer | (Ülger *et al.* 2018) |
| 10 | Tomato | Lycopene | Cancer | (Heber 2004; Ülger *et al.* 2018) |
| 11 | Pepper | Capsaicin | Cancer | (Ülger *et al.* 2018) |
| 12 | Amaranth leaf | Carotene | Cancer | (Zhang *et al.* 2015) |
| 13 | Brassicacae vegetables e.g. cabbage, rape leaf (*Rayo, Tori*) | Ascorbic acid, phenolics, carotenoids, glucosinolates | Cardiovascular diseases, cancer | (Raiola *et al.* 2018) |

Table 5.5 apparently indicates the nutrients and phytochemical contents of various Nepalese vegetables and their effects on chronic diseases. However, there are many indigeneous vegetables consumed in Nepal, which may have high potential for the prevention of various diseases.

## Recommendations

- Less utilized Nepalese vegetables should be further studied for their minerals, vitamins and antioxidants contents.
- Nepalese indigeneous vegetables should be further studied to identify phytochemicals constituents.
- Nepalese vegetables should be further studied for their bioactivities in relation to prevention of various diseases.
- Effect of consumption of vegetables on lifestyle diseases should be studied in the population groups.

- Consumption of vegetables among different age and socio-economic groups should be studied.
- Food recipes based on vegetables should be studied and promoted among the consumers.
- Schools should be positioned for nutrition learning and recipes, which may help to establish a good food/nutrition habits of the students and hence the habit of future generation.

## Conclusion

Nepalese vegetables, especially green leafy vegetables, are good sources of minerals and vitamins. They are also good sources of fiber. At the same time they are low in fat and calorie which makes them healthier option for all age group of people. The vegetables of wild origin are commoly given less importance but these vegetables were found to be very rich in vitamins, minerals and fiber.

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# Author's Biography



Purna Chandra Wasti, born in 1970, has a degree of Master of Professional Studies in Food and Nutrition Planning from the University of Philippines, Los Banos in 2001. He has obtained Bachelor's Degree in Food Technology from the Central Campus of Technology, Tribhuvan University, Dharan, Nepal in 1994. He joined the Department of Food Technology and Quality Control, Government of Nepal, Ministry of Agriculture and Livestock Development as an Assistant Food Research Officer in 1995. He has worked in the department for twenty years with different capacities, and currently holding the post of Senior Food Research Officer. He has also served non-governmental organizations and UN agencies in Nepal, Uganda and Malawi. He has an experience of teaching different nutrition subjects to the Master's level students at the College of Applied Food and Dairy Technology, Purbanchal University. He has published several articles in national newspapers. During his association with different organizations, he has gained skills of writing papers, conducting training on nutrition, and facilitating the workshops and seminars. He has also coordinated for the design and publication of behaviour change communication materials on nutrition in Nepal and elsewhere.

# Chapter 6

## Nutritional Profile of Vegetables and Significance to Human Health - A Review

**Manasa Thapa Thakurathi**
*Central Department of Home Science, Tribhuvan University*
*Bagbazar, Kathmandu, Nepal*
* Email: manasathapa@yahoo.com

*Vegetables are important for human health because of their vitamins, minerals, phytochemicals and dietary fiber content. Vegetables are mankind's most affordable source of vitamins and minerals needed for good health. Today, neither the economic nor nutrient power of vegetables is sufficiently realized. Fresh vegetables endowed with almost all of the nutritional principles that our body receives. Vegetable nutrition has also widely drawn attention of fitness-conscious as well as food scientists alike for their proven health benefits. Vegetables are nutritious foods that provide sufficient amount of nutrients needed for normal body functions, maintenance and reproduction. Also their intake in different combination is essential for the maintenance of healthy life and normal body function. Vegetables have a lot of health benefits which include reduction of cancers, diabetes and cardiovascular diseases. This can be argued that reduced fruit and vegetable consumption is linked to poor health and in increased risk of non-communicable diseases. An estimated 3.9 million deaths worldwide were attributable to inadequate fruit and vegetable consumption in 2017.*

**Keywords:** Cancer; cardiovascular disease; cooking methods; diabetes; diet; fiber; vitamins.

## Introduction

Generally speaking, an herbaceous plant or plant part which is regularly eaten as unsweetened or salted food by humans is considered to be a vegetable. Some vegetables can be consumed raw, some may be eaten raw or cooked, and some must be cooked in order to be edible. Vegetables are important for human health because they provide vitamins and other nutrients required to make a good health of an individual. Vegetables contain nutrients in terms of bioactive nutrient molecules such as dietary fiber, vitamins, minerals and non-nutritive phytochemicals (e.g. phenolic compounds, flavonoids,

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terpenes, bioactive peptides, etc.) These nutrient and non-nutrient molecules reduce the risk of non-communicable diseases and metabolic disorders such as cardiovascular diseases, diabetes, cancers and obesity (Pennington & Fisher, 2009; Septembre-Malaterreb et al., 2018). Hence a critical discourse on the relationship between vegetable intake and human health becomes an important phenomenon in promoting quality of life of people living all over the world. The main objective of this chapter is to provide a critical view on nutritional profile of vegetables and its significance to promote human health as an important component to achieve a good quality of life of people living in a given community.

## Classification of Vegetables

This is noted that vegetables and annual or perennial horticultural crops with certain sections (roots, stalks, flowers, fruits, leaves, etc.) that can be consumed wholly or partially cooked or raw. An elaborative classification of vegetables has been provided to us by botanists and nutritionists. There are approximately 10,000 plant species used as vegetables in the world (Ülger et al., 2018). Classification of these species can be done by considering a common set of features. Vegetables can also be classified according to the part of the plant used for nutrition and their specific nutritional value (Lintas, 1992). It is important for food researchers, dietitians and nutritional educators to sub-categorize vegetables by taking into account of health and nutrition. This sub-categorization will be more useful if it is based on similarities in food composition (Pennington & Fisher, 2010).

### *Classification of Vegetables on the Basis of the Parts Consumed*

According to the parts of the plant used for nutrition and the specific nutrition value, vegetables can be classified into three as depicted in Figure 6.1 (Ülger et. al., 2018).

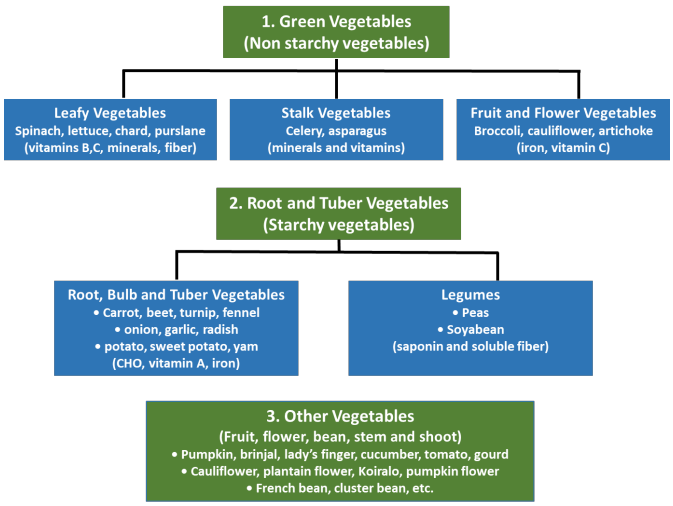



**Figure 6.1.** Vegetables classified according to the part of the plant used.

## *Classification of Vegetables on the Basis of the Colour*

Vegetables and fruits contribute a variety of colours to human diet. According to the main pigments present, vegetables can be classified on the basis of colours (Langtree, 2017).

**Green vegetables:** Green coloured, fat soluble pigments are present in many vegetables. The dark green colour of leafy vegetables is due to the presence of chlorophyll. Carotenoids are also present in green leafy vegetables, but its colour is masked by the green chlorophyll so can be seen green colour only. Thinner and greener leaves are more nutritious and usually have lower calories. It contains chlorophyll, fiber, lutein, calcium, folate, vitamin C and β-carotene.

**White vegetables:** The anthoxanthins and flavones are yellow-white in colour, and tannins and derivatives of flavones are colourless. Due to the presence of these pigments, vegetables appear white. Examples are potato, cauliflower, cabbage, turnip, onion, etc (Weaver & Marr, 2013).

**Orange/yellow vegetables:** Carotenoids are fat soluble, yellow, orange or red pigments. This colour is present in many vegetables such as carrot, pumpkin, tomato, etc. Its concentration is indicated by the intensity of the colour in the vegetables. α-Carotene and β-carotene are precursors of vitamin A. Besides carotenoids, these vegetables also contain zeaxanthin, flavonoids, lycopene, potassium, vitamin C, etc.

**Red vegetables:** Flavonoids are very widely distributed in plant kingdom. Anthocyanins are a group of flavonoids that are water soluble pigments responsible for red, blue or purple colouration of the plants. Red vegetables also constituted of phytonutrients like lycopene, ellagic acid, quercetin and hesperidin.

**Blue/purple vegetables:** Some examples of such vegetables are beet root, red cabbage, etc. that contain nutrients lutein, zeaxanthin, resveratrol, vitamin C, fiber, flavonoids and quercetin.

## Nutrient Available in Vegetables

A vegetable is nutritious and protective food that provides sufficient amount of nutrients needed for normal body functions, maintenance and reproduction. Also, its intake in different combination is essential for the maintenance of healthy life and normal body functions (Hanif et al., 2006). Vegetables have a lot of health benefits, which include reduced cancers, diabetes and cardiovascular diseases. Fresh vegetables endowed with almost all of the nutritional principles that our body requires. The nutritional content of vegetables varies considerably, though generally they contain little protein or fat and are good source of vitamins, pro-vitamins, dietary minerals, fiber and carbohydrates. Vegetables contain a great variety of other phytochemicals, some of which have been claimed to have antioxidant, antibacterial, antifungal, antiviral and anti-carcinogenic properties.

Table 6.1 provides a comprehensive and complex picture regarding nutrient availability and how important green and other vegetables remain to promote human health of individuals, and groups in which they live and work. This also motivates us to develop nutritional inventory and guidelines suited to our own ecology, economy and socio-cultural setting.

**Table 6.1.** Important nutrients available from vegetables

| Vegetable sub-groups | Important food sources | Contributing nutrients |
|---|---|---|
| Dark green leafy vegetables | Spinach, amaranth, coriander, calocassia, water cress | Iron, copper, magnesium, calcium, vitamin B complex, vitamin C, vitamin K, vitamin A, antioxidant, β-carotene, flavonoids, fiber |
| Root and tubers | Carrots, radish, turnip, potato, garlic, onion, beet root, shallot, yam, sweet potato | Starch, manganese, potassium, vitamin B6, folate, iron, β-carotene, lutein, zeaxanthin |
| Legumes | Peas, soybean, chickpea, broad bean | Fiber, protein, magnesium, copper, folate, phytosterols, favonols, iron, zinc, manganese, vitamin B6 |
| Other vegetables | Brinjal, lady's finger, cabbage, broccoli, gourd, cauliflower, pumpkin, tomato, cucumber | Vitamin B6, vitamin K, manganese, copper, β-carotene, fiber |
| Additional vegetables | Spinach, fenugreek leaf, brussel, chard, green chillies, etc. | Flavonoids, vitamin C, vitamin K |

Vegetables cultivated in soils polluted with toxic metals due to industrial activities take up heavy metals and accumulate them in their edible and non-edible parts in quantities high enough to cause clinical problems both to animals and human beings. Consumption of these metal-rich plants is health hazardous as there is not good mechanism for their elimination from the human body (Alam et al., 2003).

## Phytonutrients

Fruits and vegetables are very nutritious, dense with vitamins and minerals that we know are essential for proper health keeping our bodies functioning. However, an often overlooked aspect of these food groups is phytonutrients. Phytonutrients are naturally occurring plant compounds. There are thousands of different phytonutrients found in vegetables, usually in small amounts. Plants produce them for their own protection from insects or bacteria, as pigments required for photosynthesis (energy production) and flavouring. They are often responsible for the bright colours of fruits and vegetables, and researches reveal that these compounds may help to reduce the risk of several diseases and to promote health (Craig, 1997; Craig & Beck, 1999; Dillard & German, 2000; Singh & Rao, 2012; Forni et al., 2019). Examples of phytonutrients are lycopene in tomato, β-carotene in carrot, glucosinolates in broccoli, etc. Unlike nutrients (vitamins and minerals), no recommended dietary intake levels have been established for phytonutrients. Health claims are not permitted (with the exception of some carotenoids that can be converted to vitamin A) and further human trials are required to substantiate the potential benefits suggested below.

There is no single magic phytonutrient that can be isolated and turned into a daily tablet! The most protective effect comes from eating a wide variety of phytonutrients as they occur naturally in plant foods. Phytonutrients may work in lots of different ways to protect against diseases and promote health. Modes of action that are being investigated include anti-inflammatory activity, boosting the body's antioxidant defenses, modulating

gut microflora, lowering cholesterol, fighting against bacteria and supporting the body's immunity. Examples of the phytochemicals present in the vegetables are shown in Table 6.2.

**Table 6.2.** Main phytonutrients in vegetables

| Phytonutrients | Vegetable sources |
|---|---|
| ***Carotenoids*** | |
| Pro-vitamin A: α-carotene, β-carotene, β-cryptoxanthin | Available in many vegetables, but high in carrot, pumpkin and green leafy vegetables |
| Lycopene | Tomato |
| Xanthophylls: lutein, zeaxanthin | Sweet corn, dark green leafy vegetables such as spinach, silverbeet and lettuce |
| Glucosinolates, isothiocyanates | Brassica vegetables: broccoli, cauliflower, brussels sprout, cabbage, kale, radish, swede, turnip, watercress |
| ***Phenolics and polyphenols**** | |
| Flavonoids | Beans, onion, leafy vegetables, tomato |
| Phenolic acids | Available in most vegetables, but especially in potato |
| Anthocyanins | Red, blue or purple vegetables such as eggplant, purple broccoli, red-purple radish |
| Allium sulphur compounds | Garlic, leeks, onion |
| ***Other compounds*** | |
| Betalains | Beet root, silver beet, spinach (red and yellow varieties) |
| Falcarinol, falcarindiol | Carrot, celery, fennel, parsley, parsnips |
| Saponins | Alfalfa sprouts, asparagus, beans, spinach |
| Phytosterols | Asparagus, beans, lettuce, peas, brassica e.g. broccoli, swedes, cauliflower |
| Fructans | Onion, leeks, garlic, asparagus |
| Capsaicinoids | Capsicum, chilli |

*This is a diverse group of thousands of phytochemicals. It also includes other types of polyphenols such as catechins, isoflavones and lignans. Vegetables are not major sources of these phytochemicals.

## Health Benefits of Fresh Vegetables

Specific vegetable groups or types of vegetables have also been associated with improved health outcomes. Intakes of dark green leafy vegetables have been associated with reduced risk for diabetes mellitus type II, cancers and depression. High intake of cruciferous vegetables has been associated with reduced risk from various cancers. Intakes of β-carotene-rich vegetables, yellow- and red-pigmented vegetables, and fruiting vegetables have been associated with reduced risk from various cancers. Root vegetable consumption has been associated with reduced diabetes mellitus type II risk (Appleton et. al., 2016).

Diets high in fruits and vegetables are widely recommended for their health-promoting properties. Fruits and vegetables have historically held a place in dietary guidance because of their concentrations of vitamins, especially vitamins C and A, minerals, especially electrolytes, and more recently phytochemicals, especially antioxidants. Additionally, fruits and vegetables are recommended as a source of dietary fiber (Slavin & Lloy, 2012).

In medical nutrition therapy applied to individuals, it is important to meet the energy and nutritional needs of individual as well as including foods with functional activities against the complications of diseases in the diet. This is asserted that the most basic aspects of the control and management of the diseases in individual with health problems is the regulation of eating habits. The components found in the vegetables are thought to be protective against these diseases. In order to address the aforesaid problem, nutritionists have developed nutrition guidelines in order to promote human health.

A general guideline showing relations between vegetables by its colour to human health has been given in Table 6.3 (Langtree, 2017).

**Table 6.3.** Health benefits of fresh vegetables by its colour classification

| | |
|---|---|
| **Green vegetables** | ✓ Reduce risk of cancers<br>✓ Lower LDL cholesterol level<br>✓ Lower blood pressure<br>✓ Fight with harmful free radicals<br>✓ Support retinal health and vision<br>✓ Normalize digestion<br>✓ Boost immune system |
| **White vegetables** | ✓ Reduce risk of colon, breast and prostate cancers<br>✓ Reduce risk of hormone-related cancers<br>✓ Balance hormone levels<br>✓ Activate natural killer B and T cells |
| **Blue/purple vegetables** | ✓ Reduce tumour growth<br>✓ Lower LDL cholesterol level<br>✓ Limit the activity of cancer cells<br>✓ Act as an anti-carcinogen in the digestive tract<br>✓ Support retinal health<br>✓ Support healthy digestion<br>✓ Boost immune system<br>✓ Improve calcium and other mineral absorption<br>✓ Fight against inflammation |
| **Orange/yellow vegetables** | ✓ Reduce risk of prostate cancer<br>✓ Lower LDL cholesterol level<br>✓ Lower blood pressure<br>✓ Fight with harmful free radicals<br>✓ Reduce age-related macular degeneration<br>✓ Encourage alkaline balance<br>✓ Promote collagen formation and healthy joints<br>✓ Work with magnesium and calcium to build healthy bones |
| **Red vegetables** | ✓ Reduce risk of prostate cancer<br>✓ Lower LDL cholesterol level<br>✓ Lower blood pressure<br>✓ Scavenge harmful free radicals<br>✓ Reduce tumour growth<br>✓ Support join tissue |

## Common and Seasonal Nepali Vegetables and its Nutrient Content

According to *Nepal-Vegetable Crops Survey 2009-10* (CBS, 2010), there are 55 vegetable crops group identified as the most commonly being cultivated in the context of Nepal. Fresh vegetables according to nutritional values are low in fat, salt and sugar. Some vegetables contain higher levels of carbohydrate and are often called starchy vegetables. These are usually roots and tubers such as potato, yams, kumara, taro and sweet corn (see: Figure 6.1). The starchy vegetables are higher in energy because of their carbohydrate content. Other vegetables are classified as non-starchy which tend to have higher water content, and are lower in energy but often richer in vitamins and minerals. General nutrients content in some of the selected vegetables consumed in Nepal is presented in Table 6.4 (DFTQC, 2017).

**Table 6.4.** Nutritional composition of Nepalese common vegetables

| Name of the vegetables | Nutrient available (in 100 g ) | | | | | |
|---|---|---|---|---|---|---|
| **Green leafy vegetables** | **Moisture (g)** | **Fiber (g)** | **Vitamin C (mg)** | **Calcium (mg)** | **Iron (mg)** | **Caroten (µg)** |
| Bethe | 89.6 | 0.8 | 35 | 150 | 4.2 | 1,740 |
| Chamsoor (Garden cress) | 82.3 | 0 | 0 | 360 | 28.6 | 0 |
| Dhaniya | 86.3 | 1.2 | 135 | 184 | 1.42 | 6,918 |
| Baabari (Mint) | 84.9 | 2 | 27 | 200 | 15.6 | 1,620 |
| Dunduko saag | 92 | 1.22 | 11.92 | 86.22 | 0 | 0 |
| Karkalo (Taaro leaf) | 82.7 | 2.9 | 12 | 227 | 10 | 10,278 |
| Lundeko saag (Pigweed) | 83.9 | 5.5 | 0 | 406 | 0 | 0 |
| Methiko saag (Fenugreek Leaf) | 86.1 | 1.1 | 52 | 395 | 1.93 | 2,340 |
| Paalungo (Spinach) | 92.1 | 0.6 | 28 | 73 | 1.14 | 3,049 |
| Pharsiko munta (Pumpkin shoot) | 81.9 | 3.7 | 0 | 392 | 0 | 497.9 |
| Raayoko sag (Rape leaf) | 84.9 | 1.2 | 65 | 370 | 12.5 | 130 |
| Tori ko saag (Mustard leaf) | 89.8 | 0.8 | 33 | 155 | 16.3 | 2,622 |
| **Root and tuber** | **Protein (g)** | **CHO (g)** | **Vitamin C (mg)** | **Fiber (g)** | **Iron (mg)** | **Carotene (µg)** |
| Alu (Potato) | 1.6 | 22.4 | 17 | 0.6 | 0.46 | 0 |
| Gajar (Carrot) | 0.9 | 10.6 | 3 | 1.2 | 1.03 | 4,275 |
| Chukander (Beet root) | 1.7 | 8.8 | 10 | 0.9 | 1.19 | 0 |
| Chappy (Shallot, Leek) | 1.8 | 17.2 | 11 | 1.3 | 2.3 | 18 |
| Pidaalu (Co-co yam) | 3 | 21.1 | 0 | 1 | 0.42 | 24 |
| Pyaz (Onion) | 1.2 | 10.4 | 11 | 1.3 | 0.46 | 0 |
| Moola (Radish) | 0.7 | 22.7 | 15 | 9.6 | 0.4 | 3 |
| Salegum red (Turnip) | 1.2 | 7.7 | 0 | 1.3 | 2.3 | 1.2 |
| Sakharkhand (Sweet potato) | 1.35 | 29.1 | 2.42 | 1 | 2.21 | 0 |
| Tarul (Casavaa, Tapioca) | 1,2 | 21.1 | 0 | 1 | 0.42 | 24 |
| Ghar tarul (Yam) | 1.2 | 18.4 | - | 0.9 | 0.6 | 260 |
| Ban tarul (Wild edible yam) | 2.5 | 29.1 | 1 | 1.4 | 1 | 97 |

| Other vegetables | Fiber (g) | Minerals (g) | Carotene (µg) | Vitamin C (mg) | Calcium (mg) | Iron (mg) |
|---|---|---|---|---|---|---|
| Banda gobi (Cabbage) | 1 | 0.6 | 120 | 124 | 39 | 0.8 |
| Barelaa (Balsam apple) | 0.79 | 0.81 | 0 | 6.86 | 144 | 2 |
| Bhantaa (Eggplant) | 1.3 | 0.3 | 74 | 12 | 18 | 0.37 |
| Bhende khursani (Bell pepper, Sweet pepper) | 0.7 | 0.52 | 0 | 48.3 | 25.1 | 0 |
| Brokauli (Broccoli) | 0.94 | 1,12 | 630 | 0 | 44.86 | 1.52 |
| Bodi (Beans) | 3.2 | 1.4 | 198 | 49 | 130 | 1.08 |
| Chatel (*Momordica cochinchinensis*) | 1.2 | 0.78 | 0 | 0.92 | 70.08 | 0.92 |
| Chyau (Mushroom) | 0.4 | 1.4 | 0 | 0 | 6 | 1.5 |
| Chichindo (Serpent or Snake gourd) | 0.8 | 0.5 | 96 | 0 | 26 | 1.51 |
| Ghiraula (Sponge gourd) | 0.39 | 0.35 | 0 | 4.55 | 200 | 0 |
| Golebheda (Tomato) | 0.5 | 0.7 | 424 | 23 | 15 | 27 |
| Gyathkobi | 0.2 | 0.63 | 0 | 8,6 | 19.3 | 13.2 |
| Kaankro (Cucumber) | 0.4 | 0.3 | 0 | 7 | 10 | 0.6 |
| Karela, Tito (Bitter gourd) | 0.8 | 0.8 | 126 | 88 | 20 | 0.61 |
| Katahar (Jack fruit) | 2.8 | 0.9 | 0 | 14 | 30 | 1.7 |
| Kauli, Phulgobhi (Cauliflower) | 1.2 | 1 | 30 | 56 | 33 | 1.23 |
| Kerau or Matar (Garden peas) | 1.8 | 0.9 | 187 | 9 | 210 | 0.83 |
| Koiralo (Seto or Rato) | 5.5 | 2.1 | 0 | 0 | 312 | 0 |
| Kurilo (Common asparagus) | 0.8 | 0.6 | 0 | 12.8 | 30.6 | 1.3 |
| Lauka (Bottle gourd, Calabash) | 0.6 | 0.5 | 0 | 0 | 20 | 0.46 |
| Niuro (Fiddlehead fern) | 1 | 1.3 | 44.27 | 0 | 71.53 | 0 |
| Parwar (Pointed gourd, Patol) | 3 | 0.5 | 153 | 29 | 30 | 1.7 |
| Pharsi (Pumpkin) | 0.7 | 0.6 | 50 | 2 | 10 | 0.44 |
| Raamtoriya (Ladies finger) | 1.2 | 0.7 | 52 | 13 | 66 | 0.35 |
| Simi (Beans) | 1.8 | 0.5 | 132 | 24 | 50 | 0.61 |
| Thotne (Smart Weed) | 2.7 | 0.8 | 0 | 6.2 | 27.67 | 0 |

Fruit and vegetables are packed full of goodness and often contain a number of essential vitamins and minerals that cannot be found in other types of foods or they may contain higher levels of these nutrients than other foods. They play a significant role in human nutrition, especially as sources of vitamins C (ascorbic acid), A, B1 (thiamine), B3 (niacin), B6 (pyridoxine), B9 (folacin, also known as folic acid or folate), E; minerals; and dietary fiber. Their contribution as a group is estimated at 91% of vitamin C, 48% of vitamin A, 30% of vitamin B9, 27% of vitamin B6, 17% of vitamin B1 and 15% of vitamin B3 in the diet (Khetarpal & Kocher, 2016). These vitamins including several minerals have shown established positive consequences on human health. Vegetable sources of these phytonutrients and their proposed effects on human-wellness are tabulated in Table 6.5 (Kader et al., 2001).

**Table 6.5.** Nutritive constituents of vegetables that have a positive impact on human health and their sources

| Constituent | Sources | Health benefits |
|---|---|---|
| Vitamin C (ascorbic acid) | Broccoli, cabbage, leafy greens, pepper, potato, tomato | Prevents scurvy, aids wound healing, healthy immune system, cardiovascular disease |
| Vitamin A | Dark-green vegetables (e.g. collards, spinach and turnip greens), orange vegetables (e.g. carrot, pumpkin and sweet potato), tomato | Night blindness prevention, chronic fatigue, psoriasis, heart disease, stroke, cataracts |
| Vitamin K | Nuts, lentils, green onion, crucifers (e.g. cabbage, broccoli, brussel sprouts), leafy greens | Synthesis of procoagulant factors, osteoporosis, vitamin |
| Vitamin E (tocopherols) | Nuts, dry beans, lentils, chickpeas, dark green leafy vegetables | Heart diseases, LDL oxidation, immune system, diabetes, cancer, fiber |
| Folate (folicin or folic acid) | Dark-green leafy vegetables (e.g. spinach, mustard greens, butter head lettuce, broccoli, brussels sprouts and okra), legumes (e.g. cooked dry beans, lentils, chickpea and green pea), asparagus | Birth defects, cancer, heart diseases, nervouse system |
| Calcium | Cooked vegetables (such as beans, okra and tomato), peas, snap beans, pumpkin, cauliflower | Osteoporosis, muscular/skeletal, teeth, blood pressure |
| Magnesium | Spinach, lentils, okra, potato, nuts, corn | Osteoporosis, nervous system, teeth, immune system |
| Potassium | Baked potato or sweet potato, cooked dry beans, cooked greens, winter (orange) squash | Hypertension (blood pressure), stroke, arteriosclerosis |

## Conclusion

Vegetables are important to human health by providing various nutrient items and dietary fiber. Root vegetables may not be as nutritious as dark leafy greens, but they can still provide a fairly good nutrient profile. Vitamins and minerals and non-nutritive phytochemical molecules that reduce the risk of chronic diseases such as cardiovascular diseases, certain cancers and obesity. Basic information regarding classification of vegetable, nutrient content and their relation to heath and the effects of preparation and cooking on nutrient content of vegetable becomes important in order to improve the quality of health of people living in their own respective communities.

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## Author's Biography



Dr. Manasa Thapa Thakurathi is a retired Professor of Central Department of Home Science, Tribhuvan University, Nepal. Now, she has been working as a visiting Professor of Nutrition in Dhulikhel Hospital, Kathmandu University, Nepal. She has also worked as Senior Nutritionist and affiliated in a few hospitals as Diet Counselour. She has taught about 43 years in Tribhuvan University in different capacities. She has published several papers and research articles.

# Chapter 7

## Diversity, Availability, Using Status, Nutritional and Pharmacological Aspects of Wild Vegetables of Nepal

**Gan B Bajracharya[1]* and Bashana Bajracharya[2]**
[1]*Faculty of Science, Nepal Academy of Science and Technology (NAST) Khumaltar, Lalitpur, Nepal*
[2]*Kirtipur Sadak 27/48, Balkhu, Tekushi, Kathmandu-14, Kathmandu, Nepal*
*Email: ganbajracharya@yahoo.com

*Within a span of about 200 km from north to south, Nepal has altitudinal variation from 60 m to the top of Mount Everest (8848.86 m). This geographical variation blessed the country with diversified ecosystems, and created outstanding assemblage of biodiversity. At the same time, Nepal is also riched in cultural diversity. More than 60 ethnic groups, speaking more than 100 languages, use wild edible plants as their foods, and the different communities have their own intimate relationship with different plant resources for the culinary arts, local identity and medicinal perceptions. The wild vegetables are the nature's gift to mankind. They are cheap, delicious, refreshing, medicinal and good supplementary sources of vitamins, minerals as well as carbohydrates and proteins. Therefore, the wild vegetables are not only for the forest tribes. However, their consumption has been declining both due to the modern food habit and the market availability. Herein, we list 318 species (with parts used) of wild vegetables consumed in Nepal from different literature sources in order to their promotion and sustainable conservation.*

**Keywords:** Conservation; ethnomedicine; food security; natural resources; secondary metabolites; wild edible plants.

## Introduction

The map of Nepal is roughly a trapezoidal shape streching about 800 km from east to west and 90 to 230 km north to south with an area of 147,181 km$^2$ (Web, 1). Topographically, it lies between latitudes 26°12' to 30°27' N and longitudes 80°4' and 88°12' E. Chhetri is the largest ethnic group with 16.6% of the total population followed

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by Brahman (12.2%), Magar (7.1%), Tharu (6.6%), Tamang (5.8%), Newar (5.0%), Kami (4.8%), Musalman (4.4%), Yadav (4.0%), and Rai (2.3%). And, there is always an inseparable inter-relationship between the ethnic groups and plants. According to Hagen's classification (Hagen, 1998), Nepal comprises six physiographic regions namely (1) Terai, (2) Siwaliks or Chure, (3) Mahabharat, (4) Midlands or central hills, (5) Himalayas, and (6) Inner Himalayas and Tibetan marginal mountains (Paudel et al., 2012). A total forest area of Nepal is 6.4 million hectares covering 44.7% (including shrubland), and 23% land area has been categorized as protected area including national parks, reserves, conservation areas and buffer-zones (GoN/MoFSC, 2017). There are 1,001 species of algae (2.5% of global diversity), 1,822 species of fungi (2.6% of global diversity), 465 species of lichens (2.3% of global diversity), 1,150 species of bryophytes (8.2% of global diversity), 534 species of pteridophytes (5.1% of global diversity), 26 species of gymnosperms (5.1% of global diversity), and 6,973 species of angiosperms (3.2% of global diversity) recorded in Nepal (GoN/MoFSC, 2014). In another report, Nepal records some 6,076 species of flowering plants (229 families), 312 endemic flowering plant (46 families and 126 genera), and 534 ferns (Tiwari et al., 2019). So far over 1,434 flowering plants, 65 ferns, 8 conifers, and their allies are recorded as possessing of at least one use, including >650 species as food materials, and >1000 species of wild plants with medicinal values from Nepal (Web, 2).

Based on the purpose of use, edible plants with floral origin can be categorized into six, namely, (1) vegetables (species those are cooked as food), (2) fruits (species of which fruits are consumed fresh or dried), (3) raw food (species in which fresh plant part, other than fruit, is eaten raw as a salad, (4) chutney or pickle (parts of those species ground with salt and spices for preparing sauce), (5) flavoring food (species used for seasoning and infusing aroma), and (6) local brew (species used to prepare liquor) (Thakur et al., 2017). This chapter is mainly focused on the wild edible plants used in Nepal as vegetables consumed either by cooking with oil or boiling with water.

## Wild Plants and their Social Impacts

Simply, wild plants are those plants which grow spontaneously in natural surroundings and are not looked after by people. Wild edible plants are consumed either raw (as fruits and salads) or after cooking in oil, boiling with water, and drying as tea, spice and condiments or after processing by boiling to kill enzymes (e.g. in *orchis* tubers), destroying toxic chemicals (e.g. in *Lathyrus* seeds) or pickling (e.g. in *Capparis* leaves). Sometimes, differentiation between the terms ‘wild’ and ‘cultivated or domesticated’ is not an easy due to the degree of intervention of human and the management involved. For examples, mangoes (*Mangifera* spp.) and bananas (*Musa* spp.) are natively wild species and they can grow from seeds or propagules and eventually they are cultivated by humen.

It is estimated that there are about 800,000 plant species on earth and about 374,000 species are currently known, of which approximately 308,312 are vascular plants with 295,383 flowering plants, algae 44,000, liverworts 9,000, hornworts 225, mosses 12,700,

lycopods 1,290, ferns 10,560, and gymnosperms 1,079 (Christenhusz & Byng, 2016). Only a few hundreds species have been fully domesticated for the world trade, and about 103 plant species contribute 90% of the world's food supply, while about 30 species supply human nutritional needs (Prescott-Allen & Prescott-Allen, 1990). On the other hand, thousands of species are either scarcely grown locally or wild-collected. About 25,000 species are estimated to have been used as herbal medicines, and about 10,000 plant species are used as vegetable in all over the world. It is roughly estimated that about 75,000 species of plants distributed world-wide are believed to be edible (Walter & Hamilton, 1993). There are about 10,000-12,000 species of pteridophytes in the world. Liu et al. have listed 52 species of ferns (including 4 varieties) in the inventory of edible ferns, and it was estimated that there are about 144 species of potential edible ferns in China (Liu et al., 2012).

Forest contributes a variety of supplementary food sources, such as foods, fruits, vegatables, nuts, gums, saps, medicines, and so on. Forest food adds a variety to diets and provides essential vitamins, minerals, proteins and calories. Well known or lesser known wild plants, particulary from the forests, are used as food in many developing countries. Long ago, the consumption of wild plants would probably much more than now. Nevertheless, edible wild plants becoming a fashionable food today except for the native peoples and commercialized species. Despite, wild edible plants play an important role in ensuring food security, nutritional supplement and remedy of illness as well as economic growth to some extent of many people in developing countries. Although domesticated plants are the main source of food and income for many people, the people in rural areas are not able to meet the annual food requirements solely depending on the cultivated plants, thus ultimately they have to consume wild edible plants as 'a way of life' to fulfil supplement dietary requirements (Shrestha & Dhillion, 2006). It has also been suggested that wild edible plants are superior to the cultivated ones, not only because they are cheap, but also due to richness in nutraceuticals and secondary metabolites of potential drug candidates, as they enabled to grow in harsh conditions (Burlingame, 2000). These wild plants have both food and traditional medicinal values, and their consumption practice is basically due to the transformation of indigenous knowledge from the earlier generation. However, loss of information during knowledge transformation, choosing of a wrong variety, dangers while collecting, and consumption without proper scientific verification are associated with the threating of the lives. Due to social change and acculturation processes, indigenous knowledge on wild edible plants is declining and even vanishing with modernization lifestyles. Ignorance about the diversity of the species by indigeneous people, failure of regulating plant importance imposing the rules by the governmental bodies, over-exploitation of commercially demanded species, loss of information during verbal knowledge transformation to the next generation, and vulnerability of this important resource caused by extreme habitat and global climate change have strongly demanded for the documentation of the traditional knowledge on wild edible plants to preserve their genetic and cultural diversities for the future a head.

Benefits of wild edible plants can be listed as:

- Food security and nutritional balance for the poor rural people who desperately rely on wild plants.
- Play important role to fulfil the nutritional requirement especially for the tribal people.
- Serve as complementary food for non-indigenous people.
- Meet food demand during food crises (due to drought, war and other hardship periods).
- Fodder for domestic animals.
- Provide food to wild animals.
- An alternative source of money.
- Traditional herbal remedy for several ailments.
- Possess enormous medicinal potential for a new drug discovery.
- Maintaining of biodiversity, conservation of degraded land and improvement of ecosystem productivity.
- Preservation of social and cultural histories of a region for the people's local identity, pride and traditions.
- Development of new foods through domestication and hybridization of wild plants.

## Consumption and Utilization of Wild Vegetables

Vegetables are an essential component of our daily diet providing vitamins, minerals, fibers, specific amino acids, and other bioactive compounds. In adition, some vegetables are also capable of providing additional calories, carbohydrate and protein, and have numerous medicinal values. *Moringa oleifera* (sitalchini, sajiwan) is claimed as the most nutrient-rich plant yet discovered (Mahmood et al., 2010). The veggie leaves are said to provide 7 folds more vitamin C than that found in oranges, vitamin A 10 folds than carrotes, calcium 17 times more than milk, 9 times of protein than yogurt, 15 times more potassium than in bananas, and 25 folds of iron compared to spinach (Rockwood et al., 2013).

Bajracharya has documented 40 edible Nepalese wild fruits with their nutritive values in terms of total dry matter, ash, sugar, protein and elements (Na, K, Mg and Ca) (Bajracharya, 1980). A couple of fuits from this list are also consumed as wild vegetables. Manandhar has documented that there are about 1,500 useful plants available in Nepal (Manandhar, 2002). Out of these, 651 species are economically useful including 440 species of wild food plants, and about 200 plant species are consumed as vegetables. Shimada and Basnet have listed 210 cultivated and 150 edible wild plants in Nepal with their names in Japanese, English, Nepali, Maithili, Tamang, Tharu, Newari and Hindi languages (Shimada & Basnet, 2015). Recently, Dangol et al. 2017 have reported that 394 wild plant species are still used in Nepal for different purposes such as vegetables (246 spp.), fruits (125 spp.), pickle (44 spp.), jam (11 spp.), spices and condiments (10 spp.), oil (6 spp.), and others (Dangol et al., 2017). A few examples of country-specific studies that document the diversity of traditional and wild vegetables are depicted in Table 7.1.

**Table 7.1.** Diversity of traditional wild vegetables in different areas

| Region and country (ethnicity) | Number of wild vegetables recorded | Reference |
|---|---|---|
| Benin, Africa | 187 | (Dansi et al., 2008) |
| Togo, Africa | 105 | (Batawila et al., 2007) |
| China | 1822 (213 Families, 815 Genus) | (Guerrero & Isasa, 2003) |
| Darjeeling, India | 92 | (Sharma, 2012) |
| Nepal | 246 (out of 394 edible species) | (Dangol et al., 2017) |
| Lekam area, Darchula, Nepal | 26 (out of 83 edible species) | (Pant et al., 2005) |
| Manang, Nepal | 14 (out of 41 edible species) | (Bhattarai et al., 2009) |
| Siluwa VDC, Palpa, Nepal | 9 (out of 21 edible species) | (Ale et al., 2009) |
| Illam, Nepal | 34 (out of 74 edible species) | (Ghimeray et al., 2010) |
| Shaktikhor VDC, Chitwan and Handikhola VDC, Makawanpur, Nepal (Chepang tribe) | 15 (out of 55 edible species) | (Maharjan et al., 2010) |
| Makawanpur, Nepal | 68 | (Joshi & Siwakoti, 2012) |
| Surkhet and Kailali, Nepal (Raji tribe) | 20 (out of 67 edible species) | (Thapa et al., 2014) |
| Parsa, Nepal (Tharu tribe) | 12 (out of 54 edible species) | (Singh, 2015b) |
| Rupandehi, Nepal | 51 | (Singh, 2015a) |
| Khar VDC, Darchula, Nepal | 31 (out of 99 edible species) | (Aryal et al., 2018) |

Consumption of wild species is not always safe as they may possess toxic compounds that are health hazardous. Through the experienced gained after passing a long period of time, the local people have developed knowledge about the content and uses of wild edible plants. And, they became experienced to consume wild vegetables only after some processing or pre-treatments. Some examples of local practices before consumption of the wild vegetables are: (1) *Dioscorea bulbifera* (Githa) is boiled (with ash) to remove its bitter taste (Thapa et al., 2014); (2) *Dioscorea kamaoonensis* (Tyaguna) is boiled and placed in water overnight before eating (Thapa et al., 2014); (3) only young shoots of *Dendrocalamus hamiltonii* (Tama) are eaten as a vegetable and pickle, while young leaves are harmful (Bhandary & Shrestha, 1985); (4) *Arisaema flavum* (Timchu, Phi to) is boiled, placed in boiling water overnight and then cooked uncovered (The detoxified *A. flavum* is also used to make bread or is added to a soup or used to make Raksi, a home-made distilled alcohol) (Daniggelis, 2003); (5) *Cardamine scutata* (Chamsure ghans, Mangan sag) is dred in the sun to reduce its bitter taste before cooking (Daniggelis, 2003); etc.

The contribution of wild vegetables to the daily life of local people is significant. The tuber of *Dioscorea* [*D. bulbifera* (Githa), *D. deltoid* (Bhyakur), *D. esculenta* (Tarul), *D. hamiltonii* (Ban tarul) and *D. pentaphylla* (Mithe tarul)] are used as staple food by the

rural households. Species such as *Centella asiatica* (Ghodtapre), *Asparagus racemosus* (Kurilo) are routinely eaten for their therapeutic benefits. Other most common wild vegetables includes *Dryopteris cochleata* (Pani niuro, Unyau), *Urtica dioca* (Sisnu), *Chenopodium album* (Bethe), *Tectaria macrodonta* (Kalo niuro), *Veronica beccabunga* (Khole sag), *Bauhinia purpurea* (Tanki), *Amaranthus spinosus* (Kandelatte, Ban lunde), *Amaranthus viridis* (Latte dana), *Nasturtium officinale* (Sim sag), *Crateva unilocularis* (Siplikan), *Dendrocalamus hamiltonii* (Tama), etc., and are also available in the local markets (Shrestha & Rai, 2012). Despite of a high market value, a few species such as *Buchanania cochinchinensis* (Piyari) has a less marketing potential because of their low volume availability. At the same time, people are mostly unawared about the economic potentiality of such a species. Tender shoot of *Botrychium lanuginosum* (Jaluko) is regarded as a delicious wild vegetable in Nepal (Leach, 2003). *Bambusa tulda* (Tusa), *C. album* (Bethe), *D. hamiltonii* (Tama), *Diplazium esculentum* (Masino niuro), *D. cochleata* (Pani niuro, Unyau), *Ipomoea aquatica* (Karmi sag), *Tectaria gemmifera* (Kalo neuro), *Amaranthus viridis* (Latte dana), *Macropanax dispermus* (Chinia), *Pteris biaurita* (Danthe niuro), *U. dioica* (Sisnu), etc. are top ranked wild vegetables with respect to the taste and consumption frequency by both children and adults (Joshi & Siwakoti, 2012). Culturally, almost all Nepalese consumed *Dioscorea exculenta* (Tarul) and *Dioscorea alata* (Ghar tarul) to celebrate the occasion called Maghe Sankranti (celebrated every year in January third week). Bamboo wood of *Dendrocalamus hamiltonii* (Bans) is also used during funeral rituals in the country. *Cynodon dactylon* (Dubo) is used during different worship ceremonies.

The wild leafy vegetables are harvested in the particular season, preserved and stored for the times of scarcity. Drying and fermenting leaves also have a beneficial nutritional effect, and the processing generally does not affect the mineral contents (Adhikari & Krantz, 1989). Nepalese rural people make a fermented dried vegetable relish called Gundruk or Sinki, and store it for the winter months. *Cardamine scutata* (Chamsure ghans or mangan sag) and *Arisaema griffithii* (Dhokaya) are used to prepare Sinki including radish and rape leaves (Daniggelis, 2003; Oli & Nepal, 2003). The leaves are first sun-dried, fermented for one to four weeks and then stored.

## Status of Wild Vegetables (Marketting/Conservation) in Nepal

The wild plants are commonly used as major food and food supplement in the food deficient areas as well as in the ethnic communities of all over the world. They also contribute to the economy of millions of households. Some ethnobotanical surveys reveals that individual households, in Dhusa VDC, Dhading district, Nepal, collect about 200 kg per annum of *Dioscorea bulbifera* (Githa); Chepang households, in Gorkha district, Nepal, consumed an average of 364 kg of *D. bulbifera* and 96 kg of *Urtica dioica* (Sisnu) per annum; and people of Khar VDC, Darchula, Nepal, utilized *Paeonia emodi* (Hetto) (150 kg), *Fagopyrum esculentum* (Mithe phaper) (110 kg), *Dryopteris cochleata* (Pani niuro, Unayu) (90 kg), *Dioscorea deltoidea* (80 kg), *Bauhinia purpurea* (75 kg), *D. bulbifera* (75 kg) and *U. dioca* (65 kg) per annum (Aryal et al., 2018). To the best of our knowledge, data for the consumption of total amounts of wild vegetables per annum in the country is not available.

Indigenous vegetables of Nepal used by different ethnicity have own importance in subsistence, income generation and cultural identity. However, their availability is declining at an alarming rate in all the areas of Nepal because of population pressure, expansion of mechanized and intensive agriculture, introduction of exotic vegetable species and improved varieties, habitat destruction (drought, fire, deforestation), over-exploitation and climate change effect (Shrestha, 2013). Until today, a little emphasis has been given for the promotion of wild edible plants through appropriate management and domestication systems. Despite, recently an increased concern is realized in the need of their preservation and domestication for a longterm tangible source of income to the rural communities. Recently, Nepal Agricultural Research Council (NARC) and Nepal Academy of Science and Technology (NAST) and have estabilished their independent National Agriculture Genetic Resources Center (alias Genebank) in 2010 and Himalayan Seed Bank in 2012, respectively, and devoted for the preservation and utilization of domestic and wild seeds in order to food, nutrional and genetic security of Nepalese. NAST has initiated phylogenetic studies on wild plants using DNA barcoding technique. The Government of Nepal also amended a number of laws in order to conserve the wild diversity of Nepal (Chaudhary et al., 2016).

Many wild plants may be transferred from the forests or other ecosystems to trailsides or fields of human habitations as they are easily collected and domesticated. Therefore, some wild edible plants either wild collected or field cultivated now can also be purchased from the markets. A few wild vegetables such as *Amaranthus caudatus* (Latte sag), *Amaranthus lividus* (Marshi, Lude sag), *Fagopyrum esculentum* (Mithe phapar), *Fagopyrum tataricum* (Tite phapar), *Mentha spicata* (Pudina), etc. are now cultivated in the farmer's field (Shrestha et al., 2004). Some of the forest products such as *Asparagus racemosus* (Kurilo), *Crateva unilocularis* (Siplikan), *Dendrocalamus hamiltonii* (Tama), *Phyllanthus emblica* (Amala), *Tectaria macrodonta* (Kalo niuro), etc. have a high demand in the markets of Nepal. Although, cash generation by selling of these products is not very high; however, these wild products provide them some relief in the time of hardship.

High profitable indigenous wild vegetables and their products demand over harvesting of the species despite of their limited availability. Furthemore, when the species also possesses prominent medicinal values, then the species becomes more endangered and eventually vulnerable. Wild *Dryopteris cochleata* (Pani niuro, Unayu), *Polygonum* molle (Thotne), *Asparagus racemosus* (Kurilo), and *Rheum australe* (Padamchal) from their natural habitats are considered to be endangered because of their increasing market demand; however, people are paying efforts to cultivate them permanently as vegetables in their fields or home gardens (Shrestha, 2013). The introduction of improved agricultural techniques, in which many indigenous vegetables are treated as weeds, is a major reason for the disappearance of indigenous vegetables in some areas. Besides this, other threats to forest biodiversity of Nepal can be categorized into (GoN/MoFSC, 2014):

- Encroachment of forest areas for the settlements.
- Expansion of cultivation into the forest areas.
- Development of infrastructure inside forestland.

- Planned conversion of forestland by the government for implementing economic development priority projects, such as construction of road, electric transmission line and reservoir.
- Unsustainable overharvesting of biological resources to meet persistently high demands for fuel, construction timber, fodder and other forest products.
- Uncontrolled forest fire (natural or human error).
- Overgrazing in forests.
- Illegal harvesting of endangered and vulnerable species.
- Invasive alien species affect to native species, mainly through predation, competition and habitat modification.
- Excessive extraction of boulders, gravel and sand from rivers, and streams is a localized cause of deforestation in some areas, which has posed a direct threat to biodiversity.

Therefore, utilization of forest biodiversity should always go with the measures to ensure sustainability and conservation of the resources. Some such measures include:

- Non-destructive harvesting.
- Setting aside of reserve areas for in situ conservation and recovery of threatened species.
- Collection of seeds or other propagules for ex situ conservation.
- Domestication of wild species to take the pressure off wild populations.
- Providing technical support to the farmers for the field management.
- Establishment of community forests, fuelwood lots and similar facilities to fulfil the needs of local peoples thereby reducing the pressure on wild resources.
- Proper planning and management of the reserved areas for sustainable use of wild plant resources.
- Development of monitoring and early warning systems.
- Increasing of community participation in the forest management.
- Promoting the role of non-governmental organizations (NGOs) in the forest conservation so that they can act as intermediaries between government and local communities.
- People awareness program on the benefits of genetic resources and need of their conservation for the economic and ecological sustainability.
- Empowerment of indigenous knowledge and promotion of the value chain.
- Management of the populations of endemic species to maintain their demographic integrity and genetic variability.

## Nepalese Wild Vegetables

From the literature survey of the publications on wild edible plants of Nepal, a list of wild vegetables consumed in Nepal is generated, which is depicted in Table 7.2 (Jha et al., 1996; Lama et al., 2001; Daniggelis, 2003; Pant et al., 2005; Shrestha & Dhillion, 2006; Prasad, 2007; Dangol, 2008; Ghimire et al., 2008; Acharya, 2009; Aryal et al., 2009; Ghimeray et al., 2010; Maharjan et al., 2010; Joshi & Siwakoti, 2012; Uprety et al., 2012; Shrestha, 2013; Thapa et al., 2014; Singh, 2015a; Singh, 2015b; Dangol et al., 2017;

Aryal et al., 2018). Chutney or pickle making wild fruits and leaves; wild mushrooms, raw consumable wild fruits and salad; wild spices and condiments; wild seeds, oils and pulses are not included in the table of the indigenous wild edible plants of Nepal in the vegetable category. Orchids, potatoes, tomatoes, edible seeds and nuts from conifers are also omitted. On the other hand, wild edible fruits *Mangifera indica* (Jangali aanp), *Castanopsis indica* (Katus), *Phyllanthus emblica* (Amala), *Pyrus pashia* (Mayel), *Ziziphus jujuba* (Bayer) and *Choerospondias axillaris* (Lapsi), and *Mentha spicata* (Pudina) and *Murraya koenigii* (Karry patta) that can be categorized under wild chutney or pickle and/or spices, are included in the list as some ethenic groups in Nepal consumed them in an enough quantity either after cooking with other vegetables or boiling with water.

**Table 7.2.** Indigenous wild vegetables of Nepal

| SN | Botanical Name [Synonym] | Name[§] | Habit[¶] | Parts eaten[#] | Availability | Useful information and ethnomedicinal values* |
|---|---|---|---|---|---|---|
| **PTERIDOPHYTES** | | | | | | |
| ***Family: Athyriaceae*** | | | | | | |
| 1 | *Allantodia spectabilis* (Wall. ex Mett.) Ching [*Diplazium spectabile* (Wall. ex. Mett.) Ching] | Neuro | H | Lf | May-Jun | |
| 2 | *Diplazium esculentum* (Retz.) Sw.[$] | Masinoniuro | H | Lf | May-Jul | Used as laxative and tonic. Used in fever, glandular swelling, dermatitis, wounds and measles. |
| 3 | *Diplazium stoliczkae* Bedd. [*Allantodia stoliczkae* (Bedd.) Ching] | Kaloneura | H | Sh, Lf | May-Jun | |
| ***Family: Blechnaceae*** | | | | | | |
| 4 | *Woodwardia biserrata* C. Presl (unresolved) | | H | St | Jun-Jul | |
| ***Family: Dennstaedtiaceae*** | | | | | | |
| 5 | *Pteridium aquilinum* (L.) Kuhn | Bracken[1] | H | Sh | Jul-Jul | Contains poisonous cyanogen glycosides which are antithiamine and carcinogenic. It induces illeum sarcoma and leukemia, thus its consumption should be stopped. |
| ***Family: Dryopteridaceae*** | | | | | | |
| 6 | *Deparia boryana* (Willd.) M. Kato [*Dryoathyrium boryanum* (Willd.) Ching] | Kaloneuro | H | Lf | Jun-Jul | |

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| 7 | *Dryopteris cochleata* (D. Don) C. Chr.[$] | Paniniuro, Gheeniuro, Unyau | H | Lf | Mar-May | Used for blood purification and to treat muscular and rheumatic pains. |
| 8 | *Polystichum squarrosum* (D. Don) Fée | Phusreneuro | H | Sh | May-Jun | |
| ***Family: Lygodiaceae*** | | | | | | |
| 9 | *Lygodium flexuosum* (L.) Sw. | Parandi sag | C | Sh, Lf | Whole year | Used in jaundice, wounds, eczema and dysmenorrhea. |
| 10 | *Lygodium japonicum* (Thunb.) Sw. | Janailahara | C | Lf | May-Jun | Used in dysentery, hepatitis and pneumonia. |
| ***Family: Ophioglossaceae*** | | | | | | |
| 11 | *Botrychium lanuginosum* Wall. ex Hook. & Grev. | Jaluko | H | Sh | May-Jun | Used in dysentery and wounds. |
| 12 | *Ophioglossum nudicaule* L.f. | Jibre sag | H | Lf | Mar-Apr | Used in old skin diseases. |
| 13 | *Ophioglossum petiolatum* Hook. | Jibre sag | H | Lf | Feb-Apr | Used for checking of nose bleeding. |
| 14 | *Ophioglossum reticulatum* L. | Jibre sag | H | Lf | Mar-Apr | Used as cooling agent in burns. Used as tonic and wounds remedy. |
| 15 | *Ophioglossum vulgatum* L.[$] | Jibre sag | H | Wp | Mar-Apr | Possesses antiseptic, detergent, styptic and velnerary properties. |
| ***Family: Osmundaceae*** | | | | | | |
| 16 | *Osmunda claytoniana* L. | Interrupted fern[1] | H | Lf | May-Jun | Useful in dysentery and muscular debility. |
| ***Family: Pteridaceae*** | | | | | | |
| 17 | *Ceratopteris thalictroides* (L.) Brongn. | Panidhaniya | H | Wp | | Used as a poultice for skin problems. Its paste with turmeric is applied in cuts and wounds. |
| 18 | *Pteris biaurita* L. | Dantheniuro | H | Lf, Sh | | Used to treat chronic disorders. |
| 19 | *Pteris vittata* L. | Urakthewn[6] | H | Sh, Rh | Spring | |
| ***Family: Tectariaceae*** | | | | | | |
| 20 | *Tectaria gemmifera* (Fée) Alston [*Tectaria coadunate* C. Chr.][$] | Kaloneuro, Dantheniuro | H | Lf | | Useful in eczema and scabies. |
| 21 | *Tectaria macrodonta* (Fee.) C. Chr. (Unresolved)[$] | Kaloniuro | H | Sh | Jun-Jul | |
| 22 | *Tectaria zeylanica* (Houtt.) Sledge | Mayurkutea | H | Lf | Mar-Apr | |

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| ***Family: Thelypteridaceae*** | | | | | | |
| 23 | *Cyclosorus auriculata* (J. Sm.) C.M. Kuo [*Thelypteris auriculata* (J. Sm.) K. Iwats] | Kochaya | H | Sh | Spring | |
| 24 | *Thelypteris multilineata* (Wall. ex Hook.) C.V. Morton | Koche[6] | H | Sh | Jun-Jul | |
| **ANGIOSPERMS** | | | | | | |
| ***Family: Acanthaceae*** | | | | | | |
| 25 | *Justicia adhatoda* L. | Asuro | S | Lf, Fl, Fr | Jan-Feb | Useful to treat rheumatic pain and bronchitis. |
| 26 | *Phlogacanthus thyrsiformis* (Roxb. ex Hardw.) Mabb. | Chua, Rheeom | H | Lf, Fl | Mar-May | Leaf used in cough, cold and asthma. |
| ***Family: Adoxaceae*** | | | | | | |
| 27 | *Sambucus adnata* Wall. ex DC. | Moti phool | S | Sh | May-Jun | Leaf and fruit juices are given to relieve fever. |
| ***Family: Aizoaceae*** | | | | | | |
| 28 | *Trianthema portulacastrum* L. | Kulfa sag, Gadapuraina | H | Sh | Apr-May | Used in blood diseases and night blindness. |
| ***Family: Alismataceae*** | | | | | | |
| 29 | *Sagittaria guayanensis* Kunth [*Sagittaria aginashii* Makino] | Thokrak sag[6] | H | Wp | | It is a troublesome aquatic plant in fresh water tanks and thus for fish farming. |
| 30 | *Sagittaria sagittifolia* L. | Sigangodai | H | Lf, Rh | Jul-Aug | Useful in skin diseases. Mix with vinegar and apply as a poultice for boils and abscesses. |
| ***Family: Amaranthaceae*** | | | | | | |
| 31 | *Alternanthera sessilis* (L.) R.Br. ex DC. | Bhringi sag, Saranchi sag | H | Lf | May-Jul | Used in veneral and neural diseases. |
| 32 | *Amaranthus caudatus* L. | Latte sag | H | Lf | Apr-Jul | Used as an expectorant. |
| 33 | *Amaranthus lividus* L. [*Amaranthus blitum* subsp. *oleraceus* (L.) Costea] | Marshi, Lude sag | H | Sh, Lf | Apr-Jul | It is cooling, stomachic, emollient and used as a tonic. |
| 34 | *Amaranthus spinosus* L. | Kandelatte, Ban lunde | H | Sh, Lf | Apr-Jul | Used locally for eczema, boils, and abscess. In Ayurveda, used as febrifuge, antipyretic, laxative and diuretic. Induces abortion. |
| 35 | *Amaranthus tricolor* L. | Chinese spinach[1] | H | Lf, Sh | | Used in bilious disorders and as an aperient. |

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| 36 | *Amaranthus viridis* L. | Lattedana | H | Sh, Lf | Apr-Jul | Traditionally used to reduce labour pain. Acts as antirheumatic, analgesic, antiemetic and anti-inflammatory agent. |
| 37 | *Celosia argentea* L. | Sirvari sag | H | Lf | Aug-Dec | Used as a diuretic and blood purifier. |
| 38 | *Chenopodium album* L.[$] | Bethe | H | Sh, Lf | Jan-Mar | Used in spleen, bile and pectoral disordes. Leaf decoction is used to expel dead fetus. |
| 39 | *Chenopodium murale* L. [*Chenopodiu gandhium* Buch-Ham.] | Kalobethe | H | Lf, Sd | Aug-Sep | Antibacterial and antifungal. |
| 40 | *Deeringia amaranthaoides* (Lam.) Merr. | Latman[3] | H | Lf, Sd | Jun-Jul | Used in sores. |
| 41 | *Dysphania ambrosioides* (L.) Mosyakin & Clemants [*Chenopodium ambrosioides* L.] | Ratolatte | H | Lf | Aug-Sep | Acts as an anthelmintic, vermifuge and emmenagogue. It is believed to prevent flatulence. Shows repellency and insecticidal properties. |
| 42 | *Spinacia oleracea* L.[$] | Palungo | H | Sh | Whole year | It is an antibacterial. It is used as a raw material for producing chlorophylls. |
| ***Family: Amaryllidaceae*** | | | | | | |
| 43 | *Allium carolinianum* DC | Kage lasun | H | Lf, Bl | Jul-Aug | Used as digestive, stimulant, and tonic. |
| 44 | *Allium fasciculatum* Rendle | Lasune sag | H | Lf | Oct-Nov | Used in wound, swellings and as a blood purifier. |
| 45 | *Allium oreoprasum* Schrenk | Jimbu | H | Lf | | Effective against cold and virus infections. |
| 46 | *Allium prattii* C.H. Wright | Rukpa | H | Lf | | Taste is similar to green garlic. |
| 47 | *Allium stracheyi* Baker | Januarygali | H | Lf | Aug-Oct | |
| 48 | *Allium wallichii* Kunth[$] | Jimbujhar, Dundu | H | Lf, Bl | Aug-Oct | Contains alkaloids and sulphur compounds. Possesses antimicrobial, antioxidant and anticancer effects. |
| ***Family: Anacardiaceae*** | | | | | | |
| 49 | *Buchanania cochinchinensis* (Lour.) M.R. Almeida [*Buchanania latifolia* Roxb.][$] | Piyari | T | Sh, Fr | May-Jun | Used as a cardiotonic and powder is applied in wounds. |
| 50 | *Choerospondias axillaris* (Roxb.) B.L. Burtt & A.W. Hill [*Spondias axillaris* Roxb.] | Lapsi | T | Fr | Oct-Nov | Useful in cardiovascular diseases, renal calculi and cancers. |

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| 51 | *Mangifera indica* L.[$] | Jangali aanp | T | Fr | Jun-Jul | A rich source of vitamin C, vitamin A and potassium. |
| 52 | *Semecarpus anacardium* L.f. | Bhalayo | T | Pe, Fr | Nov-Feb | Acrid, hot and anthelmintic. It is considered beneficial in ascites, tumours, warts, asthma, rheumatism, epilepsy and psoriasis. |
| 53 | *Spondias pinnata* (L.f.) Kurtz [*Spondias mangifera* Willd.] | Amora | T | Fr, Fl | Nov-Mar | Possess antidiarrheal, anthelmintic, thrombolytic, antiulcer and hepatoprotective activities. |
| ***Family: Apiaceae*** | | | | | | |
| 54 | *Anethum sowa* Roxb. ex Fleming | Saunf sag | H | Lf | Jan-Jul | Used in digestive and respiratory disorders. |
| 55 | *Carum carvi* L. | Ban jeera, Bhote jeera | H | Lf | | Used in weakness, eye diseases, swellings, indigestion, gastritiis and fever. |
| 56 | *Centella asiatica* (L.) Urb. | Ghodtapre | H | Sh, Lf | Feb-Apr | Used in throat problems. |
| 57 | *Cortia depressa* (D. Don) C. Norman | Bhutkesh | H | Lf | Jul-Aug | |
| 58 | *Eryngium foetidum* L. | Brameli dhaniya | H | Lf | Aug-Sep | Used as a substitute for coriander for flavouring rice and curries. |
| 59 | *Oenanthe javanica* (Blume) DC. [*Oenanthe stolonifera* Wall. ex DC.; *Oenanthe javanica* (Blume) DC.] | Nakuri | H | Lf | May-Jun | Used for treating of hepatitis, alcohol hangovers, abdominal pain and inflammatory conditions. |
| 60 | *Oenanthe linearis* Wall. ex DC. | Khakibaku | H | Lf | May-Jun | Used for flavouring. |
| 61 | *Pleurospermum angelicoides* (Wall. ex DC.) Benth. ex C.B. Clarke | Chhipi[3] | H | Lf | Jul-Aug | Used in dysentery and stomach troubles. |
| 62 | *Pleurospermum apiolens* C.B. Clarke | | H | Lf | Aug-Sep | |
| ***Family: Apocynaceae*** | | | | | | |
| 63 | *Ceropegia pubescens* Wall. | Ban simi | C | Bn | | Useful in dysentery and diarrhoea. |
| 64 | *Holarrhena pubescens* Wall. ex G. Don | Kurchi, Indrajau | S | Lf, Fl | May-Jun | Possess astringent, antidysenteric, anthelmintic, stomachic, febrifugal and tonic properties. |

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| ***Family: Araceae*** | | | | | | |
| 65 | *Arisaema consanguineum* Schott [*Arisaema erubescens* var. *consanguineum* (Schott) Engl.] | Rakshya banko | H | Sh | Apr-May | |
| 66 | *Arisaema costatum* (Wall.) Mart. | Jangali makai | H | Lf | | Toxic. |
| 67 | *Arisaema erubescens* (Wall.) Schott | Chari banko, Gurbo | H | Wp, Co, Sh | Summer-rainy | |
| 68 | *Arisaema flavum* (Forssk.) Schott | Timchu, Phi to | H | Sh | May-Jun | |
| 69 | *Arisaema griffithii* Schott | Dhokayo | H | Sh, Lf | Early summer | |
| 70 | *Arisaema jacquemontii* Blume | Sarpako makai | H | Rt, Tu, Lf, Co | Apr-May | Possesses anticancer property. |
| 71 | *Arisaema tortuosum* (Wall.) Schott | Banko | H | Wp | Jun-Jul | Tubers are irritant due to constituting calcium oxalate. Useful in cold and cough. They are considered to produce antifertility and insecticidal effects. |
| 72 | *Arisaema utile* Hook. f. ex Schott | Dhokaya | H | Sh | Jun-Jul | |
| 73 | *Colocasia antiquorum* Schott[$] | Karkalo | H | Lf | | It is acrid due to calcium oxalate. Juice is used as a styptic or astringent. |
| 74 | *Colocasia esculenta* (L.) Schott[$] | Gaba, Karkalo, Pindalu | H | Lf, Tu | Aug-Oct | Tuber may be used to produce alcohol. |
| 75 | *Colocasia fallax* Schott | Ghueya[6] | H | Lf, Co | | |
| 76 | *Pistia stratiotes* L. | Jalkumbhi | H | Lf | | It provides food for fishes. It is considered antiseptic, antitubercular and antidysentric. |
| 77 | *Remusatia pumila* (D. Don) H. Li & A. Hay | Pygmy elephant ear[1] | H | Lf | May-Jun | |
| 78 | *Remusatia vivipara* (Roxb.) Schott | Jaluko | H | Sh | May-Sep | Used with turmeric to relieve itch. The juice is considered alexipharmic. |
| 79 | *Sauromatum diversifolium* (Wall. ex Schott) Cusimano & Hett. [*Typhonium diversifolium* Wall. ex Schott] | Dwa[7] | H | Co | | Toxic. |

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| ***Family: Araliaceae*** | | | | | | |
| 80 | *Aralia leschenaultii* (DC.) J. Wen [*Pentapanax leschenaultia* (DC.) Seem.] | Chinde | T | Lf | | |
| 81 | *Macropanax dispermus* (Blume) Kuntze | Chareepilaa | T | Sh | Mar-May | |
| ***Family: Arecaceae*** | | | | | | |
| 82 | *Caryota urens* L. | Rangbhang | T | Bu, Pi | | Used to prepare fibre for brushes and brooms. Used for making buttons and beads. |
| 83 | *Phoenix acaulis* Roxb. | Khajuri | T | St, Fr | Jun-Jul | Used as aperient. Leaves are used for making mats, brooms and ropes. |
| 84 | *Phoenix loureiroi* Kunth [*Phoenix humilis* Royle ex Becc.] | Thakal | S | Lf, Fr | Feb-Mar | Used as aperient. Leaves are used for making mats, brooms and ropes. |
| 85 | *Wallichia disticha* T. Anderson | Thakal | T | Fr, Pi | | It may cause dermatitis. |
| ***Family: Asparagaceae*** | | | | | | |
| 86 | *Asparagus filicinus* Buch.-Ham. ex D. Don | Ban kurilo | H | Sh | May-Jun | Considered as a tonic. |
| 87 | *Asparagus racemosus* Willd.[$] | Kurilo | S | Sh, Tu | Apr-Jun | Considered as a female tonic. Tuber is used in kidney and liver problems. |
| 88 | *Chlorophytum nepalense* (Lindl.) Baker | Ban pyaj | H | Lf | Aug-Sep | |
| 89 | *Maianthemum purpureum* (Wall.) LaFrankie [*Smilacina purpurea* Wall.] | Sikari sag, Khirro | H | Lf, Sh | May-Jul | |
| 90 | *Polygonatum cirrhifolium* (Wall.) Royle | Coiling leaf[l] | H | Lf | Aug-Sep | Used as a tonic and vulnerary. |
| 91 | *Polygonatum verticillatum* (L.) All. | Khinraula | H | Lf | May-Jun | Possesses diuretic property and is considered to be poisonous by hill people. |
| ***Family: Balsaminaceae*** | | | | | | |
| 92 | *Impatiens bicornuta* Wall. | Tiuri | H | Sh | Aug-Sep | Leaf paste is used in joint pains. Plant decoction to treat inflammation. |
| ***Family: Basellaceae*** | | | | | | |
| 93 | *Basella alba* L. | Poi sag | H | Lf | Jun-Jul | Rare in its natural habitat but it is now grown in tropical region, as a spinach substitute. Acts as demulcent, diuretic and emollient. Leaf juice is applied in catarrh and oils. |

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| ***Family: Bignoniaceae*** | | | | | | |
| 94 | *Oroxylum indicum* (L.) Kurz | Tatahalo, Tatelo | T | Fr, Pd, Fl | Mar-May | Lives in relationship with the actinomycete *Pseudonocardia oroxyli*. Fruits are useful in cardiac disorders, gastropathy, bronchitis, piles and jaundice. Seeds are used in the famous tonic *Chyawanprash*. |
| ***Family: Brassicaceae*** | | | | | | |
| 95 | *Capsella bursa-pastoris* (L.) Medik. | Tori ghans | H | Lf, Rt | Jan-Apr | Used as haemostatic, diuretic and antipyretic. It is an effective antifertility plant. Tea used against haemorrhages and urinary calculi. |
| 96 | *Cardamine macrophylla* Willd. | Chhurukpa[5] | H | Lf | | |
| 97 | *Cardamine scutata* Thunb. [*Cardaminehirsuta* L.] | Chamsure ghans, Mangan sag | H | Lf | Feb-Mar | |
| 98 | *Erysimum odoratum* Ehrh. [*Erysimum hieracifolium* L.] | Ban chamsur | H | Lf, Sd | Jun-Jul | |
| 99 | *Lepidium sativum* L.[$] | Chamsur | H | Sh | Dec-Feb | Used in syphilis, piles, asthama and cough. |
| 100 | *Megacarpaea polyandra* Benth. ex Madden | Ruga sag | H | Lf | Jun-Jul | Useful in malarial fever and to remove body heat. |
| 101 | *Nasturtium officinale* R.Br. [*Rorippa nasturtium-aquaticum* (L.) Hayek][$] | Sim sag | H | Wp | Whole year | Tastes like a pepper hence used in salad. Acts as a tonic. Showed antidiabetic, anti-inflammatory and anticancer activities. |
| 102 | *Rorippa indica* (L.) Hiern | Pahelojhar | H | Lf | Feb-May | Considered to be diuretic, stimulant and antiscorbutic. |
| ***Family: Campanulaceae*** | | | | | | |
| 103 | *Codonopsis convolvulacea* Kurz. | Nyiba[7] | H | Rt | Aug-Sep | Used in cough, cold, stomach disorders and as a tonic. |
| ***Family: Capparaceae*** | | | | | | |
| 104 | *Capparis spinosa* L. | Bagh mukhwa | S | Sh, Fr | Nov-Dec | Showed hepatoprotective and anticarcinogenic effects. It is a major ingredient in the popular liver tonic, *Liv-52*. |

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| 105 | *Capparis zeylanica* L. | Karaluwa[6] | S | Fr | | |
| 106 | *Crateva religiosa* G. Forst. | Siplegan | T | Sh | Mar-Apr | Bruished leaf with vinegar is applied in rheumatism. Leaf used in jaundice, eczema and rabies. |
| 107 | *Crateva unilocularis* Buch.-Ham.[$] | Siplikan | T | Sh, Lf, Fl | Jan-Mar | Leaf juice is used in helminth infestation. |
| ***Family: Caryophyllaceae*** | | | | | | |
| 108 | *Drymaria cordata* (L.) Willd. ex Schult. | Abhijalo | H | Lf | May-Jun | Used in herbal formulations for analgesic, wound healing and anti-inflammatory effects. |
| 109 | *Drymaria cordata* subsp. *diandra* (Blume) J.A. Duke [*Drymaria diandra* Blume] | Aavijalo | H | Lf | | Traditionally used for treating fever, hepatoma, malaria, rheumatism and cancers. |
| 110 | *Stellaria media* (L.) Vill. | Armalejhar | H | Lf | | Traditionally used to treat asthma, blood diseases, inflammation and mental tension. Used in plasters for broken bones. |
| 111 | *Stellaria monosperma* Buch.-Ham. ex D. Don | Jethimadhu | H | Lf | May-Jun | |
| ***Family: Cleomaceae*** | | | | | | |
| 112 | *Cleome viscosa* L. | Bantori | H | Lf, Sd | Aug-Sep | Useful in the treatment of malarial fever, skin diseases, leprosy, blood diseases and uterine complaints. Leaf juice is used in earache. |
| ***Family: Colchicaceae*** | | | | | | |
| 113 | *Disporum cantoniense* (Lour.) Merr. | Sano kukurdaino | H | Lf | Jan-Mar | |
| ***Family: Combretaceae*** | | | | | | |
| 114 | *Terminalia chebula* Retz. | Harro | T | Fr | | It is a constituent of *Triphala churna*, a popular Ayurvedic formulation. Used to cure cough, constipation, urinary and intestinal disorders. |
| ***Family: Commelinaceae*** | | | | | | |
| 115 | *Commelina benghalensis* L. | Bankane, Kanejhar | H | Wp | Jun-Jul | Used as depressant, demulcent, emollient, anti-inflammatory and laxative. Also use as an antidote for snake bites. |

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| 116 | *Commelina paludosa* Blume | Kane sag | H | Rt, Tu | Jun-Jul | |
| 117 | *Floscopa scandens* Lour. | Kane | H | Sh, Lf | | Used in fractured bones. Stem juice is used for sore eyes. |
| 118 | *Murdannia nudiflora* (L.) Brenan | Ryauryau | H | Sh | Rainy | |
| ***Family: Compositae*** | | | | | | |
| 119 | *Acmella calva* (DC.) R.K. Jansen | Latoghans | H | Fl | Aug-Nov | Used to relieve toothache. Possesses pesticidal property. |
| 120 | *Acmella ciliata* (Kunth) Cass. [*Spilanthesciliata* Kunth] | Pirpiriya[6] | H | Fl | | |
| 121 | *Ageratum conyzoides* (L.) L. | Gane | H | Lf | May-Jun | Used to treat cuts and wounds. Plant decoction is used in stomachache. |
| 122 | *Bidens biternata* (Lour.) Merr. & Sherff | Kurro | H | Sh | May-Jun | Useful in nausea, leprosy, fever, cough and asthma. |
| 123 | *Bidens pilosa* L. | Kuro | H | Sh | May-Jun | Plant juice is used to check bleeding. |
| 124 | *Blumea lacera* (Burm. f.) DC. | Kurkure | H | Lf | May-Jun | Leaf juice is used in threadworm infection and as *Kajol*. |
| 125 | *Cirsium arvense* (L.) Scop. | Creeping thistle[1] | H | Sh | | Emetic, tonic and diaphoretic. |
| 126 | *Cirsium wallichii* DC. | Thakal | H | Sh | Jun-Jul | |
| 127 | *Eclipta prostrate* (L.) L. | Bhringraj | H | Lf | Jun-Jul | Effective against liver injury and inflammation. |
| 128 | *Emilia sonchifolia* (L.) DC. ex DC. | Dudhe, Tori phool | H | Lf | Jul-Aug | Plant decoction in fever and bowel complaints. |
| 129 | *Guizotia abyssinica* (L.f.) Cass. | Jhusetil | H | Sd | Winter | |
| 130 | *Launaea aspleniifolia* (Willd.) Hook. f. | Dudhejhar | H | Lf | Jun-Jul | |
| 131 | *Sonchus oleraceus* (L.) L. | Dudhikanda | H | Sh, Lf | May-Jun | Useful in stomachache, hepatitis, infection, inflammation, headache, rheumatism, general pain and as a general tonic. |
| 132 | *Sonchus wightianus* DC. | Tite sag | H | Lf | Jul-Aug | Used in earache. |
| 133 | *Taraxacum sikkimense* Hand.-Mazz. | Tuki phool | H | Lf, Fl | Jul-Sep | Used as galactagogue. |
| 134 | *Taraxacum tibetanum* Hand.-Mazz. | Nigale sag | H | Lf, Fl | Jul-Aug | Used in bile and stomach disorders. |

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| 135 | *Tragopogon gracilis* D. Don | Dowajha | H | Rt, Sh | | |
| 136 | *Youngia japonica* (L.) DC. | Japanese hawkweed[1] | H | Lf | | Used as an antipyretic and for detoxification. |
| ***Family: Convolvulaceae*** | | | | | | |
| 137 | *Ipomoea alba* L. | Chandrakali | H | Lf, Fl | May-Jun | Traditionally use as a rubber vulcanizer and in treating snake bite. |
| 138 | *Ipomoea aquatica* Forssk. | Karmi sag | H | Sh, Lf | Feb-Jul | Used in piles, leucoderma, sleeplessness, and as an emetic in opium and arsenic poisonings. |
| 139 | *Ipomoea batatas* (L.) Lam. | Sakharkand | H | Tu | | Useful in fever, diarrhoea, splenosis, tumours, asthma, anemia, hypertension and diabetes. |
| ***Family: Costaceae*** | | | | | | |
| 140 | *Cheilocostus speciosus* (J. König) C. Specht [*Costus speciosus* (Koenig.) Sm.] | Betlauri | H | Sh | | |
| ***Family: Cucurbitaceae*** | | | | | | |
| 141 | *Benincasa hispida* (Thunb.) Cogn.[$] | Kubhindo | C | Fr | Aug-Nov | Fruit juice is used as an antidote in alcohol poisoning. Used in epilepsy and nervous diseases. |
| 142 | *Ceratosanthes palmata* (L.) Urb.[*Trichosanthes palmata* L.] | Indreyni | H | Sh | | |
| 143 | *Coccinia grandis* (L.) Voigt | Golkankri | C | Fr | Jul-Dec | Used to treat leprosy, fever, asthma, infective hepatitis, jaundice and sore throat. Also used as expectorant and astringent. |
| 144 | *Cucurbita maxima* Duchesne[$] | Pharsi | C | Sh | Apr-Oct | Produces cooling effect. |
| 145 | *Diplocyclos palmatus* (L.) C. Jeffrey | Ban karela, Titambi[6] | C | Fl, Fr | Rainy | Used as a laxative and to cure stomachache. |
| 146 | *Edgaria darjeelingensis* C.B. Clarke | Chathil[6] | C | Fr | Aug-Sep | |
| 147 | *Momordica charantia* L.[$] | Tite karela | C | Fr | Jul-Sep | Considered to be tonic, stomachic, carminative and cooling. Useful in rheumatism, diabetes and diseases of liver and spleen. |

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| 148 | *Momordica dioica* Roxb. ex Willd. | Ban karela | C | Fr | Aug-Nov | Possesses antiasthmatic, antidepressant, antidiabetic, antihypertensive, anti-inflammatory, antileprosy, antipyretic, antivenomous, diuretic, hepatoprotective and laxative properties. Fruit juice is prescribed for hypertension and diabetes. |
| 149 | *Solena heterophylla* Lour. | Golkankri | H | Fr | Jul-Aug | Used in curing abdominal ulcer and to treat indigestion. |
| 150 | *Trichosanthes cucumerina* L. | Ban chichinda | H | Fr | Autum | Considered as cathartic and anthelmintic. |
| 151 | *Trichosanthes dioica* Roxb.[$] | Parwar | C | Fr | | Considered to be diuretic and laxative. Useful to the patients with circulatory system disorders. |
| ***Family: Cyperaceae*** | | | | | | |
| 152 | *Cyperus rotundus* L. | Mothe | H | Tu | | Tuber is used for the treatment of dysmenorrheal and menstrual irregularities. Used to treat skin diseases, tooth decay and pain. |
| ***Family: Dilleniaceae*** | | | | | | |
| 153 | *Dillenia indica* L. | Panchphal | T | Fr | Jan-Feb | Used as a laxative and cosmetics to prevent dandruff. It increases appetite and used in diabetes. |
| 154 | *Dillenia pentagyna* Roxb. | Tantari, Nepali elephant apple[1] | T | Sh, Fl, Fr | Mar-Apr | Endangered species. Fruits are used for dropsy therapy to relieve pain and to treat diabetes. Leaf decoction for the treatment of chest pain, cancers and burns. |
| ***Family: Dioscoreaceae*** | | | | | | |
| 155 | *Dioscorea alata* L.[$] | Ghartarul | C | Tu | Dec-Feb | Used as a diuretic, aphrodisiac, anthelmintic and antidiabetic. |
| 156 | *Dioscorea belophylla* (Prain) Voigt ex Haines | Tarul | C | Tu | | |

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| 157 | *Dioscorea bulbifera* L. | Githa | C | Tu | Dec-Feb | Juice is used in cuts and wounds, and to expel intestinal worms. |
| 158 | *Dioscorea deltoidea* Wall. ex Griseb. | Bhyakur | C | Tu, Fr | Dec-Feb | Used to get relief from the intestinal worms, and in orthopaedic and metabolic disorders. |
| 159 | *Dioscorea esculenta* (Lour.) Burkill | Tarul | C | Rt, Tu | Dec-Feb | Tuber paste is applied in ulcer, boils and abscess. Used as a contraceptive in the treatment of menopausal symptoms and genital disorders. |
| 160 | *Dioscorea hamiltonii* Hook. f.[$] | Bantarul | C | Tu, S | | |
| 161 | *Dioscorea kamaoonensis* Kunth. | Tyaguna | C | Tu | | |
| 162 | *Dioscorea oppostifolia* L. | Gidha | C | Tu | | Promotes health and longevity. |
| 163 | *Dioscorea pentaphylla* L. [*Dioscorea triphylla* L.] | Mithetarul | C | Tu | Dec-Feb | Useful as anti-inflammatory, antimicrobial and antiaging. |
| 164 | *Dioscorea pubera* Blume | Panglang | C | Tu | | |
| ***Family: Ebenaceae*** | | | | | | |
| 165 | *Diospyros malabarica* (Desr.) Kostel. | Khalluk, Tendu, | T | Fr, Lf | | Useful in curing of sore throat. |
| ***Family: Ericaceae*** | | | | | | |
| 166 | *Rhododendron arboretum* Sm. | Laligurans | T | Fl | Feb-Apr | It is Nepal's national flower. Flower juice used as a refresher, appetizer and to prevent high altitude sickness. Dried flower efficacious in diarrhea, dysentery and diabetes. |
| ***Family: Euphorbiaceae*** | | | | | | |
| 167 | *Euphorbia hirta* L. | Dudheghans | H | Lf | May-Jun | It is a popular herb among traditional medicine practitioners to cure several ailments. Also used as an antidote of scorpion-stings and snake bites. |
| 168 | *Euphorbia royleana* Boiss. | Siudi | S | Fl | | |

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| 169 | *Manihot esculenta* Crantz[$] | Simaltarul | S | Tu | Dec-Feb | It is a cheap source of daily carbohydrate in some tropical developing countries; however, it constituted toxic cyanogenic glycosides which are health hazardous. |
| 170 | *Ricinus communis* L. | Ander | T | Fr, Fl | May-Oct | It produces castor oil. Possesses purgative and laxative properties. |
| ***Family: Fagaceae*** | | | | | | |
| 171 | *Castanopsis indica* (Roxb. ex Lindl.) A. DC.[$] | Katus | T | Sh, Fr | Sep-Nov | Leaf deccoction for treatment of stomach disorders and skin diseases. Leaf shows antitumor and CNS depressant activitites. |
| ***Family: Icacinaceae*** | | | | | | |
| 172 | *Natsiatum herpeticum* Buch.-Ham. ex Arn. | Kalilahara | H | Lf | May-Jun | Used to cure headache and influenza. Leaf paste is used for quick healing of cuts and wounds. |
| ***Family: Lamiaceae*** | | | | | | |
| 173 | *Gmelina arborea* Roxb. | Khamari | T | Fl | Summer | It is given in blood diseases. |
| 174 | *Leucas cephalotes* (Roth) Spreng. | Guma | H | Lf | Mar-Jun | Used in digestive disorders and toothache. |
| 175 | *Mentha spicata* L. | Pudina | H | Sh | Whole year | It has cooling effect and useful in treating gastrointestinal disorders. |
| 176 | *Platostoma hispidum* (L.) A.J. Paton [*Acrocephalus capitatus* (Roth) Benth.] | Leruwi jhangi[6] | H | Wp | | |
| 177 | *Thymus linearis* Benth. | Ghoda marcha | S | Lf | | Used as appetic stimulant, blood purifier and antiviral. Decoction used in gum problems. |
| ***Family: Leguminosae*** | | | | | | |
| 178 | *Acacia rugata* (Lam.) Fawc. & Rendle | Sikakai | C | Sh | Jun-Aug | |
| 179 | *Bauhinia malabarica* Roxb. | Amilotanki | T | Fl | Aug-Sep | |
| 180 | *Bauhinia purpurea* L. | Tanki | T | Sh, Fl | Aug-Oct | Used as a laxative. |
| 181 | *Bauhinia vahlii* Wight & Arn. | Bhorla | C | Pd | Aug-Sep | |

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| 182 | *Bauhinia variegata* L.[$] | Koiralo | T | Sh, Lf, Fl, Bd | Apr-May | Useful for the treatment of diarrhoea, worms, piles and tumours. Flowers are laxative. Bud decoction is given in cough, piles, haematuria and menorrhagia. |
| 183 | *Caragana brevispina* Benth. | Bebalikanda | S | Fl | Aug-Sep | Decoction for relieving pains. |
| 184 | *Cassia fistula* L. | Rajbrikshya | T | Fr | | Useful in constipation. |
| 185 | *Crotalaria pallida* Aiton | Jhyalicha swan[4] | H | Fl | May-Jun | |
| 186 | *Crotalaria spectabilis* Roth | Bansanai | H | Fl | Aug-Nov | Useful in skin diseases. |
| 187 | *Crotalaria tetragona* Andrews | Bhugan | H | Fr, Sd | Sep-Oct | |
| 188 | *Entada phaseoloides* (L.) Merr. | Pangra | C | Sd | | Seeds are considered as tonic, emetic, antiperiodic and anthelmintic. |
| 189 | *Glycyrrhiza glabra* L. | Jethimadhu | H | Sh | Dec-Feb | Anbacterial and antiviral. Useful in cold, sore throat, weakness, pains and skin diseases. Used for composting as it is rich in nitrogen content. |
| 190 | *Indigofera atropurpurea* Hornem. | Sakhino | S | Fl | | |
| 191 | *Indigofera cassioides* DC. | Sakhino | S | Fr, Fl | | |
| 192 | *Indigofera hebepetala* Baker | Masino sakhino | S | Fr | Aug-Sep | |
| 193 | *Lablab purpureus* (L.) Sweet [*Dolichoslablab* L.] | Simi | C | Sd | | Seeds are considered as febrifube, stomachic, antispasmodic and aphrodisiac. |
| 194 | *Lathyrus aphaca* L. | Bankhesari, Bahabulaba | H | Lf | Mar-Apr | It may produce narcotic effects. |
| 195 | *Maughania philippinensis* (Merr. & Rolfe) H.L. Li [*Flemingia macrophylla* (Willd.) Merr.] | Bhatamaase | S | Lf | | Leaf is febrifuge and is used for treating postpartum fever, paralysis and pains. |
| 196 | *Medicago falcate* L. | Bhirin sag | H | Lf | Sep-Dec | |
| 197 | *Mimosa pudica* L. | Lajawati, Buharijhar | H | Sh, Lf | | Hair loss and toxic symptoms occurs at large dose. A paste is applied to glandular swellings. Leaf juice is used in sores and piles. |

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| 198 | *Mucuna pruriens* (L.) DC. | Kauso | C | Fr | | Acridic. Consumption may cause itching and blisters. |
| 199 | *Piptanthus nepalensis* (Hook.) D. Don | Suga phool | S | Fl | Apr-May | |
| 200 | *Pithecellobium dulce* (Roxb.) Benth. | Jalebi | S | Fr, Fl | May-Jun | |
| 201 | *Senna tora* (L.) Roxb. [*Cassia tora* L.] | Chakramandi | H | Lf | Jul-Aug | |
| 202 | *Vicia hirsuta* (L.) Gray | Kutilkosa | H | Fr, Lf | Jun-Jul | |
| 203 | *Vicia sativa* subsp. *Nigra* (L.) Ehrh. [*Vicia angustifolia* L.] | Kutilkosa | H | Fr | Mar-Apr | Useful in diarrhoea. |
| ***Family: Liliaceae*** | | | | | | |
| 204 | *Clintonia udensis* Trautv. & C.A. Mey. [*Hylocharis cyanocarpa* Tiling] | Bead lily[1] | H | Lf | Mar-Jun | |
| 205 | *Lilium nepalense* D. Don | Khiraulo, Banlasun | H | Lf, Bl | Mar-Apr | Useful for heart diseases and pains. |
| ***Family: Linaceae*** | | | | | | |
| 206 | *Reinwardtia indica* Dumort. | Pyauli | S | Lf | | Used in skin infections like boils, pimples and carbuncles. |
| ***Family: Malvaceae*** | | | | | | |
| 207 | *Abelmoschus manihot* (L.) Medik. | Bannalu | H | Fr | May-Jun | |
| 208 | *Abelmoschus moschatus* Medik. | Latakasturi | H | Fr | May-Jun | Useful in hysteria and other nervous troubles. |
| 209 | *Bombax ceiba* L. | Simal, Red silk cotton tree[1] | T | Fl, Fr, Sd | Feb-Mar | Used in gastrointestinal and skin diseases, gynecological and urinogenital disorders, diabetes and impotence. |
| 210 | *Corchorus aestuans* L. [*Corchorus acutangulus* Lam.] | Nalu[4] | H | Lf | Jun-Jul | Useful in dysentery. |
| 211 | *Hibiscus sabdariffa* L. | Chhuka | S | Lf, Fr | Winter | Used as a flavouring agent and herbal drinks. Leaves are used for diuretic, cholerectic, febrifugal and hypotensive effects, decreasing of blood viscosity and stimulating intestinal peristalsis. |

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| 212 | *Malva parviflora* L. | Kongatahari[6] | H | Lf | Winter | Used in the treatment of purulent wounds, boils and sores. Leaf tea is used for treating cough and bronchitis. |
| 213 | *Malva verticillata* L. | Lafe sag | H | Lf | May-Jun | Used as an herbal tea. |
| | ***Family: Melanthiaceae*** | | | | | |
| 214 | *Paris polyphylla* Sm. | Satuwa | H | Lf, Rt | | Useful as analgesic, antitussive, febrifuge and narcotic. Root decoction is used in snake bite. |
| | ***Family: Menispermaceae*** | | | | | |
| 215 | *Cissampelos pareira* L. | Batulpate, Gudargano | H | Lf | | Leaf used to treat problems related to female reproductive systems e.g. hormonal disbalance, miscarriage, excessive menstrual bledding, uterine haemorrhage, etc. |
| | ***Family: Moraceae*** | | | | | |
| 216 | *Artocarpus heterophyllus* Lam.[$] | Katahar | T | Fr | Apr-Jun | Used to treat mastitis. |
| 217 | *Artocarpus lacucha* Buch.-Ham. [*Artocarpus lakoocha*Roxb.] | Badahar | T | Sh, Fr | Jun-Aug | Possesses antinociceptive, antiaging, taeniasis properties. Fruit is an excellent source of vitamin C and β-crotene. |
| 218 | *Ficus auriculata* Lour. | Timilo, Bhutuk | T | Sh, Lf | Jan-Mar | Latex is used to treat diarrhea, dysentery, cuts and wounds. |
| 219 | *Ficus hispida* L.f. | Thotne, Khasreto | T | Fr | Jul-Aug | Fruits have emetic and purgative effects. |
| 220 | *Ficus lacor* Buch.-Ham.[$] | Kavro | T | Bd, Lf, Fr | May-Jun | Buds decoction is used in leucorrhoea, boils, pimples, blisters and gingivitis. Fruit is neuroprotective and leaf is antifilarial. |
| 221 | *Ficus neriifolia* Sm. | Dudhilo | T | Sh, Fl | | Latex is applied in boils on the tongue. |
| 222 | *Ficus palmata* Forssk. | Bedu, Anjir | T | Lf, Fr | | Fruit is demulcent, emollient, laxative and poultice. It is used for making squash, jam and jelly, and used in lungs and bladder diseases. |

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| 223 | *Ficus racemosa* L. | Dumri | T | Fr | Jul-Sep | Used as a remedy for visceral obstruction, diarrhea, constipation and diabetes. |
| 224 | *Ficus rumphii* Bl. | Pakar | T | Lf | May-Jun | Used in stomach disorders and as a blood purifier. |
| | ***Family: Moringaceae*** | | | | | |
| 225 | *Moringa oleifera* Lam.[$] | Sitalchini, Sajiwan | T | Pd, Fl, Fr, Sh | Mar-Jun | It is claimed as the most nutrient-rich plant yet discovered. Useful in diabetes, and can decrease urea and creatinine in blood preventing renal dysfunction. |
| | ***Family: Musaceae*** | | | | | |
| 226 | *Ensete glaucum* (Roxb.) Cheesman | Bankera | S | Fr | | Rich source of calcium, iron, potassium, magnesium, sodium and phosphorus. |
| 227 | *Musa acuminata* Colla[$] | Bankera | T | Fr | | It contributes daily requirement of vitamin C and minerals. Antioxidant, anticancer, antidiabetic, anti-HIV, antimicrobial, immunomodulatory and hypolipidemic activities are reported. |
| 228 | *Musa balbisiana* Colla | Bankera | H | Fr | | Rich source of calcium, iron, potassium, magnesium, sodium and phosphorus. |
| | ***Family: Nyctaginaceae*** | | | | | |
| 229 | *Boerhavia diffusa* L. | Punarva | H | Lf | Jun-Jul | It is an important herb in Ayurveda, and said to be antiaging and hepatoprotective. Useful in spleen enlargement, abdominal pains, joint pains and bronchial asthma. |
| 230 | *Mirabilis jalapa* L. | Four o'clock plant[1] | H | Lf | | It is popular for coloured flowers with pleasant fragrance. Useful in dysentery, constipation, diabetes and genitourinary disorders. Poisoning of children by consuming roots, seeds or fruits has been reported. |

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| | ***Family: Oxalidaceae*** | | | | | |
| 231 | *Oxalis corniculata* L. | Chariamilo | H | Lf | Apr-Oct | Used to treat stomach disorders and dysentery. Used to relieve intoxication produced by *Datura*. |
| | ***Family: Paeoniaceae*** | | | | | |
| 232 | *Paeonia emodi* Royle | Hetto | H | Lf, Sh | | Useful in cough. |
| | ***Family: Phyllanthaceae*** | | | | | |
| 233 | *Antidesma acidum* Retz. | Archal | T | Lf, Fr | Sep-May | Leaves are used in the treatment of diabetes, and fruits are used as tonic and appetizer. |
| 234 | *Phyllanthus emblica* L.[$] | Amala | T | Fr | Oct-Dec | Fruits are extensively used as a tonic and for several therapeutic effects in the Ayurvedic and Unani medicinal systems. |
| | ***Family: Phytolaccaceae*** | | | | | |
| 235 | *Phytolacca acinosa* Roxb. | Jaringo sag | H | Lf | May-Jun | It is used as a diuretic and for the treatment of edema, swelling and sores. |
| | ***Family: Piperaceae*** | | | | | |
| 236 | *Peperomia pellucida* (L.) Kunth | Latapate | H | Lf | Jul-Aug | It has worldwide diversified uses. Used in skin diseases, breast cancer, cough, edema, constipation, renal diseases, mental disorder, tetanus, etc. |
| | ***Family: Plantaginaceae*** | | | | | |
| 237 | *Bacopa monnieri* (L.) Wettst. | Khole sag | H | Sh | Feb-Mar | Useful in dysentery and nervous disorder. |
| 238 | *Plantago asiatica* subsp. *erosa* (Wall.) Z. Yu Li [*Plantago erosa* Wall.] | Isbgol | H | Lf | Jan-Feb | Useful in fever, boils, pains, diarrhoea and urinary tract complaints. |
| 239 | *Plantago lanceolata* L. | Isapgol | H | Lf | Jan-Feb | Crushed leaves mixed with salt or honey is used to treat arthritis. |
| 240 | *Veronica beccabunga* L. | Khole sag | H | Lf | | It is a succulent herb. It is an appetizer, alterative, diuretic and antiscorbutic. |
| | ***Family: Poaceae*** | | | | | |
| 241 | *Bambusa bambos* (L.) Voss [*Bambusa arundinacea* Retz.][$] | Bans | T | Sh | Jun-Aug | Useful in jaundice. |

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| 242 | *Bambusa nepalensis* Stapleton[$] | Choyabans | T | Sh | Jun-Aug | Acrid. It is considered to possess antifertility and insecticidal properties. |
| 243 | *Bambusa tulda* Roxb.[$] | Tusa | T | Sh | | Acrid. It is considered to possess antifertility and insecticidal properties. |
| 244 | *Cynodon dactylon* (L.) Pers. | Dubo | H | Sh | | Used in cuts and wounds. Juice is considered to be good for health. |
| 245 | *Dendrocalamus hamiltonii* Nees & Arn. ex Munro | Tama, Bans | T | Sh | Jun-Jul | Considered to be helpful in prevention of colon cancer and in controlling cholesterol level in blood. |
| 246 | *Dendrocalamus strictus* (Roxb.) Nees | Tamabans | T | Sh | Jun-Jul | Acrid. Used as a raw material for making papers and instruments. Used as a core for concrete in place of steel rods. |
| 247 | *Drepanostachyum falcatum* (Nees) Keng f. | Nigalo | T | Sh | Apr-Jun | |
| 248 | *Phragmites australis* subsp. *altissimus* (Benth.) Clayton [*Phragmites maximus* (Forssk.) Chiov.] | Narkat | S | Sh | Summer | |
| 249 | *Phyllostachys edulis* (Carrière) J. Houz. | Kattabans | H | Sh | | |
| 250 | *Thamnocalamus spathiflorus* (Trin.) Munro | Ban nigalo | S | Sh | Jun-Jul | Stems are used for making pipes, mats and baskets. |
| 251 | *Yushania maling* (Gamble) R.B. Majumdar & Karthik. [*Arundinariamaling* Gamble] | Malingo | H | Sh | | |
| ***Family: Polygonaceae*** | | | | | | |
| 252 | *Fagopyrum acutatum* (Lehm.) Mansf. ex K. Hammer [*Fagopyrum dibotrys* (D. Don) H. Hara] | Ban phaper | H | Lf | May-Jun | |
| 253 | *Fagopyrum esculentum* Moench | Mithe phapher | H | Lf | May-Jun | Useful in constipation, haemostatis, ulcer, hypertension, diabetes and gum bleeding. It is considered to improve the functions of sight and hearing. |
| 254 | *Fagopyrum tataricum* (L.) Gaertn. | Tite phaper | H | Lf | May-Jun | |

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| 255 | *Persicaria nepalensis* (Meisn.) Miyabe | Priyaghans | H | Lf | May-Jun | |
| 256 | *Polygonum microcephalum* D. Don [*Persicaria microcephala* (D. Don) H. Gross] | Banpire | H | Lf | Jul-Aug | |
| 257 | *Polygonum molle* D. Don [*Aconogonum molle* (D. Don) H. Hara] | Thotne | H | Tw | Dec-Mar | It is an astringent and used in diarrhoea. |
| 258 | *Polygonum perfoliatum* L. [*Persicaria perfoliata* (L.) H. Gross] | Ghumauro kanda | C | Lf | May-Jun | Possesses emollient property and used as a cataplasm on tumours. |
| 259 | *Polygonum plebeium* R.Br. | Baluni sag | H | Lf | Whole year | |
| 260 | *Polygonum runcinatum* Buch.-Ham. ex D. Don [*Persicaria runcinata* (Buch.-Ham. ex D. Don) H. Gross] | Ratnaulo | H | Wp | Jul-Aug | Useful in diarrhoea, bleeding, bruishes and mastitis. |
| 261 | *Rheum australe* D. Don [*Rheum emodii* Wall. ex Meisn.] | Padamchal | H | Lf | May-Aug | Acts as purgative. |
| 262 | *Rheum nobile* Hoof. f. & Thomas | Padamchal | H | Sh | Jun-Jul | It is pleasantly acidic in taste and is vulnerable. |
| 263 | *Rumex acetosa* L. | Amile ghans | H | Lf | Aug-Sep | Useful in jaundice, sore throat, scurvy, wound and wart. |
| 264 | *Rumex dentatus* L. | Palkimausi[6] | H | Lf | Jul-Aug | It has diuretic, refrigerant and cooling effects. |
| 265 | *Rumex hastatus* D. Don | Charemala | H | Lf | Feb-Mar | Juice is astringent and used in bloody dysentery. |
| 266 | *Rumex nepalensis* Spreng. | Halhale | H | Lf | Aug-Sep | Leaf juice is gargled with water to prevent gum bleeding. |
| 267 | *Rumex vesicarius* L. | Bhote palungo | H | Lf | May-Jun | Used as an antidote to scorpion sting. Useful to treat jaundice, liver problems and constipation. |
| ***Family: Pontederiaceae*** | | | | | | |
| 268 | *Eichhornia crassipes* (Mart.) Solms | Jalkumbhi | H | Lf, Pl, In | | It is a noxious troublesome aquatic weed. Used to treat goitre diseases, burns and minor injuries. It can be used for the production of high caloric fuel. |

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| 269 | *Monochoria hastate* (L.) Solms | Thokarak | H | Sh, Lf | Rainy | It is a noxious freshwater herb. Leaves are laxative and the paste is used for cattle with diarrhoea. Also used for the treatment of wounds, gastropathy and cough. |
| 270 | *Monochoria vaginalis* (Burm. F.) C. Presl | Duke's tongue[1] | H | Wp, Fl | | Used to treat cough, venereal and liver diseases, asthma, toothache, fever, scurvy, boils, hemorrhages, etc. |
| | ***Family: Portulacaceae*** | | | | | |
| 271 | *Portulaca oleracea* L. | Nundhiki | H | Sh | Whole year | Used as a folk medicine in many countries acting as a febrifuge, antiseptic, vermifuge, astringent and so forth for alleviating a wide range of diseases. |
| | ***Family: Primulaceae*** | | | | | |
| 272 | *Anagallis arvensis* L. | Armale | H | Lf | Dec-Mar | Used in fungal infections, wounds, snake and dog bites. It is toxic at high doses and potentially nephrotoic. |
| | ***Family: Ranunculaceae*** | | | | | |
| 273 | *Caltha palustris* L. | Cowslip[1] | H | Lf | Aug-Sep | Used as an antispasmodic and sedative, and used to treat arthritis, leprosy, rheumatism, gonorrhea and skin lesions. |
| 274 | *Clematis acuminata* DC. | Jungelahara | C | Sh | Jul-Aug | |
| 275 | *Clematis buchananiana* DC. | Jungelahara | C | Sh | Aug-Sep | |
| 276 | *Ranunculus diffuses* DC. [*Ranunculus vitifolius* D. Don] | Nakkorejhar | H | Lf | Jan-Feb | Used in rheumatism. |
| 277 | *Ranunculus sceleratus* L. | Jaldhaniyaa, Dhungrejhar | H | Lf | Whole year | All parts of the plant are poisonous when fresh, but the toxins are destroyed when the plant is heated or dried. It can be used in internal abscess, malaria, snake or scorpion venom, asthma, arthritis, etc. |
| | ***Family: Rhamnaceae*** | | | | | |
| 278 | *Ziziphus jujuba* Mill. [*Ziziphus mauritiana* Lam.][$] | Bayer | S | Fr | | Fruit is mucilaginous, cooling, digestible, laxative, tonic and considered to purify blood. |

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| | ***Family: Rosaceae*** | | | | | |
| 279 | *Pyrus pashia* Buch.-Ham. ex D. Don | Mayel | T | Fr, Sd | | It is an astringent. |
| | ***Family: Rubiaceae*** | | | | | |
| 280 | *Adina cordifolia* (Roxb.) Hook. f. [*Haldina cordifolia* (Roxb.) Ridsdale] | Karam, Karma | T | Fr | | |
| 281 | *Catunaregam spinosa* (Thunb.) Tirveng. [*Xeromphis spinosa* (Thunb.) Keay; *Randia dumetorum* (Retz.) Lam.] | Mainkanda, Mainphal, Mainato | S | Fr, Fl | Summer | Used in piles, dysentery, asthma, jaundice and gonorrhea. |
| 282 | *Ceriscoides campanulata* (Roxb.) Tirveng [*Gardenia companulata* Roxb.; *Gardenia blumeana* DC; *Genipa campanulata* (Roxb.) Bail] | Pedar | S | Fl | Spring | It is a highly restricted distribution within Nepal, and no significant information is available. |
| 283 | *Spermadictyon suaveolens* Roxb. | Banchampa | S | Sh | Aug-Sep | It is pharamacologically a lesser known but cultivated for its fragnant flower. |
| 284 | *Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre [*Randia uliginosa* (Retz.) Poir.] | Maidal, Pidar | T | Fr | Sep-Oct | Fruits are used for curing of dysentery and as a fish poison. |
| | ***Family: Rutaceae*** | | | | | |
| 285 | *Murraya koenigii* (L.) Spreng. | Karry patta | S | Lf | Feb-Jun | Useful in stomach disorders and vomiting. |
| | ***Family: Sapotaceae*** | | | | | |
| 286 | *Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev. [*Bassia latifolia* Roxb.; *Madhuca latifolia* (Roxb.) J.F. Macbr.; *Madhuca indica* J.F. Gmel.] | Mahuwa, Butter nut tree[1] | T | Fl, Fr | Mar-Apr | It is a highly nutritious tree. Flowers are used in respiratory infections and worm infestation. Fruits are used in chronic ulcers. |
| | ***Family: Saururaceae*** | | | | | |
| 287 | *Houttuynia cordata* Thunb. | Gane | H | Sh | May-Jun | Useful for the freshness, good sleep heart disorders. |
| | ***Family: Smilacaceae*** | | | | | |
| 288 | *Smilax aspera* L. [*Smilax rigida* Sol. ex Sm.][$] | Kukurdaino | C | Sh | May-Jun | Used in gastritis. |
| 289 | *Smilax ferox* Wall. ex Kunth | Kukurdaino | C | Sh | May-Jun | Useful in chronic skin affections. |
| 290 | *Smilax lanceifolia* Roxb. | Chhatiwan | C | Sh | May-Jun | |

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| 291 | *Smilax ovalifolia* Roxb. ex D. Don [*Smilax macrophylla* Roxb.] | Kukurdaino | C | Sh, Lf, Fr | May-Jun | Leaves are used to treat skin problems, veneral diseases and rheumatic complaints. |
| 292 | *Smilax perfoliata* Lour. | Kukurdaino | C | Sh, Lf, Fr | May-Jun | Juice is applied in rheumatism. |
| 293 | *Smilax zeylanica* L. | Kukurdainy | H | Lf, Sh | | |
| ***Family: Solanaceae*** | | | | | | |
| 294 | *Physalis minima* L. | Photongi[2] | H | Fr | Winter | Useful for the treatment of hypertension, diabetes and malaria. |
| 295 | *Solanum aculeatissimum* Jacq. | Kantakari | H | Fr | Summer-rainy | Used to relieve headache and to treat intestinal diseases. |
| 296 | *Solanum americanum* Mill. [*Solanum nigrum* L.] | Kalobihi | H | Lf | May-Jun | It has antiseptic and antidysenteric properties. It is also credited with emollient, diuretic and laxative properties. Its decoction is regarded as an antispasmodic and narcotic. |
| 297 | *Solanum surattense* Burm. f. | Charhenti[6] | H | Fr | | Carminative and antibacterial. |
| 298 | *Solanum torvum* Sw. | Thulobihi | S | Fr | Aug-Oct | Useful for cough ailments and liver and spleen problems. |
| ***Family: Sphenocleaceae*** | | | | | | |
| 299 | *Sphenoclea zeylanica* Gaertn. | Wedgewort[1] | H | Lf, Sh | May-Jun | Useful to cure ulcers. |
| ***Family: Talinaceae*** | | | | | | |
| 300 | *Talinum portulacifolium* (Forssk.) Asch. ex Schweinf. [*Talinum cuneifolium* (Vahl) Willd.] | Chinia sag | H | Lf, St | | Useful to treat arthritis, diabetes, hepatitis, mouth ulcers and constipation. |
| ***Family: Typhaceae*** | | | | | | |
| 301 | *Typha angustifolia* L. | Pat | H | Lf | Summer-rainy | It tastes like asparagus. |
| 302 | *Typha latifolia* L. | Pat | H | Sh | Whole year | |
| ***Family: Urticaceae*** | | | | | | |
| 303 | *Boehmeria macrophylla* Hornem. [*Boehmeria ternifolia* D. Don; *Boehmeria platyphylla* D. Don] | Chalnusisnu, Kamle | S | Lf | | Useful in dermatitis, boils and trauma. |
| 304 | *Elatostema platyphyllum* Wedd. | Sano gangleto | H | Lf | May-Jun | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 305 | *Elatostema sessile* J.R. Forst. & G. Forst. | Gangleto | H | Lf, Sd | May-Jun | A poultice of the leaves is used for abdominal disorders. |
| 306 | *Girardinia diversifolia* (Link) Friis | Allosisnu, Allo sag | H | Sh, Lf, In, Sd | Jun-Aug | Leaf juice is applied to treat headache and joint pains. |
| 307 | *Girardinia palmata* (Forssk.) Gaudich. | Sisnu | H | Lf | | Leaves are applied for headaches and swollen joints. A decoction is useful in fevers. |
| 308 | *Lecanthus peduncularis* (Wall. ex Royle) Wedd. | Kholejhar | H | Lf, Rt | May-Jun | |
| 309 | *Oreocnide frutescens* (Thunb.) Miq. | | S | Lf, Sd | Aug-Sep | Useful for the treatment of pain, inflammation, menstrual disturbance and promoting hair growth. It is used to make ropes, nets and cloths. |
| 310 | *Pilea symmeria* Wedd. | Kamle | H | Lf | May-Jun | |
| 311 | *Pilea umbrosa* Blume | Nildanthe | H | Lf | May-Jun | |
| 312 | *Pouzolzia sanguinea* (Blume) Merr. | Red-stem Pouzolz's bush[1] | H | Lf | Jul-Aug | |
| 313 | *Pouzolzia zeylanica* (L) Benn. | Banpaate, Nicha sag | H | Lf | | Useful in pulmonary diseases, urinary infections, swellings and dysentery. |
| 314 | *Urtica dioca* L.[$] | Sisnu | H | Sh, Lf, In | Whole year | Useful in cough and cold. |
| 315 | *Urtica hyperborea* Jacq. ex. Wedd. | Sisnu | H | Sh | | Used in swellings and cleaning of stomach. |
| 316 | *Urtica parviflora* Roxb. | Sisnu | H | In, Lf | | Useful as an expectorant and as a blood-purifier. |
| ***Family: Vitaceae*** | | | | | | |
| 317 | *Cissus javana* DC. | Jogilahara | C | Lf | Sep-Nov | Useful to treat kidney stone. |
| ***Family: Zingiberaceae*** | | | | | | |
| 318 | *Cautleya spicata* (Sm.) Baker | Sanosaro | H | St | May-Jun | |

[§] Name in Nepali language, unless otherwise indicated. Name in other language is indicated as: 1 = Common name; 2 = Darai; 3 = Hindi; 4 = Newari; 5 = Sherpa; 6 = Tharu; and 7 = Tibetan.

[¶] General appearance of the plant categorized as: C = Climber; H = Herb; S = Shrub; and T = Tree.

[♯] Plant parts eaten are abbreviated as: Bd = Bud; Bl = Bulb; Bn = Bean; Co = Corm; Fl = Flower; Fr = Fruit; In = Inflorescence; Lf = Leaf (Tender leaf); Pd = Pod; Pe = Petal; Pi = Pith; Pt = Petiole; Rh = Rhizome; Ro = Root; Sd = Seed; Sh = Shoot (young tender shoot); St = Stem; Tu = Tuber; Tw = Twig; and Wp = Whole plant.

*Informations are gathered from various sources.

[$] Species available in the market for purchasing.

## Nutraceuticals and Bioactive Phytochemicals of the Wild Vegetables

The quality of food depends upon the availability of the centration of various nutrients such as carbohydrates, proteins, enzymes, fats, amino acids, vitamins, minerals, and anti-nutritional parameters. Vegetables are important nutrient souce for the human health and they complement other food sources. In Nepal, several ethnic communities rely on wild resources to meet their food requirements. In the rural areas of Nepal and in some particular ethnicities like Chepangs and Rautes, the tubers of *Dioscorea* are one of the important sources of carbohydrates. Tubers of *Dioscorea alata* (Ghar tarul), *Dioscorea bulbifera* (Githa), *Dioscorea deltoidea* (Bhyakur) and *Dioscorea pentaphylla* (Mithe tarul) also contain a high protein amount, comparativey higher than reported value for potato and sweet potato, thus these tubers are nutritionally desirable tropical species (Wanasundera & Ravindran, 1994; Bhandari et al., 2003).

Among all vegetables, green leafy vegetables have occupied a unique place because of their color, flavor, and health benefits. Leaves of many plants are aromatic, sour, sweet, bitter or tasteless, and they can provide proteins, vitamins, minerals, and essential amino acids. They provide adequate amounts of crude fiber, carotene, vitamins, folic acid and mineral salts like Ca, Fe, P, Zn, etc. They are also fair sources of proteins (containing about 2–7%) (Aletor et al., 2002). They are also a rich source of a number of micronutrients and phytochemicals that provide the disease fighting power. They are highly seasonal available and easily cooked.

There are numerous nutritional edible wild plants gathered in Asian (China, Japan, India, etc.) and African countries. For the most species, the moisture content of the edible leaves ranged from 70–90% (Guerrero & Isasa, 2003). Comparably, the nutritional values and minerals content of wild edible plants were richer than that of commercial vegetables, and hence could be used for nutritional suppliments (Seal, 2012). However, nowadays, the food habit is changing with the changing of life style. People are gradually depending on readymade packed foods made up of grains, meats and sweets neglecting vegetables, fruits and nuts. As a result, the health of the people is deteriorating, and simultaneously the food plants are being neglected at large. Therefore, wild vegetables could serve as an indispensable constituent of the human diet, supplying abundant of minerals, vitamins, bioactive secondary metabolites and certain hormone precursors, together with protein, carbohydrate and energy. Wild green vegetables possess high concentrations of iron and β-carotene, which is the precursor of vitamin A. They are also important sources of vitamin C (ascorbic acid) that enhance the absorption of the non-haeme iron present in a diet consisting primarily in grains. Among the wild leafy vegetables, *Urtica dioica* (Sisnu) is one of the readily available but largely neglected vegetables. It is the richest source of proteins and calcium of all cultivated and wild vegetables supplying abundant amounts of folic acid, iron, calcium, proteins, vitamins A, C, K, and riboflavin (Gopalan et al., 1984; Adhikari & Krantz, 1989).

The study of wild vegetables is important not only to identify the potential food source, but also to select promising types for the domestication. In the recent years, various lesser known plants are being evaluated for their nutritional and medicinal properties; however, there are still a large number of edible plant species have not been investigated yet. Among wild plants, edible ferns also play an important role, even though; they are often neglected in our daily diet. In Table 7.3, a few examples of the nutrional analysis of some wild vegetable of Nepal are presented.

**Table 7.3.** Proximate analysis of some wild vegetables of Nepal (values in g/100 g of dried material)

| Species (Nepali name) | Part used | Ash | Carboh-ydrate | Protein | Fat | Fiber | Minerals | Reference |
|---|---|---|---|---|---|---|---|---|
| *Allium pratii* (Rukpa) | Leaf | 12.0 | 61.7 | 24.6 | 1.6 | – | K, Na, Fe, Mn, Zn, Cu | (Bajracharya et al.,2013) |
| *Artocarpus lacucha* (Badahar) | Shoot | 8.0 | 0.8 | 28.6 | 1.5 | 1.5 | – | (Dhungana et al., 2012) |
| *Asparagus racemosus* (Kurilo) | Tender shoot | – | 6.8* | 5.2* | 2.1* | 3.2 | – | (Malla, 2015) |
| *Castanopsis indica* (Katus) | Fruit | 1.3 | 17.0 | 3.4 | – | – | K, Na, Ca, Mg | (Bajracharya, 1980) |
| *Choerospondias axillaris* (Lapsi) | Fruit | 4.4 | 7.5 | 10.0 | – | – | K, Ca, Mg | (Bajracharya, 1980) |
| *Dioscorea bulbifera* (Githa) | Tuber | 1.2* | 25.9* | 3.1* | 0.3* | 1.1* | K, Na, P, Ca, Mg, Cu, Fe, Mn, Zn | (Bhandari et al., 2003) |
| *Dioscorea deltoidea* (Bhyakur) | Tuber | 0.6* | 17.4* | 1.6* | 0.2* | 1.5* | K, Na, P, Ca, Mg, Cu, Fe, Mn, Zn | (Bhandari et al., 2003) |
| *Dioscorea esculenta* (Tarul) | Tuber | 0.5* | 17.5* | 1.7* | 0.2* | 1.1* | K, Na, P, Ca, Mg, Cu, Fe, Mn, Zn | (Bhandari et al., 2003) |
| *Dioscorea pentaphylla* (Mithe tarul) | Tuber | 0.6* | 20.0* | 2.3* | 0.2* | 0.6* | K, Na, P, Ca, Mg, Cu, Fe, Mn, Zn | (Bhandari *et al.* 2003) |
| *Diplazium esculentum* (Masino niuro) | Tender leaf | 1.4 | 4.9 | 3.4 | 0.2 | – | Fe | (Subba et al., 2001) |
| *Ficus lacor* (Kavro) | Shoot | 4.0 | 9.4 | 17.6 | 1.9 | 42.1 | – | (Dhungana et al., 2012) |
| *Ophioglossum vulgatum* (Jibre sag) | Tender leaf | 1.0 | 3.4 | 2.5 | 1.0 | – | Ca, Fe | (Subba et al., 2001) |
| *Phyllanthus emblica* (Amala) | Fruit | 2.2 | 12.0 | 11.4 | – | – | K, Ca, Mg | (Bajracharya, 1980) |
| *Pyrus pashia* (Mayel) | Fruit | 2.3 | 26.0 | 10.0 | – | – | K, Ca, Mg | (Bajracharya, 1980) |
| *Tectaria macrodonta* (Kalo niuro) | Tender leaf | 1.1 | 4.2 | 2.9 | 0.3 | - | Ca, Fe | (Subba et al., 2001) |

* Values in g/100 g of fresh plant materials used.

Scientific studies have proved that plants produce a variety of chemicals to protect themselves as well as humans from various diseases and pathogens. These chemicals donot categorized under 'essential nutrients' and used a new term 'phytochemicals' due to their plant origin. A large number of dietary phytochemicals have been identified, out of which, only a small fraction has been studied closely, while a large percentage of these compounds still remain unknown with respect to their biological role (Liu, 2013). Some phytochemicals exhibit in vitro or in vivo biological activities, hence they are called as 'bioactive phytochemicals'. The bioactive phytochemicals mainly include phenolics, flavonoids, terpenoids, alkaloids, and steroids which produce health benefits. Effectiveness of plant species against wide array of microorganisms is primarily due to flavonoids, which also play significant role in the protection of lipids and vital cell components damaging from oxidation (Lovkova et al., 2001). Flavonoids are potent scavengers of singlet oxygen and a variety of free radicals, which are perhaps concerned with DNA damage and tumor promotion. Thereby, flavonoids with possessing of potential nutritional and therapeutic values, act as anticancer, neuroprotective, cardioprotective, antiaging agents and many more (Marchand, 2002). Flavonoids also provide bright colors to plant petals contributing in plant pollination (Escarpa & González, 2000). It is noteworth to mention that majority of the wild edible plants contain alkaloids which determine the special taste of wild plants differring from the cultivated ones, and also able to produce therapeutic effects.

A large number of phytochemicals have been isolated form the different parts of the wild vegetables by different research groups world-wide. Herein, we present some examples of bioactive phytochemicals with their biological activity considering that they are also present in the corresponding part of the wild vegetables consumed in Nepal (Figure 7.1). Drymaritin (**1**) isolated from the whole part of *Drymaria cordata* subsp. *diandra* (Aavijalo) has exhibited anti-HIV effects in H9 lymphocytes with an $EC_{50}$ value of 0.699 µg/mL (Hsieh et al., 2004). From the tubers of *Cyperus rotundus* (Mothe), 10, 12-peroxycalamenene (**2**) has been isolated that possessed a strong antimalarial effect against *Plasmodium falciparum* ($EC_{50} = 2.33 \times 10^{-6}$ M) (Thebtaranonth et al., 1995). The aerial parts of *Euphorbia hirta* (Dudhe ghans) constituted afzelin (**3**), quercitrin (**4**) and myricitrin (**5**), which also exhibited a strong antimalarial effect against *P. falciparum* with $IC_{50}$ values of 1.1, 4.1 and 5.1 µg/mL, respectively (Liu et al., 2007). Isolation of nortangeretin 8-O-β-D-glucuronopyranoside, malvaflavone A (**6**), isoscutellarein 8-O-β-D-glucuronopyranoside (**7**), hypolaetin 8-O-β-D-glucuronopyranoside (**8**), herbacetin 8-O-β-D-glucuronopyranoside (**9**), and herbacetin 3-O-β-D-glucopyranosyl-8-O-β-D-glucuronopyranoside (**10**) from the aerial parts of *Malva verticillata* (Lafe sag) were reported by Baek and co-workers (Ko et al., 2018). All these compounds **6**-**10** exhibited a high antioxidant activity with $EC_{50}$ value of 5.98-50 µM. Furthermore, compounds **6**, **8** and **9**

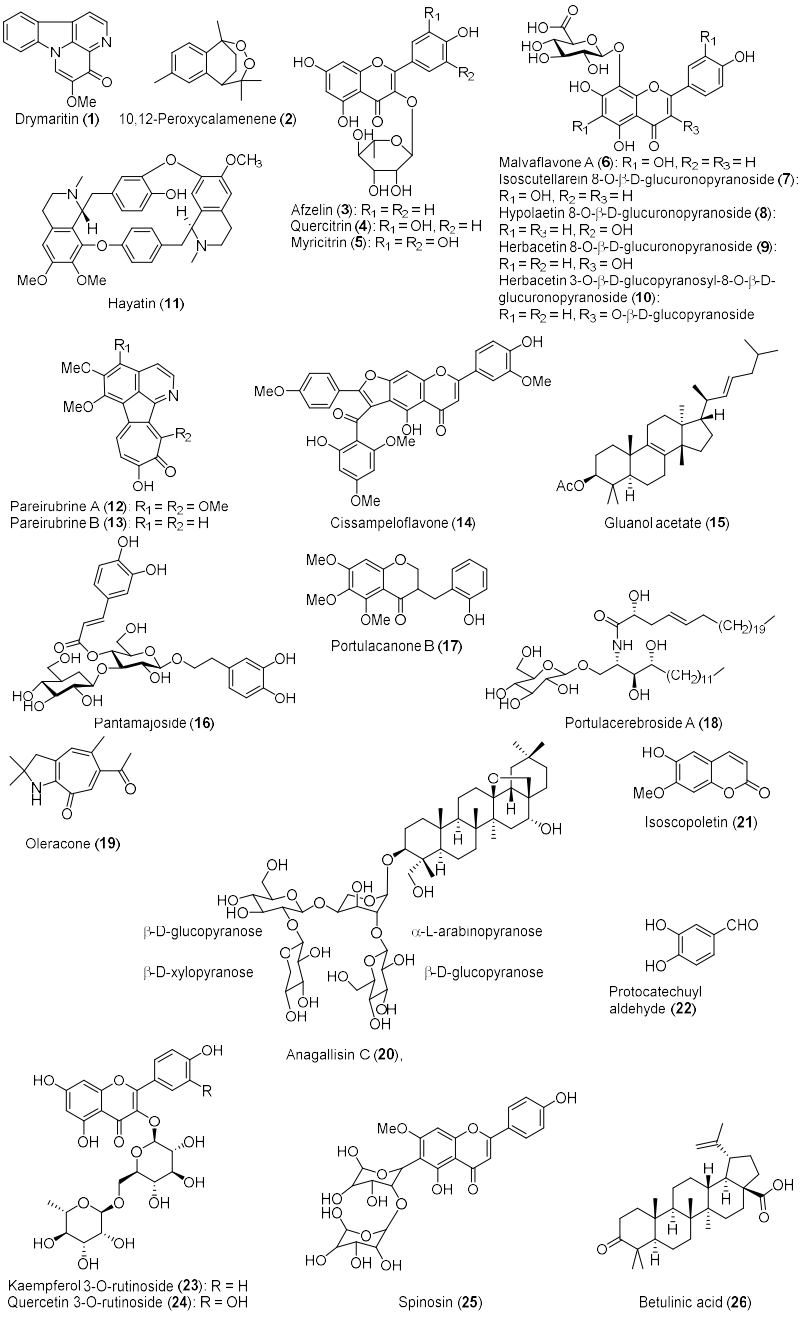



**Figure 7.1.** Some bioactive phytochemicals from the wild vegetables.

could repair damaged pancreatic islets in zebrafish larvae showing antidiabetic effect. Hayatin (**11**), an alkaloid, is one of the important constituents present in the roots of *Cissampelos pareira* (Batulpate). The methiodide and methchloride derivatives of compound **11** are muscle relaxant drugs that lower blood pressure (Pradhan & De, 1953; Basu, 1970). Pareirubrines A (**12**) and B (**13**), constituted in the aerial parts of *C. pareira*, were antileukemic substances against the P-388 cell line with $IC_{50}$ values of 0.33 and 0.17 µg/mL, respectively (Morita et al., 1993). And, cissampeloflavone (**14**), isolated from the aerial parts, has shown to be an active antiprotozoal agent against *Trypanosoma cruzi* and *Trypanosoma brucei rhodesiense* (Ramírez et al., 2003). Gluanol acetate (**15**), a tetracyclic triterpene of *Ficus racemosa* (Dumri) fruits was found to be a very potent larvicidal against fourth-instar larvae of *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus* (Rahuman et al., 2008.). From the leaves of *Plantago lanceolata* (Isapgol), a phenylethanoid plantamajoside (**16**) has been isolated, which exhibited antispasmodic activity (Fleer et al., 2007). Portulacanone B (**17**) was isolated from the aerial parts of *Portulaca oleracea* (Nundhiki), and this compound showed cytotoxic activity against SGC-7901 and NCI-H460 cells with $IC_{50}$ valuse of 16.2 and 17.8 µg/mL, respectively (Yan et al., 2012). Portulacerebroside A (**18**) was also isolated from the aerial parts of *P. oleracea* that stimulated human liver cancer HCCLM3 cell apoptosis *via* the activation of the p38 MAPK- and JNK-triggered mitochondrial death pathway showing anticancer property (Zheng et al., 2014). Alkaloid oleracone (**19**) present in *P. oleracea* displayed remarkable anti-inflammatory effect (Meng et al., 2016). A highest antifungal activity against *Candida albicans* with MIC = 0.5–1 µg/mL was reported for anagallisin C (**20**), which was isolated from the aerial parts of *Anagallis arvensis* (Armale) (Soberón et al., 2017). Isoscopoletin (**21**) and protocatechuyl aldehyde (**22**), isolated from the whole parts of *Ranunculus sceleratus* (Jal dhaniya, Dhungre jhar), have exhibited antiviral activity against hepatitis B virus and *Herpes simplex* virus type-1, respectively (Li et al., 2005). Kaempferol 3-O-rutinoside (**23**), quercetin 3-O-rutinoside (**24**) and spinosin (**25**) present in the fruits of *Ziziphus jujuba* (Bayer) exhibited neuroprotective effect (Zhu et al., 2007; Wang et al., 2010). Betulinic acid (**26**), present in the fruits of *Z. jujuba*, showed anti-inflammatory, antibacterial inhibiting the growth of *Staphylococcus aureus* and *Eschericheria coli*, antiviral, and anticancer properties (Pisha et al., 1995; Eiznhamer & Xu, 2004).

## Conclusion

Wild edible plants are very important nutrional sources in our daily diet. They are healthy, medicinal, seasoning and famine foods. Wild vegetables are an essential diet particularly for the poor rural people while they are fascinating food for people residing in the urban areas. In this chapter, altogether 318 pteridophytic and angiospermic wild species that consumed in Nepal as cooked vegetables are listed. Some of these wild species, such as *Arisaema costatum* (Jangali makai), *Sauromatum diversifolium* (Dwa), *Mimosa pudica* (Lajawati, Buhari jhar), *Mirabilis jalapa* (Four o'clock plant) and *Anagallis arvensis*

(Armale), etc. produce toxic effects at large doses, and they have to consume only after processing. Furthermore, *Pteridium aquilinum* (Bracken) contains poisonous cyanogen glycosides which may induce illeum sarcoma and leukemia; therefore, its consumption should be stopped. Nutritional analysis and therapeutic values of wild vegetables on human health are still missing. Therefore, further studies on the wild vegetables for the identification of valuable nutraceuticals and bioactive constituents, and their positive and negative consequences on the human health are essential. Nutritional analysis of the cooked vegetables is also worthy to be investigated.

**Abbreviations:** $EC_{50}$ = half maximal effective concentration; HIV = human immunodeficiency virus; $IC_{50}$ = half maximal inhibitory concentration; MIC = minimum inhibitory concentration; VDC = Village Development Committee.

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## Author's Biography



Gan B. Bajracharya has received D.Sc. degree in chemistry in 2004 from Tohoku Univeristy, Sendai, Japan. He carried out his post-doctoral studies at the Institute of Scientific and Industrial Research, Osaka University, Japan; University of Houston, Texas; and HEJ Research Institute of Chemistry, University of Karachi, Pakistan. He has worked in the capacities of as an Asst. Prof. in Tohoku University (2004-2005), and an Assoc. Prof. in Osaka University (2012-2013, 2016-2017). Currently, he is working as a Senior Scientific Officer in the Nepal Academy of Science and Technology (NAST), Nepal. He has published more than 50 research articles in international and national peer-reviewed journals.



Bashana Bajracharya has received M.Sc. degree in chemistry in 1999 from Tribhuvan University, Nepal. She has involved in teaching of chemistry in several colleges. She has pursued advanced research on asymmetric catalysis with Prof. Hiroaki Sasai at the Institute of Scientific and Industrial Research, Osaka University, Osaka, Japan. She has co-authored a book *Methodologies in Chemical Research* (for the graduate students and researchers) with Prof. Shiva P. Dhaubhadel and Gan B. Bajracharya.

# Chapter 8

## Mushroom: A True Super Food

**Jay Kant Raut* and Mahesh Kumar Adhikari**
*Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal*
*Email: raut_jk2000@yahoo.com

*Mushrooms have been consumed by humans since antiquity and considered as a culinary wonder due to their organoleptic merits. In the era of healthy eating by cutting down the calories, saturated fat and cholesterol, mushrooms are bound to attract the public attention a lot. At present they are widely used across the globe not only as food but also in the area of pharmaceuticals, nutraceuticals and cosmeceuticals. In this chapter an attempt has been made to provide the up to date insight on the nutritional and medicinal properties of mushrooms. Mushroom proteins are considered of higher nutritional quality than those of vegetables, being comparable to proteins of animal origin such as meat, eggs and milk. Furthermore, modern mushroom culture produces more protein per unit area of land than any other kind of agricultural technology at present available. Food and Agriculture Organization (FAO) has recommended mushrooms as a food item contributing significantly to the protein nutrition of the developing countries like Nepal, which depend heavily on the cereal diets. In the recent years, a lot of research has been done on the chemical composition of mushrooms around the globe including Nepal which revealed their several nutritional and medicinal attributes. Contemporary researches have also validated and documented much of the ancient knowledge on the mushrooms and recognized them as functional foods as well as a vital natural source for the development of pharmaceuticals, cosmeceuticals and nutraceuticals in the 21st century.*

**Keywords:** Anti-aging; anti-allergic; dietary supplement; fungi; white vegetables; vegetarian meat.

## Introduction

Mushrooms are higher fungi that are biologically distinct from plant and animal belonging to divisions Basidiomycota and Ascomycota (Hawksworth et al., 2008). They have been informally categorized among the 'White vegetables' and described as the forgotten source of nutrients (Feeney et al., 2014; Weaver & Marr, 2013). Mushrooms are widely consumed across the globe; especially for their organoleptic properties and have been praised by humankind as a culinary wonder (Ergönül et al., 2013; Valverde et al.,

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2015). In the era of healthy eating by cutting down the calories, saturated fat and cholesterol, mushrooms are bound to attract the public attention a lot (Zhang et al., 2014). Mushroom proteins are considered of higher nutritional quality than those of vegetables, being comparable to proteins of animal origin such as meat, eggs and milk (Wang et al., 2014). Furthermore, modern mushroom culture produces more protein per unit area of land than any other kind of agricultural technology available at present (Aneja, 2001). Health awareness and demand for meat substitutes have prompted global mushroom consumption. Currently, the usage of mushrooms has expanded up to a wider extent not only as food but also in the area of pharmaceuticals, nutraceuticals and cosmeceuticals for the mankind. In the recent years, a lot of researches have been done on the chemical composition of mushrooms around the globe which revealed their several nutritional and medicinal attributes. Contemporary researches have validated and documented much of the ancient knowledge on the mushrooms and recognized them as functional foods as well as a vital natural source for the development of pharmaceuticals, cosmeceuticals and nutraceuticals in the 21$^{st}$ century (Kostić et al., 2017; Reis et al., 2014; Soković et al., 2016). In this chapter, the nutritional and medicinal attributes of mushrooms, with an emphasis on as a functional as well as a true super food are reviewed and highlighted.

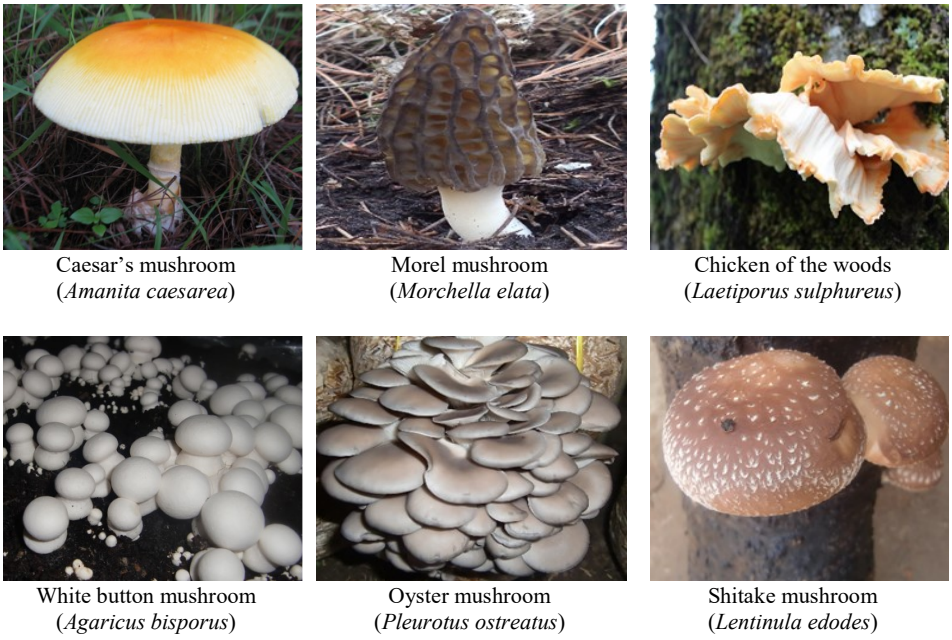
## Mushroom in Folklore

Mushrooms have been used as both food and medicine since prehistoric time (Chang & Miles, 2004; O'Neil et al., 2013). It is known from the fossil record that mushrooms have existed since the lower cretaceous period (130 million years ago), long before human beings evolved on this planet. It is assumed that the primitive man also consumed mushrooms (Miles & Chang, 1997). Mushroom has got a place in the scriptures of many ancient civilizations. Theophrastus (372–227 BC), the great Greek philosopher, wrote about food value of mushroom and treated them as the royal dishes, a part of vegetable kingdom. The Egyptians regarded them as a food for Pharaohs (King of ancient Egypt). The Greek and Romans described them as 'Food for the Gods' and were served only on festive occasions. Chinese treasured mushroom as elixir of life (Kotowski, 2019). Reference to mushroom is also found in the Vedas (Wasson, 1971). Mushroom is a dish of Jannat for Islamic people (Marwat et al., 2009). Recently, the importance of the role of mushrooms in history was evidenced by the fact that the desert truffle, *Terfezia arnenari*, was described in the Bible as 'Bread from Heaven' and 'Manna of the Israelites' (Pegler, 2002). Moreover, various mushroom rituals were practiced in various civilizations of Russia, China, Greece, Mexico and Latin America throughout the world. Many believed that mushrooms had properties that could produce super-human strength, help in finding lost objects and lead the soul to the realm of the gods (Chang & Miles, 2004). In the past, they were often considered as exotic and luxurious food reserved for the rich only. But today mushrooms have become food for both the rich and the poor (Aneja, 2001).

## Wild versus Cultivated

Mushrooms belong to the kingdom Fungi, which constitutes the most diverse group of organisms after insects on this biosphere. They are found all around the world and grow in a wide range of habitats (desert, grassland, roadway and forest). The number of

mushroom species on the earth is currently estimated at 150,000–160,000. Out of these, only 16,000 species are described so far which is only around 10% of the estimated mushroom species (Hawksworth et al., 2008; Hawksworth & Lücking, 2018). Due to many reasons (such as habitat, environmental factors, etc.), the availability of mushrooms in the wild is uncertain and seasonal. The need and greed to ensure the regular availability of mushrooms impelled the mankind to domesticate wild delicious mushrooms. For the first time *Auricularia auricula-judae* in 600 AD, *Flammulina velutips* in 800 AD and *Lentinula edodes* in 1000 AD were domesticated in China, but the real commercial ventures started with the cultivation of the common white button mushroom (*Agaricus bisporus*) in the limestone caves in France, in late eighteenth century, which can be truly termed as biggest milestone in the history of artificial mushroom production (Figure 8.1). In the late 18$^{th}$ century, mushroom production made its way across the Atlantic to the United States, where curious home gardeners in the East tried their luck at growing this new and unknown crop (Miles & Chang, 2004). Since then, more than 20 species of edible and medicinal mushrooms have been domesticated, and technologies have been improved to the commercial level.



Caesar's mushroom (*Amanita caesarea*) | Morel mushroom (*Morchella elata*) | Chicken of the woods (*Laetiporus sulphureus*)

White button mushroom (*Agaricus bisporus*) | Oyster mushroom (*Pleurotus ostreatus*) | Shitake mushroom (*Lentinula edodes*)

**Figure 8.1.** Some popular wild edible mushrooms (upper row) and cultivated mushrooms (butttom row) in Nepal.

## Mushroom Production and Consumption in Nepal

The tradition of collection and consumption of wild edible mushrooms by the various ethnic groups in Nepal have been very popular since ancient times (Adhikari & Adhikari, 1996; Adhikari, 2000). Some ethnic groups (Chepang, Danuwar, Tamang, Tharu, Raute,

etc.) found to be heavily depend on collection and consumption of wild mushrooms for their food and medicine (Adhikari, 2014; Pandey & Budhathoki, 1970). Some wild mushroom are being used in the Newar community during their ethnic festival (Adhikari & Adhikari, 2011). The country is very rich in mushroom diversity due to its complex geomorphology, diversity in altitude and climatic conditions. However, to date, very little number of mushroom species has been unveiled and exploited scientifically. There are altogether 1291 mushroom species, among them, 159 are edible, 100 are poisonous, 74 are medicinal and 25 are using in other purposes (Devkota & Aryal, 2020). There is also significant trade and revenue from the collection of some wild mushrooms such as *Ophiocordyceps sinensis* (yarsagumba), *Morchella* spp. (guchhi-chyau) and *Ganoderma* spp. (rato-chyau) (Adhikari, 2008; Adhikari, 2009). They play an important role in the national bio-economy (Raut, 2019; Raut et al., 2019). In addition of wild collection, the artificial farming started in 1974 with button mushroom. Oyster (*Pleurotus* spp.), button mushroom (*A. bisporus*), shitake (*L. edodes*) and milky mushroom (*Calocybe indica*) are the most popular mushrooms in Nepal which have been farming on commercial scale (see Figure 8.1). However, all these cultivars are exotic. None of native species is in the cropping system yet. The production follows the upward trend. Total national output of mushroom was only 30 kg in 1974 that reached 9300 tonnes in the year 2016 (Raut, 2019). In the last few years, with the change in the food habit and the recognition of its nutritional and medicinal values, domestic market is increasing rapidly. The per capita consumption/year reached 115 g in 2015 from 4 g in 2000 (Raut, 2019). Several mushrooms both wild as well as cultivated from different parts of the country have been chemically characterized (Adhikari et al., 2019; Adhikari, 2000; Adhikari et al., 2018; Adhikari et al., 1996; Aryal et al., 2017; Aryal & Budhathoki, 2015; Gautam & Adhikari, 2007; Giri & Rana, 2009; Bang et al., 2014; Jha & Tripathi, 2012; Mishra & Mishra, 2017; Pandey & Budhathoki, 1970; Tamrakar et al., 2016, 2017, 2019; Upadhyaya et al., 2017; Upadhyaya et al., 2018). These studies indicate the researches on the nutritional and nutraceutical values of the Nepalese mushrooms are getting momentum in the recent years making Nepalese peoples more aware on their food and medicinal value.

## Nutritional Attribute

### *Proteins*

Mushrooms offer high quality protein. The protein present in mushrooms contains all nine essential amino acids (EAAs) essential for humans, in contrast to most other plant-based protein options which are typically missing one or more EAAs. Moreover, mushrooms have a high branched-chain amino acid composition, which is usually only found in animal-based protein sources. In fact, mushroom proteins are nearly equivalent to the animal protein. It is also known as *White vegetables* or *Boneless vegetarian meat* (Kakon et al., 2012). Greeshma et al. (2018) found in a study that the amino acid content in mushrooms is comparable to that of ovalbumin and surpasses soybean and wheat scores (WHO/FAO reference standards). In a study that assessed the difference in satiety levels between mushrooms and meat, participants expressed significantly less hunger, a greater sense of fullness, and reduced prospective consumption after consuming the mushroom meal compared with those participants given meat (Hess et al., 2017).

The crude protein content of edible mushrooms is usually high, but varies greatly and is affected by factors such as species, developmental stage, environment and substrate (Cheung, 2010; Ferreira et al., 2017; Kakon et al., 2012). It contains 20–35% protein dry weight basis (DW) as compared to 7.3% in rice, 13.2% in wheat, 39.1% in soybean and 25.2% in milk. This shows that protein content in mushrooms ranks below animal meats but well above most other foods including milk (Chang & Miles, 2004; Kakon et al., 2012; Rahi & Malik, 2016). On a fresh weight basis, an average value of protein content in mushroom is 3.5–4% which is, in general, about twice that of asparagus and cabbage, and 4 times and 12 times those of oranges and apples, respectively (Chang & Miles, 2004). In fact, in populations who do not consume animal proteins (either due to lack of availability or religious beliefs), mushrooms can be used to combat protein deficiency and as a supplement to cereal grains. The complete protein composition found in mushrooms is a great alternative to bridge the gap for vegans and vegetarians who may be burnt out on other traditional plant-based protein sources such as pea, rice, and other grains and legumes (Jayachandran et al., 2017).

## *Carbohydrates and Fiber*

Arabinose, fructose, rhamnose, xylose, fucose, mannose, mannitol, glucose, trehalose, sucrose and melezitose are some carbohydrates of mushroom. The carbohydrate content of edible mushrooms varies with species and ranges from 35 to 70% DW (Ooi, 2009). Mannitol and trehalose are the major sugars reported in mushrooms that varies from species to species. Mannitol is mainly responsible for the growth and firmness of the fruit body and the most abundant sugar in the wild species (Ferreira et al., 2017). *Pleurotus* species contain carbohydrates ranging from 46.6 to 81.8% as compared to 60% in *A. bisporus* on dry weight basis (Rahi & Malik, 2016).

Mushrooms are also a good source of fiber, particularly the soluble fiber β-glucan. Most of the active polysaccharides, water soluble or insoluble, isolated from mushrooms can be classified as dietary fibers. Dietary fibre is a type of carbohydrate that cannot be digested by gastrointestinal enzymes. Mushrooms contain 10–50% dietary fibers in dried matter (Rahi & Malik, 2016). The soluble fiber is mainly β-glucans, a polysaccharide. Soluble fiber helps to lower total and low-density lipoprotein (LDL) cholesterol levels. It also helps regulate blood sugar levels (Kakon et al., 2012). The fiber content ranges from 7.4 to 27.6% in *Pleurotus* species as compared to 10.4% in *A. bisporus* and 4 to 20% in *Volvariella volvacea* (Rahi & Malik, 2016).

## *Fat*

Mushrooms contain extremely small amount of fat usually ranging from 0.1 to 16.3%, most of which are polyunsaturated fat (Sande et al., 2019). As a result, they are considered as a low caloric heart-healthy food choice without cholesterol. Instead, they have ergosterol that acts as a precursor for vitamin D synthesis in human body. Similarly, ergosterol in button mushroom is converted into vitamin D2 when exposed to UV radiation or sunlight. It has been observed that a diet rich in sterols is important in the prevention of cardiovascular diseases (Valverde et al., 2015). In general, the crude fat of mushrooms represents all classes of lipid compounds including free fatty acids,

monoglycerides, diglycerides, triglycerides, sterols, sterol esters, and phospholipids (Chang & Miles, 2004). Linoleic acid, oleic acid and linolenic acid are the major constituents in their lipid profiles and, in general, unsaturated fatty acids predominate over saturated fatty acids. Therefore, compared to other food of vegetable and animal origin, mushrooms have the advantage of possessing high levels of polyunsaturated fatty acids. Percentage of these fatty acids (in 100 g of total fatty acids) in mushrooms varies greatly: linoleic acid ranges from 0.0–81.1%, oleic acid between 1.0 and 60.3%, and linolenic acid from 0.0–28.8% (Sande et al., 2019). Unsaturated fatty acids are essential to human body while saturated fatty acids, which are present in high amounts in animal fats, may be harmful to human health (Rahi & Malik, 2016). The high content of unsaturated fatty acids in mushrooms make them a healthy food. Unsaturated fatty acids are useful for a wide range human physiology such as in management of cardiovascular diseases, triglyceride levels, blood pressure and arthritis (Ferreira et al., 2009; Heleno et al., 2012; Reis et al., 2012; Valverde et al., 2015).

## *Vitamins*

Mushroom is an excellent source of vitamins especially C and B (folic acid, thiamine, riboflavin and niacin). The riboflavin (vitamin B2) content in mushrooms is higher than that generally found in vegetables, and some varieties of *A. bisporus* even have a level of vitamin B2 as high as that found in egg and cheese (Mattila et al., 2000). The content of riboflavin (vitamin B2), niacin and folates, varies within the range of 1.8–5.1, 31–65 and 0.30–0.64 mg/100 g DW, respectively, depending on the species. In addition to riboflavin, niacin and folates, cultivated mushrooms also contain small amounts of vitamin C and vitamin B1, and traces of vitamins B12 and D2. Folic acid and vitamin B12, which are normally absent in vegetative foods, are present in mushrooms. Vitamin A is uncommon, although several mushrooms contain detectable amounts of pro-vitamin A measured as the β-carotene equivalent. Most cultivated mushrooms are believed to contain low amounts of the fat-soluble vitamins, K and E, and only a small contribution to the daily requirement of vitamin C (Mattila et al., 2001). Vitamin C content has been reported to be highest in *L. edodes* (9.4 mg/100 g dry sample) followed by *Pleurotus sajor-caju, A. bisporus* and *V. volvacea* with 7.4, 1.8 and 1.4 mg/100 g DW, respectively (Chang & Miles, 2004).

It has been reported that the vitamin D2 content in *A. bisporus* (0.21 µg/100 g DW) cultivated in the dark is lower than that of *L. edodes* (22.0–110 µg/100 g DW) cultivated in natural climatic conditions (Takamura et al., 1991), which is mainly due to the influence of illumination on the conversion of ergocalciferol (provitamin D) to vitamin D (Mattila et al., 2002). Unfortunately, few foodstuffs naturally contain significant levels of vitamin D. Mushrooms are the only non-animal-based food containing vitamin D, and hence they are the only natural vitamin D source for vegetarians. Mushrooms cultivated in indoors contain lower levels of vitamin D2 than those cultivated at outdoors because the metabolic route from ergosterol to ergocalciferol (vitamin D2) requires sunlight or artificial ultraviolet (UV) light. Common cultivated mushrooms could be remarkably enriched with vitamin D2 by UV- irradiation after harvest (Mau et al., 1998). This easy way to improve the nutritional value of common mushrooms and make them more functional as a source of vitamin D is worth noting (Mattila et al., 2000).

## *Ash and Minerals*

The ash content gives us a general idea about the mineral content of mushrooms and usually ranges from 6 to 10.9% on dry weight basis (Cheung, 2010). Mushrooms are a good source of wide variety of minerals, containing macro-elements such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P) and micro-elements such as copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). The amount of K, P, Na, Ca, and Mg accounts about 56 to 70% of the total ash content, while potassium, an extremely important mineral that regulates blood pressure, alone forms 45% of the total ash (Li & Chang, 1982; Rahi & Malik, 2016). Mushrooms in general are rich in selenium (Se), an essential trace mineral (Cocchi et al., 2006). Se is a powerful antioxidant that fights oxidative stress and helps defend human body from chronic conditions, such as heart disease and cancer. Mushrooms contain more Se than any other form of produce and are one of the richest, natural sources of Se (Rahi & Malik, 2016). Mushrooms can also have low contents of toxic elements, such as arsenic (As), cadmium (Cd) and lead (Pb) (Ferreira et al., 2017). These toxic elements are not found or are very low in the cultivated species (Mallikarjuna et al., 2013). The mineral content in mushrooms are greatly vary with mushroom species, types of substrate and the environmental factors (Liu et al., 2012).

## *Moisture*

Generally, mushrooms comprise a high moisture content that ranges about 85 to 95% of their fresh weight. Freshly harvested mushrooms are highly perishable because of high moisture content metabolism and susceptible to enzymatic browning. Water content in mushroom greatly varies depending on the time of cropping, watering condition during cultivation, postharvest period, and temperature and relative humidity during growth (Cheung, 2010). The moisture is easily lost after harvest, due to evaporation; consequently, the chemical composition of mushrooms varies within and between species, and corresponding maturation. Therefore, the dry matter content of mushrooms is relatively low, about 10–30% on fresh weight basis and it is mainly formed by carbohydrates, lipids, proteins and ash; low lipid concentrations result in low energy value (Ferreira et al., 2017).

## *Energy*

Due to low energy content (generally 25.08-50 cal/100 g of fresh weight), edible mushrooms should be regarded as dietetic food. Cultivated species, such as *A. bisporus* and *Pleurotus ostreatus* are characterized by a medium calorific value of 30 and 36 cal/100 of the edible part, respectively (Bernas et al., 2006; Manzi et al., 2001). Wild species, *Suillus luteus*, *Morchella esculenta*, *Cantharellus cibarius*, *Lactarius deliciosus* and *Leccinum scabrum* show low calorific values varying from 11 to 14 cal/100 g fresh matter; a medium one was found for *Boletus edulis* (17 cal/100 g) and the highest one for *Tuber melanosporum* (56 cal/100 g) (Aletor, 1995). A serving of 100 g of fresh edible mushrooms provides only 1.4–4.4% of the daily energy requirement for a 70 kg adult male who engages in moderate physical activity (Cheung, 2010).

## Medicinal Attribute

### *Antioxidants in Mushrooms*

Oxidation is essential to many living organisms for the production of energy to fuel biological processes. Free radicals are produced in the normal natural metabolism of aerobic cells. A free radical is defined as any atom or molecule possessing unpaired electrons in the outer orbit (Halliwell & Gutteridge, 1984). They are generally unstable and very reactive. Free radicals derived from molecular oxygen ($O_2$) are usually known by reactive oxygen species (ROS) and represent the most important class of radical species generated in living systems (Miller et al., 1990). Once produced, most of the free radicals are neutralized by cellular antioxidant defenses (enzymes and non-enzymatic molecules). Maintenance of equilibrium between free radical production and antioxidant defenses (enzymatic and non-enzymatic) is an essential condition for normal organism functioning. Due to either by the over-production of ROS or by the loss of the cell antioxidant defenses, a disequilibrium occurs which is known as oxidative stress (Machelin & Bendich, 1987). The excess ROS may oxidize and damage cellular lipids, proteins and DNA leading to abnormal function (Ferreira et al., 2009; Fu et al., 1998; Valko et al., 2007). In fact, the uncontrolled production of oxygen-derived free radicals is involved in the onset of more than one hundred diseases including several kinds of cancers (Valko et al., 2006), diabetes (Valko et al., 2007), cardiovascular diseases (Shah & Channon, 2004), neurological disorders (Perry et al., 2008), among others (Valko et al., 2007). The over-production of ROS has also been related to the aging process (Halliwell & Gutteridge, 1984; Halliwell, 1996). Therefore, it becomes very important for many to supplement their diet with good levels of antioxidants and free radicals scavengers to protect themselves from the oxidative damage. Recently, many studies have found that edible mushrooms possess potent antioxidants (Adhikari et al., 2019; Barros et al., 2007; Boonsong et al., 2016; Elmastas et al., 2007; Ferreira et al., 2009; Gursoy et al., 2009; Bang et al., 2014; Kalaras et al., 2017; Kalyoncu et al., 2010; Kozarski et al., 2015; Keleş et al., 2011; Mau et al., 2004; Srikram & Supapvanich, 2016; Strapáč et al., 2016; Unekwu et al., 2014; Wani et al., 2010). Phenolics, tocopherol, ascorbic acid and caretenoids are the responsible compounds which has been isolated from the different species of mushrooms. They are reported to boost the immune system; have anticancerous, anti-hypercholesterolaemic and antiviral activities; and ameliorate the toxic effect of chemo- and radiotherapies (Chang & Miles, 2004; Rathore et al., 2017). Also, mushrooms might be used directly in diet and promote health taking advantage of the additive and synergistic effects of all the bioactive compounds present.

### *Hypocholesterolemic/Antiatherogenic Effects*

Increasing incidence of cardiovascular diseases in the globe leads to search for natural substances as hypocholesterolemic agents that can lower blood cholesterol. In this regard, mushrooms contain variety of such bioagents with promising effects on several cardiovascular risk biomarkers (Murugan et al., 2018). Edible mushrooms as a natural hypocholesterolemic and antisclerotic diet are often prescribed in Oriental medicine (Ishikawa et al., 1984). Elevated serum cholesterol levels are widely recognized as a contributing risk factor for the development of cardiovascular diseases, such as

atherosclerosis, coronary heart disease and stroke. Atherosclerosis, a progressive disease characterized by the accumulation of lipids and fibrous elements in the large arteries, constitutes the single most important contributor to the growing burden of cardiovascular diseases (Libby, 2012). Intake of mushrooms with hypocholesterolemic properties reduces the cardiovascular risk (Bobek & Galbavý, 1999; Kaneda & Tokuda, 1966; Mori et al., 2008; Yamada et al., 2002). In general, the hypocholesterolemic effects, including the lowering of plasma triglycerides, and hepatic total cholesterol and triglycerides, of edible mushrooms e.g., *A. auricula-judae*, *A. bisporus*, *P. ostreatus*, and *Tremella fuciformis* have been mainly attributed to dietary fiber (Caz et al., 2015; Guillamón et al., 2010).

Based on the capacity of the reduction of cholesterol absorption, the European Food Safety Authority (EFSA) recognizes two types of functional food that can reduce the risk of cardiovascular diseases (EFSA, 2009, 2010, 2012). One that contains sterols (phytosterols) or derivatives (sitostanol esters) and another type contains β-glucanspolysacharides. These compounds can reduce LDL-cholesterol in hypercholesterolaemic patients by 10–15% within 3–4 weeks with the intake of 1.5 g/day (Chen & Huang, 2009; Miettinen et al., 1995). Edible mushrooms are good sources of phytosterol-like structures such as ergosterol, fungisterol and many other derivatives. The major fungal sterol, ergosterol (9.61–1.28 mg/g DW), is abundant in all mushrooms species since it is a constitutive compound of the hyphae membranes and it is known as a vitamin D2 (ergocalciferol) precursor (Kalač, 2009; Mattila et al., 2002; Teichmann et al., 2007). According to the reports, several oyster mushroom strains showed lovastatin (mevinolin), a compound able to lower cholesterol levels by inhibiting the 3-hydroxy-3-methyl-glutaryl CoA (HMG-CoA) reductase, a key-enzyme in the cholesterol metabolism (Gunde-Cimerman & Cimerman, 1995). However, other compounds, such as lanosteroids, ganoderols, etc., obtained from other mushrooms are also able to perform such an inhibition (Berger et al., 2004; Gil-Ramirez et al., 2011). Mushroom intake clearly has a cholesterol-lowering effect or hypocholesterolemic effect by different mechanisms such as decreasing very-low-density lipoproteins, improving lipid metabolism, inhibiting of activity of HMG-CoA reductase, and consequently preventing the development of atherosclerosis (Guillamón et al., 2010). According to current dietary recommendations for preventing and treating for cardiovascular diseases, edible mushroom presents an appropriate nutritional value and its consumption can affect some known cardiovascular risk biomarkers.

## *Hypoglycaemic/Antidiabetic Effects*

Diabetes mellitus (DM) is a multifactorial metabolic disorder characterized by chronic hyperglycemia due to defects in insulin secretion, insulin action, or both (American Diabetic Association, 2014). The increasing worldwide incidence of DM with the number of DM patients estimated to be doubled from 171 million in 2000 to 366 million in 2030 is creating a global public health burden (WHO, 2005). Management of diabetes basically initiates with a modification in diet and exercise. Currently, available therapy for diabetes includes insulin and various oral antidiabetic agents such as sulphonylurea, biguanide, metformin, α-glucosidase inhibitors and troglitazone, but these are known to have a number of serious adverse effects in patients (Berger, 1985; Sukalingam et al., 2015).

Thus, there is an urgent requirement for effective substitutions to reduce the complications of diabetes with lower side-effects. In recent years, the search for alternate medications has drawn great attention to combat diabetes (Ganesan & Xu, 2019). Therefore, development of safe and effective oral hypoglycemic agents from natural sources to manage DM without side effects is of great interest recently and is strongly recommended by The World Health Organization (WHO) (Singh et al., 2007).

Several mushrooms species such as *Tremella aurantia, O. sinensis, Ganoderma lucidum, A. auricula-judae, L. edodes, P. ostreatus*, *Phellinus linteus* and others have been shown to decrease blood glucose and triglyceride levels. Such results strongly suggest that these mushrooms have potential preventive and therapeutic actions in DM (type I and II) (Shamtsyan, 2016). The hypoglycemic activity of mushrooms has been recorded on fruit bodies and on bioactive compounds isolated from the fruit bodies, such as polysaccharides (Kiho et al., 1994; Kiho et al., 1994, 2000; Kurushima et al., 2000; Mori et al., 1998) and lectin (Ewart et al., 1975). Furthermore, endo and exopolymers produced in submerged mycelial cultures have also been found to have a hypoglycemic effect (Kim et al., 2001; Kim et al., 1997). The most common animal models used for the study of the hypoglycemic effects of mushrooms are rats and mice with insulin-dependent diabetes mellitus (IDDM) induced by streptozotocin (STZ), and genetically diabetic mice with non-insulin-dependent diabetes mellitus (NIDDM) (Beattie et al., 1980; Cheung, 2010; Kiho et al., 2001; Swanston-Flatt et al., 1989). In conclusion, mushrooms have been recognized as an ideal food for the dietetic prevention of hyperglycemia because of their high dietary fiber and protein, and low fat content.

## *Antiviral Effect*

Mushroom can be considered as a powerhouse of antiviral agent. Cochran was the first to report the antiviral substances in mushrooms (Goulet et al., 1960). They have shown potential activity against prominent viruses such as human immunodeficiency virus (HIV), influenza, herpes simplex virus (HSV), hepatitis B and C viruses, etc. The antiviral activity of these mushrooms is associated mainly to the presence of polysaccharides in mycelium and fruiting bodies, and synthesis of triterpenoid secondary metabolites (Chen et al., 2012; Linnakoski et al., 2018; Rincão et al., 2012). Antiviral agents in mushrooms can be divided into two major groups of molecules; the high-molecular weight compounds such as polysaccharides, proteins and lignin-derivatives from the fruiting bodies exhibiting their effect indirectly through immunostimulating activity; and the low-molecular weight compounds, small organic molecules excreted by mushrooms in a liquid culturing (fermentation) setups that directly inhibits viral enzymes, synthesis of viral nucleic acids or adsorption and uptake of viruses into cells. High molecular weight polysaccharides (such as glucan, chitin, mannan, polysaccharide krestin (PSK) or lentinan) extracted from fruiting bodies and fungal mycelia have been reported to present antiviral activities (Cardozo et al., 2011; Rincão et al., 2012; Tochikura et al., 1987).

Antiviral activity against HIV has shown by various types of mushroom. Several triterpenes from *G. lucidum* i.e. ganoderiol F, ganodermanontriol and ganoderic acid B are active antiviral agents against human immunodeficiency virus type 1 (HIV-1). A low molecular weight laccase (LAC), from the dried fruiting body of *Hericium erinaceus*

(Wang & Ng, 2004a, 2004b), fruiting body of *Pleurotus eryngii* (Wang & Ng, 2006b), *Lentinus edodes* and *G. lucidum* (Sun et al., 2011; Wang & Ng, 2006a, 2006b) possess the strong antiviral activities against HIV. Lanostane-type triterpenoid derived from *Scleroderma citrinum* was also shown to have antiviral response against HSV (Kanokmedhakul et al., 2003). Acidic protein-bound polysaccharide isolated from water-soluble extracts of *G. lucidum* showed potent antiviral activity against both HSV-1 and HSV-2 (Eo et al., 2000). *P. ostreatus*, *Fomes fomentarius*, *Auriporia aurea* and *Trametes versicolor* were promising in blocking HSV in RK-13 cells (Krupodorova et al., 2014). *A. aurea*, *F. velutipes*, *F. fomentarius*, *G. lucidum*, *Lentinus edodes*, *Lyophyllum shimeji*, *P. eryngii*, *P. ostreatus*, *Schizophyllum commune* and *T. versicolor* extracts were tested for inhibition against influenza A H1N1 virus (Krupodorova et al., 2014). Two phenolic compounds from *Inonotus hispidus* showed antiviral action against influenza A and B viruses (Ali et al., 2003). *Datronia mollis*, *Daedaleopsis confragosa*, *Ischnoderma benzoinum*, *T. versicolor*, *Trametes gibbosa*, *Laricifomes officinalis* and *Lenzites betulina* as promising antivirals against H5N1 and H3N2 (Teplyakova et al., 2012). *Inonotus obliquus* polysaccharides were tested for their antiviral activity against a number of feline viruses and found to be active against feline influenza H3N2 and H5N6 (Tian et al., 2017).

The need for natural antiviral compounds arises from the issues of side effects and development of drug-resistant mutant viruses (De Clercq, 1997). Mushrooms having antiviral activity with no side effects and being readily available make it an effective source of foods and therapeutics. Different compounds extracted from mushrooms include lectins (Hassan et al., 2015), polysaccharides (Friedman, 2016), polysaccharopeptides (Ng, 1998), enzymes and other molecular compounds (Lindequist et al., 2005), which possess antiviral activity against HIV, herpes virus, influenza virus, Epstein-Barr virus, coxsackie virus, etc. Medicinal mushrooms having different components each of which showing antiviral action against different viruses make them more interesting for pharmacological exploration. Isolated and extracted compounds can be formulated into tablets, capsules and teas depending on the source. Usage of mushrooms as dietary supplements should further be encouraged. The ease of mushroom cultivation could provide a ubiquitous supply of antiviral compounds, once large-scale production is formulated for these compounds.

## *Antitumour/Anticancer Effects*

There are many reports on mushroom polysaccharides as antitumour and immune-stimulating agents (Cheung, 2010; Ooi, 2009; Zhang et al., 2007). They show their antitumour activity by stimulating the host immune system rather than direct killing the tumour cells. The use of mushrooms as an anticarcinogenic agent is known for a very long time in Korea, China, Japan, Russia, USA and Canada (Daba & Ezeronye, 2003). A variety of polysaccharides from a number of mushroom varieties have been demonstrated to enhance the immune system. Naturally-occurring substances having immunotherapeutic effects are termed as immunoceuticals which can be included in the general category of nutraceuticals, or dietary supplements. Immunoceutical has become a tool for immunotherapy, a new dimension of anticancer therapy by which the body's immune defenses, beaten down by the cancer and by toxic therapies used against the cancer, can

be revitalized to carry out their natural functions of eliminating abnormal tissues from the body (Kidd, 2000).

More than 50 mushrooms species have yielded potential immunoceuticals that exhibit anticancer activity in vitro or in animal models. Six of these carcinostatic (immunotherapeutic) agents that have been investigated in human cancers include lentinan, schizophyllan, active hexose correlated compounds (AHCC), maitake D-fraction, polysaccharide-K and polysaccharide-P (Daba & Ezeronye, 2003). *G. lucidum*, *Lentinus edodes*, *T. fuciformis*, *Griflola*, *H. erinaceus*, *Agaricus blazei*, *F. velutipes*, *Coriolus versicolor*, *I. obliquus*, *P. ostreatus*, *Sparassis crispa, Poria cocos* and *Cordyceps militaris* are some major mushroom species have been used as carcinostatic agents (Meng et al., 2016). These mushrooms are associated with the treatment of various cancers including breast, colorectal, cervical, skin, liver, ovarian, bladder, prostate, gastric, skin, lung, leukemia and stomach cancers (Ayeka, 2018; Wasser, 2002). There are many mushroom based commercial anticancer products in the global market and some have been patented (Pandya et al., 2019). Despite the discovery of many antitumor components of mushrooms, still, there is a need to increase the range of available compounds, find more effective and less toxic molecules and to understand deeply single and/or multiple targets, so as to battle cancer more precisely.

## *Antimicrobial Effect*

Antimicrobial agents are substances used to treat infections caused by pathogenic microorganisms. They have been in widespread and largely effective therapeutic use since their discovery in the 20$^{th}$ century (Glamoclija & Sokovic, 2017). However, the emergence of multi-drug resistant pathogens now presents an increasing global challenge to both human and veterinary medicine (WHO, 2014). Mushrooms need antimicrobial compounds to survive in their natural environment. Hence mushrooms must have strong antimicrobial properties to fight such microbes to survive (Lindequist et al., 2005). Antimicrobial compounds with more or less strong activities could be isolated from many mushrooms and that could be very useful in the treatment of human infections (Glamoclija & Sokovic, 2017). Only a handful mushrooms species have been studied for antibacterial, antifungal, antiviral and /or antiprotozoal properties. During recent years many investigations confirmed antimicrobial activity of numerous edible and inedible mushrooms (Balakumar et al., 2011; Chowdhury et al., 2015; Gebreyohannes et al., 2019; Hearst et al., 2009; Imtiaj et al., 2007; Klaus et al., 2016; Liu et al., 2010; Nikolovska-Nedelkoska et al., 2013; Ren et al., 2014; Sharma et al., 2014; Singh, 2017; Tamrakar et al., 2017; Venturini et al., 2008). Primary and secondary metabolites such as oxalic acid, peptides or proteins, terpenes, steroids or benzoic acid derivatives from mushrooms have been associated with their antimicrobial properties (Alves et al., 2012). The antimicrobial potential of mushroom species depends on sample's origin, type of extract, assays applied, and bacterial and fungal species investigated, as well as the numerical values of the results are presented (Alves et al., 2012; Barros et al., 2007; Glamoclija & Sokovic, 2017; Harikrishnan et al., 2012). One of the first antimicrobial compounds ever isolated from a polypore was biformin, a poly acetylenic carbinol. Biformin is produced by *Trichaptum biforme* (*Polyporus biformis*) and is active against a wide variety of bacteria and fungi (Robbins et al., 1947). Ethanolic mycelial extracts from *Lentinus edodes*

possess antiprotozoal activity against *Paramecium caudatum* (Lindequist et al., 2005). Trehalose present in the extract of *L. edodes* is considered to be an important factor to improve the beneficial intestinal bacterial flora of the gut. It is also effective to reduce the harmful effects of certain bacterial enzymes such as α-glucosidase, α-glucuronidase and tryptophanase preventing colon cancer formation (Wasser & Weis, 1999). Some mushroom extracts, particularly obtained from *L. edodes* and *P. linteus*, have been reported as effective even against highly resistant bacteria, such as methicillin-resistant *Staphylococcus aureus* (MRSA) (Hearst et al., 2009; Hur et al., 2004). *Agaricus* genus represents the most important cultivated edible mushroom. Antimicrobial activity of three *Agaricus* species was published by Öztürk et al. (2011), who have described effects of methanolic extracts against six species of Gram-positive bacteria and seven species of Gram-negative bacteria. Giri et al. (2012) have described that a methanolic extract of *A. campestris* from India showed antimicrobial activity against seven bacterial species. Glamočlija et al. (2015) have investigated biological activity of the methanolic and ethanolic extracts of *Agaricus bisporus*, *A. bitorquis*, *A. campestris* and *A. macrosporus*. All the extracts showed antibacterial potential.

Some Ascomycestes such as *M. esculenta* and *Tirmania pinoyi* also demonstrated excellent antibacterial activity. The methanolic extracts of *M. esculenta* exhibited very good activity against five bacteria (Heleno et al., 2013). Coprinol, a new antibacterial cuparane-type terpenoid from cultures of a *Coprinus* sp., exhibited activity against multidrug-resistant Gram-positive bacteria (Johansson et al., 2001). Cordycepin, a derivative of the nucleoside adenosine, the main active constituent of *C. militaris*, has antibacterial property, which is now being produced synthetically (Paterson, 2008). Liu et al. (2010) have isolated novel compounds with effective antimicrobials from two American mushroom species, *Jahnoporus hirtus* and *Albatrellus flettii*: 3,11-dioxolanosta-8,24(Z)-diene-26-oic acid, a new lanostane type triterpene from *J. hirtus*, and confluentin, grifolin, and neogrifolin from *A. flettii*. Grifolin showed promising activity against *Bacillus cereus* (10 μg/mL) and *Enterococcus faecalis* (0.5 μg/mL). Menaga et al. (2012) have found that bioactive compounds from *Pleurotus florida* mushroom extracts could be used as an alternate therapeutics as antibiotics. Alves et al. (2012) have reported that *Fistulina hepatica*, *Russula botrytis* and *Russula delica* are the most promising species as antimicrobial agents.

## *Antiobesity Effect*

Obesity is an excessive accumulation of fat in adipose tissue caused by an imbalance between the intake and expenditure of energy (WHO, 2000; Hofbauer, 2002; Leslie et al., 2007). It is a serious and growing worldwide health challenge that increases the risk of other diseases and health problems, such as heart disease, diabetes, high blood pressure and certain cancers (WHO, 2000). WHO considers obesity as one of the most obvious and neglected public health issue. It has become a global epidemic, affecting not only developed but also developing countries and among all the segments of society (WHO, 2000; Gortmaker et al., 2011). It is estimated that 1.12 billion people will be obese around the world in 2030. Once considered a high-income country problem, overweight and obesity are now on the rise in low- and middle-income countries, particularly in urban settings (WHO, 2020b).

To prevent or reduce obesity, the imbalance between energy intake and expenditure needs to be addressed by improving dietary habits and/or increasing physical activity, though this is difficult to achieve in modern society. Antiobesity drugs, as an alternative option, have side effects and are expensive (Enzi et al., 1976; Kang & Park, 2012). Conversely, the habitual consumption of foods with antiobesity effects may be a cost-effective and manageable way to overcome obesity. Natural products can be an outstanding, effective and safe strategy for the prevention of obesity (Bessesen & Van Gaal, 2018). Recently, many studies have reported anti-obesity effects of mushrooms. The antiobesity activity of maitake mushroom (*Grifola frondosa*) has been demonstrated in both animals and humans (Mayell, 2001; Shamtsyan, 2016). Antiobesity and triglyceride lowering effect has been reported for fermented milk product containing edible mushroom water extracts (mushroom yogurt) (Jeon et al., 2005). *Flammulina velutipes* (Enokitake), *Hypsizygus marmoreus* (Bunashimeji), *Lentinus edodes* (Shiitake), *G. frondosa* (Maitake) and *Pleurotus eryngii* (Eringi or King oyster mushroom) contain many nutritional components such as dietary fiber, vitamin B1, vitamin B2, niacin, vitamin B6, vitamin D and folic acid (Valverde et al., 2015), and are reported to have antiobesity effects (Handayani et al., 2011; Mizutani et al., 2010; Yeh et al., 2014), immunomodulatory effects (Vetvicka & Vetvickova, 2014), antitumor effects (Masuda et al., 2013), antiatherosclerotic effects (Mori et al., 2008) and antidiabetes effects (Hong et al., 2007). Dried powder of *A. auricula-judae*, suspension of *Coprinus comatus*, α-glucan of *G. frondosa*, and ethanol extract of *P. ostreatus* inhibited body weight increase in healthy and diabetic patients (Soković et al., 2016).

Mushroom intake suppressed fat accumulation by inhibiting fatty acid synthesis and promoting lipolysis of visceral fat. Mushroom intake also suppressed adipocyte enlargement and promoted adiponectin production. Moreover, mushroom intake caused some lactic acid- and short chain fatty acid (SCFA)-producing bacteria to proliferate, possibly because of the dietary fiber content of the mushrooms, which promote energy metabolism in the host and play a role in suppressing fat accumulation. Thus, the regular mushroom intake results in synergistic and improved effects, and can be an effective strategy for the prevention of obesity (Shimizu et al., 2018).

## *Immunosuppressive, Anti-inflammatory and Antiallergic Effects*

Inflammation is the body's natural reaction against injury and infection. It is a vital part of the immune system's response to injury and infection through which body signals the immune system to heal and repair damaged tissue, as well as defend itself against foreign invaders. An abnormal inflammation can occasionally be triggered by non-infectious/ harmless environmental agents or by an autoimmune process, as in rheumatoid arthritis (Jayasuriya et al., 2020). An abnormal severe immune response to non-infectious elements, also called antigens or allergens is known as hypersensitivity or allergy. Allergies can be subdivided into type I–IV depending upon the antigens, cells and symptoms that trigger the hypersensitivity reaction (Chinen & Shearer, 2008). Type I allergy, the most frequent type of a pathogenic immune reaction, is caused by IgE-mediated reactions, which result in the release of vasoactive substances, e.g. histamine from mast cells. Although many mushrooms can stimulate the immune system, some suppress immune responses that are useful for the treatment of allergic diseases, which

are increasing worldwide. The pharmacological treatment of allergy consists mainly of administration of immunosuppressants, antiphlogistic, and/or antiallergic drugs.

Some mushroom species are known to provide significant anti-inflammatory properties (Jose et al., 2004; Kim et al., 2004; Lull et al., 2005; Tamrakar et al., 2019). It has been reported that ergosterol and ergosterol peroxide from the edible mushroom *H. marmoreus* can inhibit inflammatory processes (Yasukawa et al., 1994). Some mushrooms were investigated for possible treatments of allergic diseases like allergic asthma (Li et al., 2000; Liu et al., 2003), food allergy (Hsieh et al., 2003), atopic dermatitis (Kuo et al., 2002), inflammation (Jose et al., 2004; Kim et al., 2004), autoimmune joint inflammation such as rheumatoid arthritis (Kim et al., 2003). *Agaricus subrufescens*, *Armillaria ostoyae*, *Flammulina velutipes*, *Ganoderma lucidum* and *G. tsugae*, *Innonotus obliquus*, *Phellinus linteus*, *Pleurotus ostreatus, P. pulmonarius, Tricholoma populinum* are some mushrooms with promising antiallergic property, which have been detected only in vitro and/or in animal assays, and necessary to verify the results in further test systems, to elucidate the mode of action, to conduct clinical trials, to identify the responsible bioactive compounds, and to ensure safety and quality of resulting products (Merdivan & Lindequist, 2017).

## *Antihypertensive Effect*

Hypertension is characterised by elevated arterial blood pressure and also known as the 'silent killer' as it raises the risk of cardiovascular diseases (CVDs), strokes, kidney dysfunction, premature mortality and disability while remaining asymptomatic (WHO, 2005). It has become an epidemic and a global challenge. WHO has estimated that hypertension causes one in every eight deaths, making it the third leading killer in the world (Haldar, 2013). A review of current trends shows that the number of adults with hypertension increased from 594 million in 1975 to 1.13 billion in 2015, with the increase seen largely in low- and middle-income countries (WHO, 2020a). Hypertension alone does not pose the threat; rather, it is correlated to hypercholesterolaemia, obesity and atherosclerosis that makes a person vulnerable to vascular dysfunctions (Ariyo et al., 2000; Egan & Zhao, 2013; Kearney et al., 2005).

Renin angiotensin aldosterone system (RAAS) is one of the key regulators of blood pressure, which involves a series of enzymatic reactions. Angiotensin-converting enzyme (ACE) in RAAS is one of the enzymes that controls blood pressure by converting inactive angiotensin I to the potent vasoconstrictor angiotensin II (Atlas, 2007). Exploiting the inhibitor of ACE as one curative means for hypertension is therefore paramount. ACE inhibitors such as captopril, enalapril and lisinopril are the first-line synthetic drugs used as clinical antihypertensive medications (Wong et al., 2004). Adverse side effects of these synthetic antihypertensive drugs compel to find the natural, safe and alternative therapeutic approaches. In this regard, mushrooms have been suggested to lower blood pressure by improving lipid metabolism and kidney function and hindering angiotensin converting enzymes (Miyazawa et al., 2008). The low concentration of sodium and the presence of a great amount of potassium (182–395 mg/100 g) supports the utilization of mushroom within an antihypertensive diet. Potassium-rich food helps to reduce blood pressure (WHO, 2012). WHO recommends that adults should consume at least 3,510 mg of potassium per day. ACE inhibitory peptides present in mushrooms lowered blood

pressure with no adverse effect (Abdullah et al., 2012; Hong et al., 2008; Jao et al., 2012). Several studies have investigated the antihypertensive effects of some edible mushroom species such as *Ganoderma lucidum*, *Grifola frondosa*, *Tricholoma giganteum*, *Marasmius androsaceus*, *Pleurotus* species, *Lentinula edodes*, *Sparassis crispa*, *Pholiota adipose*, *Sarcodon aspratus*, *H. marmoreus*, *Flammulina velutipes*, *Hericium erinaceus*, *Phlebia tremellosa* and *Agaricus bisporus* (Guillamón et al., 2010; Bang et al., 2014; Kabir et al., 1987, 1988; Miyazawa et al., 2008; Mizuno & Zhuang, 1995; Yahaya et al., 2014). These studies have attracted scientists of all over the world to focus further studies on mushroom.

## *Antihepatotoxic Effect*

Hepatotoxicity is liver dysfunction or liver damage that is associated with an overload of drugs or xenobiotics (Navarro & Senior, 2006). Liver is the largest organ of the human body weighing approximately 1,500 g, and performs more than 500 vital metabolic functions (Naruse et al., 2007). The chemicals that cause liver injury are called hepatotoxins or hepatotoxicants. Hepatotoxicity can be caused by a wide variety of pharmaceutical agents, natural products, chemicals or environmental pollutants and dietary constituents.

Exposure to these hepatotoxic agents is usually accidental, through contaminated food, water or air, or from unanticipated side effects of therapeutic agents. Severe intoxication with hepatotoxic agents can lead to liver necrosis and death of the organism if left untreated (Singh et al., 2011). Drug-induced hepatotoxicity is the most important cause of acute liver failure in many countries (Andrade et al., 2019; Deng et al., 2009). Mushrooms are considered to be beneficial for a wide range of hepatic disorders, including hepatitis. Many mushroom extracts possess hepatoprotective property against liver injury caused by toxic chemicals (Soares et al., 2013). Ethanolic extract of *Calocybe indica* protects carbon tetrachloride ($CCl_4$)-induced chronic hepatotoxicity in mice by restoring the liver antioxidant status (Chatterjee et al., 2011). Sumy et al. (2014) found the hepatoprotective effect of oyster mushroom (*P. florida*) against paracetamol-induced liver damage in Wistar albino rats. *G. lucidum* aqueous extracts induce hepatoprotective effects on acute liver injury induced by α-amanitin (α-AMA) (Wu et al., 2013). A significant hepatoprotective effect on cirrhosis of the liver and chronic hepatitis B with the extracts or polysaccharides from *Dendropolyprus umbellatus*, *Schizophyllum commune*, *Trametes versicolor*, *Pseudoepicoccum cocos*, *T. fuciformis* and others has been reported (Shamtsyan, 2016). Several bioactive agents isolated from the fruit body, mycelia and spores of *G. lucidum*, such as ganoderic acids and ganosporeric acid A, are shown to have strong antihepatotoxic activity. A polysaccharide fraction from *Lentinula edodes* demonstrated liver protective action in animals together with improved liver function and an increased production of antibodies to hepatitis B (Mizuno et al., 1995). Aqueous extracts of *Volvariella volvacea*, *Lentinula edodes*, *F. velutipes*, *Auricularia auricular-judae*, *Tramella fuciformis*, *Grifola frondosa* and *Tricholoma lobayense* are screened for their hepatoprotective activity using paracetamol-induced liver injury (doses of 1.0 g/kg body weight) in rats as the model of chemical hepatitis (Ooi, 1996; Soares et al., 2013). Phenolics, triterpenes, polysaccharides and peptides are the main classes of compounds which could be responsible for the hepatoprotective activity of the mushroom extracts.

## *Anti-aging Effect*

Aging is a natural process that involves progressive physiological changes in an organism leading to senescence, or a decline of biological functions and of the organism's ability to adapt to metabolic stress (Zhou et al., 2014). Among the numerous theories associated with aging, the oxidative stress and free radical accumulation theories stand out the most that states ROS generated inside the cell will lead to aging (Kim et al., 2016; Wang et al., 2017). Oxidative stress is a result of imbalance between the antioxidant defense system and the formation of ROS, which has been considered deleterious because of the damage to cell membranes and DNA (Sies, 1997). Post-mitotic tissues such as brain, heart and skeleton muscle are more susceptible to aging, compared with other organs (Kayali et al., 2006). In brain, the accumulation of free radicals and attenuation of respiratory chain enzyme complex activity cause damage to cerebral mitochondria (Trushina & McMurray, 2007), wherein their dysfunction can induce the onset of some neurodegenerative diseases, such as Parkinson's disease, Alzheimer's disease, Huntington's disease, among others (Islam, 2017). Besides oxidative stress, aging is also closely associated with bringing about structural and functional defects in the immune system (Vulevic et al., 2008). Immunological dysfunction could be the cause of the increased susceptibility of the aged population to bacterial and virus infections, which are commonly seen in the elderly. Human body's natural antioxidant systems are not sufficient to repair oxidative damage entirely (Zheng et al., 2015) and lead to the severe damage of cell functions eventually aging and death (Harman, 2006). In order to reduce the oxidative damage of free radicals, a lot of synthetic antioxidants are widely used, such as butylatedhydroxyanisole, butylatedhydroxytoluene, tert-butylhydroquinone and propyl gallate (Sun & Kennedy, 2010). In recent years, researches have shown that synthetic antioxidants are restricted due to their potential hazards related to health, such as liver damage and carcinogenesis (Yuan et al., 2008).

In view of this, several mushrooms have been investigated for anti-aging property. Extracted polysaccharide TLH-3, isolated from the fresh fruiting body of *Tricholo mamalobayense*, shows anti-aging capability when measured in D-galactose-induced aged mice model (Ding et al., 2016). Many anti-aging cosmeceuticals have been developed from several types of mushrooms that are used in topical creams, serums and facial preparations as anti-aging ingredients (Wu et al., 2016). Anti-aging patented product from *G. lucidum* spores is available (Chung & Tong, 2005). Two novel anti-aging ergosterols, ganodermasidase A and B are found in the methanolic extract of *G. lucidum* (Weng et al., 2010). Water-soluble polysaccharide (AAP I-a), isolated from *Auricularia auricular-judae*, prevents oxidative stress in D-galactose-induced aged mice. A paste of polysaccharides is used for the production of anti-aging creams or lotions and other skin-related cosmetics in the industry (Zhang et al., 2011). These polysaccharides (AAP I-a) have the ability to delay aging as they result in the inhibition of the functional enzymes responsible for skin aging, such as elastase, tyrosinase, hyaluronidase and MMP-1 enzymes (Chaturvedi et al., 2018). Many extracted ingredients from the fruiting body of medicinal mushroom such as polysaccharides, polyphenolic, phenolics, terpenoids, selenium, vitamins and volatile organic compounds show tremendous antioxidant, anti-aging, anti-wrinkle, skin whitening and moisturizing effects (Hyde et al., 2010; Wu et al., 2016).

## Conclusion

Mushrooms are beneficial to the humankind not only in terms of nutrition but also for improved health. They are appropriate for inclusion in low calorie diets. Thus, mushrooms are not only food but are the raw material for development of functional food and dietary supplements (nutraceuticals). Furthermore, mushrooms as functional food can help in the early intervention of sub-healthy states and may prevent the consequences of several life-threatening diseases. Nevertheless, more scientific efforts are needed in order to elucidate the mechanisms and to identify and characterize the responsible and novel bioactive compounds from mushrooms around the globe, in addition to long term clinical trials.

**Abbreviations:** DM = diabetes mellitus; EFSA = European Food Safety Authority; FAO = Food and Agriculture Organization; HIV = human immunodeficiency virus; HSV = herpes simplex virus; LDL = low-density lipoprotein; ROS = reactive oxygen species; WHO = The World Health Organization.

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# Author's Biography



Dr. Jay Kant Raut is currently working as a Senior Scientist at Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur. He is curator of Nepal Fungal Database (NFD) and Editor of NFD newsletter. He has graduated his PhD degree in Mushroom Science in 2011 AD from Graduate School of Horticulture, Chiba University, Japan. After completing his Master Degree with Botany in 1997 from Tribhuvan University, he has been actively working in the field of mycology. He is a founder member of International Society for Fungal Conservation and member of several other national and international professional societies. At present, he is serving as regional representative in Asian Mycological Association Executive Committee (2019-2023). Dr. Raut has authored/co-authored about three dozens of research articles in national and international journals, about dozen of op-eds and a mushroom book. He has more than two decades of teaching and research experiences in Nepal and Japan. Mushroom systematic and nomenclature, mushroom biotechnology, mushroom cultivation, mycorrhiza, mushroom diversity and conservation are the research areas of his interest. He is a prominent crusader for mushroom science and non-green revolution in Nepal. He is recipient of National Research Scientist Award 2019, Nepal Bidhya Bhushan Padak 'Ka' and others.



Dr. Mahesh Kumar Adhikari is an eminent mycologist and currently serving as the Secretary of Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur. He received MSc in Botany (in 1973) from Tribhuvan University, Kathmandu Nepal, and PhD in 1996 from University Paul Sabatier, Toulouse, France. Since 1976, he has been working on the systematics and biodiversity of fungi and published around 200 fungal related articles and seven books. He has discovered 16 fungal species from the territory of Nepal which are new to science. Two newly discovered fungi have been named as *Puccinia adhikarii* Ono and *Suillus adhikarii* Das, Chakraborty & Cotter after him. The mushrooms *Russula nepalensis* Adhikari and *Russula kathmanduensis* Adhikari described by him, were released as postage stamp by Government of Nepal, Department of Postal Services. Dr. Adhikari has edited several books, proceedings and bulletins.

He is the Life member/member of Nepal Botanical Society, Natural History Society of Nepal, Ecological Society of Nepal and other professional societies. He has already served as the Vice-President of Nepal Botanical Society, and Mycological and Phytopathological Society of Nepal. He has also served as Member Secretary of APINMAP/ SCAMAP committee, Nepal National commission for UNESCO, Ministry of Education and Culture, and IUFRO committees.

Dr. Adhikari is decorated with Young Scientist Traveling Fellowship Award, Janpad Sewa Padak, Shree Panch Birendra Rajyarohan Rajat Mahotsav Padak, Mahendra Vidhya Bhushan Padak (A grade), Nepal Science and Technology Award, National Plant Resource Award, etc.

# Chapter 9

## Secondary Metabolites of Cucurbitaceae, Occurrence, Structure and Role in Human Diet

**Sajan L. Shyaula* and Mangala D. Manandhar**
*Faculty of Science, Nepal Academy of Science and Technology (NAST)*
*Khumaltar, Lalitpur, Nepal*
* Email: shyaulasajan@gmail.com

*Cucurbit plants were used actively as traditional herbal remedies for various diseases. The medicinal importance of plants lies in some chemical substances or secondary metabolites that produce a specific physiological action on the human body. Secondary metabolites are non nutritive chemical constituents of plants which are restricted in distribution in the particular plant species. The scarcity of scientific reports of vegetable gourds compared to the traditional usage and folkloric beliefs has further limited us in proper inclusion of cucurbits in our diet and versatile utility. The versatile utility of gourd vegetables as folk medicine and functional food ingredient provoked a compilation of a comprehensive review of these vegetables about their traditional usage and nutritional and medicinal properties together with their phytochemicals. Understanding the nutritional potential of gourd vegetables from scientific reports may influence both the work areas and consumers in the appropriate direction. In this sense, the present chapter aims to provide compilation of references and a detailed overview to the folk medicinal uses of Cucurbita plants. Brief discussion of phytochemicals and its activities are given in the text and for further details, cited references in the text and tables can be consulted.*

**Keywords:** Cucurbitaceae; cucurbits; gourd vegetables; pharmacology; secondary metabolites

## Introduction

The *Cucurbitaceae*, popularly known as cucurbits, includes many vegetable gourds. Cucurbitaceae are found in almost every vegetable garden and are important items in the diet. Cucurbitaceae family commonly called as a gourd family, shares 5 to 6% of the total vegetable produced which generally includes climbers with 134 genera and 965 species (Web, 1). They are climbers and the members of this family are excellent fruit crops. They usually produce spiraling tendrils or modified shoots that wrap around adjacent

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objects and use them for their support. Generally, cucurbits are climbing plants with alternate, simple, palmately veined leaves and dioecious species. All Cucurbitaceae are frost-sensitive and the family is confined to the warmer parts of the globe; those few that extend to temperate regions either winter underground as tubers below frost level, or are annuals and pass the winter as seeds.

Nepal has rich resources of cucurbits and these gourds are commonly served as vegetable curries in daily food items. In Nepal, 23 genera and 43 species of Cucurbitaceae are present (Web, 2). Among them, most commonly cultivated 12 cucurbits with its secondary metabolites and role in human diet are described in this chapter.

## Nutritional Composition

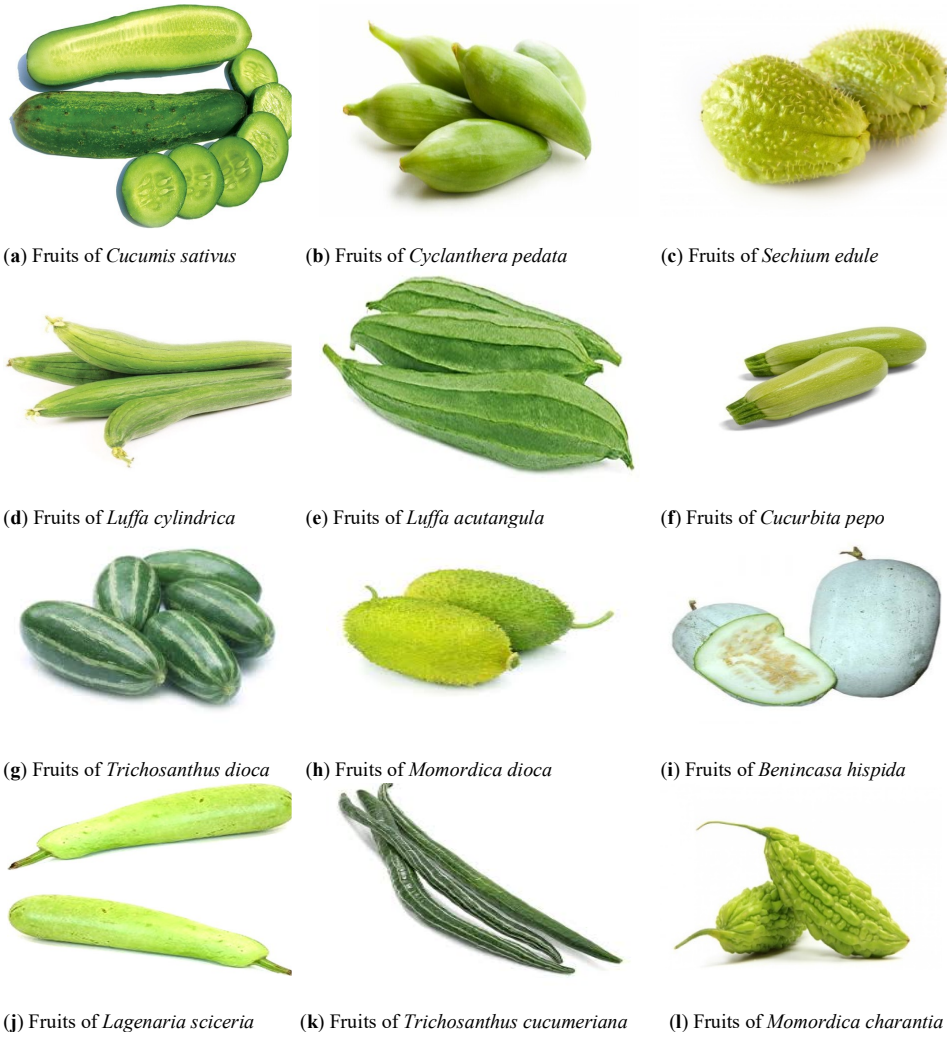
The nutritional composition of edible portion of gourd vegetables reveals that moisture contents are quite high, accounting for more than 90% of edible weight portion. The compositional value mentioned in different texts by various authors and authorities might be different because of various factors like genetic and environment. The general table of nutritional composition can be consulted in *Nepal Food Composition Table* published by Department of Food Technology and Quality Control (DFTQC), Government of Nepal (GoN) (DFTQC, 2017). The amount of protein and ash are in the range of 0.2–1.6% and 0.4–0.8%, respectively. Fat content is low, contributing less than 0.3% by weight of edible portion. The highest amount of vitamin C is found in bitter gourd. Among the minerals, potassium, phosphorus and calcium are the major mineral present in the gourd vegetables, with concentrations ranging between 20 and 30 mg/100 g.

## Commonly Consumed Cucurbits in Nepal: Bioactivity and Pharmacology

Most commonly cultivated and consumed cucurbits in Nepal are presented in Table 9.1 and Figure 9.1. From the study undertaken by Ministry of Agricultural Development (MoAD), GoN in 2015/16, *C. sativus*, *L. acutangula*, *M. charantia*, *C. maxima/moschata* and *L. sciceria* are produced in large amount in Nepal (APSD, 2016). Among them, cucumber has the highest production. The total production of each cucurbit is shown in the Table 9.1.

**Table 9.1.** Total production of gourd vegetables in Nepal

| Name of vegetables | Common name | Nepali name | Total production |
|---|---|---|---|
| *Cucumis sativus* | Cucumber | Kankro | 159041 |
| *Cyclanthera pedata* | Balsam gourd | Barela | 2229 |
| *Sechium edule* | Chayote | Skush | 29564 |
| *Luffa cylindrica* | Sponge gourd | Gheraula | 12008 |
| *Luffa acutangula* | Ridge gourd | Gheraula | 101044 |
| *Cucurbita pepo* | Summur squash | Zucchini | 18256 |
| *Cucurbita maxima / moschata* | Pumpkin | Pharsi | 103169 |
| *Trichosanthus dioca* | Pointed gourd | Parwal | 22443 |
| *Momordica dioca* | Spiny gourd | Chattel | - |
| *Benincasa hispida* | Ash gourd, wax gourd | Kubhindo | 11604 |
| *Lagenaria sciceria* | Bottle gourd | Lauka | 129798 |
| *Trichosanthus cucumeriana* | Snake gourd | Chichindo | 15776 |
| *Momordica charantia* | Bitter gourd | Karela | 132350 |



(**a**) Fruits of *Cucumis sativus* (**b**) Fruits of *Cyclanthera pedata* (**c**) Fruits of *Sechium edule*

(**d**) Fruits of *Luffa cylindrica* (**e**) Fruits of *Luffa acutangula* (**f**) Fruits of *Cucurbita pepo*

(**g**) Fruits of *Trichosanthus dioca* (**h**) Fruits of *Momordica dioca* (**i**) Fruits of *Benincasa hispida*

(**j**) Fruits of *Lagenaria sciceria* (**k**) Fruits of *Trichosanthus cucumeriana* (**l**) Fruits of *Momordica charantia*

**Figure 9.1.** Common cucurbits consumed in Nepal.

Comprehensive review on the bioactive compounds present and pharmacological studies of the most commonly consumed cucurbits as vegetables in Nepal is discussed below.

## 1. *Cucumis sativus*

Cucumber is anannually growing creeping vine. Its leaves are hispidly hairy tralling or climbing type. The fruits are sweet, refrigerant, haemostatic and tonic (Figure 9.1a). It is widely consumed fresh in salads or fermented (pickles) or as a cooked vegetable. The fresh, immature fruit are eaten in salads. Fruits are sliced or cut into small pieces, eaten as

such or served with vinegar or a salad dressing on its own or mixed with other vegetables. In Asia, the older, ripe and larger fruits are used in fermented pickles. The young tender leafy shoots are consumed as green. Cucumber fruit is composed mostly of water; more than 96% of edible unpeeled fruit is water. *C. sativus* is a species known to accumulate high levels of silicon (Si) in the tops including the fruits (Liang et al., 2005).

Cucumber pulp has been used to clean skin for centuries around the world. The fruits and seeds of cucumber are recommended globally to prepare cosmetic products for the treatment of various skin problems like wrinkles and sunburn. The pulp of cucumbers is primarily composed of water with ascorbic acid (vitamin C) and caffeic acid, which gives a soothing effect on skin and reduces swelling. Ascorbic acid and caffeic acid prevent water retention, which may explain why cucumbers applied topically are often helpful for swollen eyes, burns and dermatitis. Anti-hyaluronidase and anti-elastase activities of lyophilized juice of *C. sativus* proved that it may have potential role on skin care (Mukherjee et al., 2013). The fruit pulp having natural α-hydroxyacid compounds, like lactic acid, is widely used in cosmetics to reduce the thickness of the stratum corneum by reducing corneocyte cohesion, and used for dry skin, icthyosis, follicular hyperkeratosis, seborrheickeratosis, actinic and keratosis. Pulp tissues are used for treatments of warts, xerosis and chemical peeling of the skin. Cucurbitacin D and 23,24-dihydrocucurbitacin D are found in cucumber extracts, and these are responsible for the inhibition of tyrosinase and melanin syntheses. Hard fruit skin is rich in fiber and contains a variety of beneficial minerals including silica, potassium and magnesium, which shows a cooling effect and therefore *C. sativus* can be used as a potential anti-wrinkle agent in cosmetic products. Cucumber juice is often recommended as a source of silica to improve the complexion and health of the skin, plus cucumber's high water content makes it naturally hydrating required for glowing skin. Cucumber has a cleansing action within the body by removing accumulated pockets of old waste materials and chemical toxins.

## *Bioactive Components*

Fruits contain a high concentration of ascorbic acid where as pulp and peel extracts contain lactic acid. Bitter principles, cucurbitacins, are the characteristic properties of this species. Cucurbitacins have a tetracyclic cucurbitane nucleus skeleton, namely, 9β-methyl-19-norlanosta-5-ene. On maturity of the fruits, due to the effects of the enzyme Elaterase, cucurbitacins are hydrolyzed to its non bitter principles. Usually, the bitter principal does not accumulate very heavily in the fruit. Stem end of the fruits are comparatively richer of Cucurbitacin C than the middle or blossom end of the fruit; therefore, it is general practice to cut the stem end first before consuming the fruits. Dry seeds of *C. sativus* were found to contain albumins, globulins and glyoxysomal enzymes. C-glycosyl flavonoids like Cucumerin A, Cucumerin B and Megastigmane have also been isolated. Extraction of cucumber leaf tissue expressing induced resistance against powdery mildew fungi revealed the presence of C-glycosyl flavonoid products.

Volatile constituents mainly include Z-6-nonenol, E-2-nonenal, E,Z-2,6-nonadienal, etc. The extracellular enzyme α-galactosidase was detected by the presence of reddish-brown zones when coupling with hexazonium p-rosaniline on the agar plates around the plant material. Seeds contain number of sterols such as codisterol, isofucosterol,

stigmasterol and campesterol. Different class of compounds with its representative examples and references are given in Table 9.2.

**Table 9.2.** Different classes of bioactive compounds of cucumber

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Cucurbitacin | Cucurbitacins A, B, C, D, E and I | (Rice et al., 1981; Barham, 1953; Horie et al., 2007; Kano et al., 1999; Gill & Bali, 2012) |
| Sterol | Isofucosterol; stigmasterol; campesterol | (Garg & Nes, 1986) |
| Volatiles | Z-6 nonenol; E-2-nonenal; E,Z-2,6-nonadienal | (Sotiroudis et al., 2010; Kemp et al., 1974; Scriven & Meloan, 1984; Gandía-Herrero et al., 2003; Zhou & McFeeters, 1998) |
| Flavonoid, C-glycosyl flavonoid | Cucumerins A and B; vitexin; isovitexin; orientin; isoorientin; saponarin; isovitexin 2"-O-(6"'-(E)-p-coumaroyl) glucoside; rhamnetin (3,5,3',4-tetrahydroxy-7-O-methoxyflavone) | (McNally et al., 2003; Abou-Zaid et al., 2001; Krauze-Baranowska & Cisowski, 2001; Fawe et al., 1998) |
| Phenolic | p-Coumaric; caffeic acid; ferulic acid; p-coumaric acid methyl ester; chlorogenic acid; syringic acid | (Daayf et al., 2000; Ibrahim et al., 2010; Jamal et al., 2011) |
| Alkaloid | Indole-3-aldehyde; indole-3-carboxylic acid adenosine | (Kai et al., 2007) |
| Megastigmane | Cucumegastigmanes I and II; (+)-dehydrovomifoliol | (Kai et al., 2007) |
| Sphingolipid | 1-O-β-D-glucopyranosyl(2S,3S,4R,10E)-2-[(2'R)-2-hydroxy-tetracosanoylamino]-1,3,4,-octadecanetriol-10-ene; soya-cerebroside I | (Tang et al., 2010) |
| Enzyme, glyoxysomal enzyme | Elaterase; chitinase; crepsin; malate synthase; isocitrate lyase; citrate synthase; trypsin inhibitors; α-galactosidase | (Kapoor, 2018; Enslin et al., 1956; Ji & Kuć, 1996; Koller et al., 1979; Wieczorek et al., 1985; Stano et al., 2001) |
| Fatty acid | Tricosanoic; tricosenoic; lignoceric; nervonic acids | (Peng & Gnsman, 1976) |
| Acid | Ascorbic acid; lactic acid | (Chu et al., 2002; Nema et al., 2011) |
| Hormone | Gibberellins | (Hemphill et al., 1972) |
| Polysaccharide | Pectins | (Sudheesh & Vijayalakshmi, 1999) |
| Carotenoid | Luteins | (Kai et al., 2008) |

## *Pharmacological Properties*

**Antioxidant:** The study showed that *C. sativus* is the active antioxidant determined by the 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay. High performance liquid chromatography (HPLC) analysis of phenolic content showed the presence of chlorogenic acid as a major phenolic acid. 9-β-Methyl-19-norlanosta-5-ene cucurbitane glycoside, isolated from *C. sativus* seeds, also showed maximum antioxidant activity by DPPH assay. Other groups of researchers have also evaluated the antioxidant potential of *C. sativus* (Agarwal et al., 2012; Gill et al., 2009; Gill & Bali, 2012; Ibrahim et al., 2010; Jain et al., 2004; Kumar et al., 2010a; Murad et al., 1995; Nema et al., 2011; Sotiroudis et al., 2010; Stratil et al., 2006).

**Antidiabetic:** Alterations in serum glucose, insulin, triiodothyronine, thyroxine, total cholesterol, triglyceride, high density lipoprotein (HDL), low density lipoprotein (LDL), very low density lipoprotein (VLDL), hepatic lipid peroxidation, superoxide dismutase and catalase were studied during the study of antidiabetic effects of ethanolic extracts of *C. sativus* (Chandrasekar et al., 1989; Roman-Ramos et al., 1995). The peel extracts nearly reversed most of these changes induced by alloxan suggesting their possible role in ameliorating diabetes mellitus and related changes in serum lipids (Dixit & Kar, 2010; Sharmin et al., 2012). Hydroalcoholic and buthanolic extracts were effective on diminishing blood glucose levels and controling the loss of body weight in streptozotocin (STZ)-induced diabetic rats (Minaiyan et al., 2011). In the study, *C. sativus* was examined on β-glucosidase inhibitory activity for response surface optimization of the process conditions. β-Glucosidase inhibitory activity reached the highest value at the optimum conditions of temperature, incubation time, agitation speed, and volume of solvent. p-Coumaric and syringic acids are major responsible for β-glucosidase inhibitory activity (Jamal et al., 2011; Stano et al., 2001).

**Hepatoprotective:** *C. sativus* could protect hepatocytes against cumene hydroperoxide (CHP)-induced cytotoxicity and reactive oxygen species (ROS) formation (Heidari et al., 2012). Hepatocytes were obtained by collagenase perfusion of the liver and viability was assessed by plasma membrane disruption determined by trypan blue exclusion test. Isolated hepatocytes were incubated with cumene hydroperoxide. There was an initial rapid increase in ROS formation measured by the fluorescence intensity of dichlorofluorescein added to it. Aqueous extract of *C. sativus* fruit prevented the formation of ROS. The ethanolic extract of the fruits of *C. sativus* has highly significant hepatoprotective effect on the liver of paracetamol-induced toxicity (Gopalakrishnan & Kalaiarasi, 2013). Treatment with the ethanolic extract of fruits of *C. sativus* had significant protection against hepatic damage by maintaining the biochemical parameters such as glutamic oxalacetic transaminase, serum glutamic pyruvate transaminase, serum alkaline phosphatase, γ-glutamate transpeptidase, total bilirubin, conjugated bilirubin, unconjugated bilirubin and lipid peroxidase as well as the levels of liver homogenates glutathione peroxidase, glutathione reductase, superoxide dismutase, catalase and reduced glutathione within normal range.

**Antifungal:** An acidic β-1,3-glucanase and three isoforms of Chitinase (A, B and C) were isolated and purified from cucumber leaves (Ji & Kuć, 1996). Purified enzymes were tested for antifungal activity to *C. lagenarium* in vitro. These enzymes significantly inhibited spore germination and inhibited the growth of *C. lagenarium* in different

concentration. Lysis of hyphal tips and abnormal growth were observed in the presence of a mixture of β-1,3-glucanase and Chitinase C. The antifungal activity was attributable to the presence of phytoalexin, identified as a flavonol aglycone, rhamnetin (3,5,3',4'-tetrahydroxy-7-O-methoxyflavone). Further silicon mediated accumulation of flavonoid is involved in the increased resistance of cucumber to powdery mildew by enhancing the antifungal activity of infected leaves (Fawe et al., 1998). Cucumber is able to release antifungal compounds that are instrumental in repressing powdery mildew infection. Accumulation of phenolic compounds (p-coumaric, caffeic and ferulic acids, and p-coumaric acid methyl ester) played a role in resistance against powdery mildew following a prophylactic treatment with Milsana (McNally et al., 2003). The ethanol extracts showed antifungal activity against *Aspergillus niger*, *Blastomyces dermatittidis*, *Candida albicans*, *Pityrosporum ovale*, *Trichophyton* spp. and *Microsporum* spp (Das et al., 2012; Mallik & Akhter, 2012; Tang et al., 2010).

**Antibacterial:** The effects of (E,Z)-2,6-nonadienal and (E)-2-nonenal on *Bacillus cereus*, *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella typhimurium* were investigated. The compounds demonstrated an apparent bactericidal activity against these pathogens (Cho et al., 2004; Khan et al., 2013a; Sotiroudis et al., 2010). Sphingolipids isolated from *C. sativus* also showed antimicrobial properties (Sood et al., 2012; Tang et al., 2010).

**Analgesic:** The aqueous extract of *C. sativus* fruits showed maximum analgesic effect compared with diclofenac sodium. The presence of flavonoids and tannins in the extract might be responsible for the free radical scavenging and thereby analgesic effects (Kumar et al., 2010a).

**Wound healing:** A cream was formulated using soft white paraffin base containing aqueous extract of *C. sativus* fruit and applied on experimentally induced wounds in rats. Epithelialization period, wound contraction, scar width and histopathological evaluation parameters were used for pharmacological evaluation of wound healing activity. Cream formulation of aqueous extract when applied topically did not show any sign and symptoms of skin irritation. The treatment with aqueous extract of *C. sativus* fruit cream formulation resulted in significance decrease in wound area, epithelization period and scar width, whereas rate of wound contraction significance increased demonstrating the wound healing property in laboratory animals (Patil et al., 2011).

**Laxative:** The aqueous fruit pulp extract of *C. sativus* has a significant laxative activity (Sharma et al., 2012d). The aqueous fruit pulp extract of *C. sativus* administered orally reduced loperamide-induced constipation in dose dependant manner and results similar to that of reference drug sodium picosulphate. The extract also produced a significant increase of intestinal transit in comparison with castor oil.

**Antiulcer:** In in vivo antiulcer activity by pyloric ligation and water immersion stress induced ulcer models in rat, methanolic extract of *C. sativus* showed maximum reduction of gastric acid volume and free total acidity (Gill et al., 2009). The results suggested that methanolic extract of *C. sativus* seeds possessed significant antiulcer potential. In indomethacin and pyloric ligation model, the pretreatment with *C. sativus* fruit pulp aqueous extract significantly reduced the lesion index, in comparison with control (Sharma et al., 2012). *C. sativus* fruit pulp aqueous extract resulted in significant increase

in pH, enzymic antioxidants i.e. super oxide dismutase and catalase, with a significant decrease in volume of gastric juice, and free total acidity, protein and carbohydrate concentrations and lipid peroxide (LPO) levels. The extent of healing was also determined with post administration of *C. sativus* fruit pulp aqueous extract in acetic acid-induced model and cause significant reduction in lesion index (Patil et al., 2012). In another experiment, pretreatment with *C. sativus* exhibited significant effect in lowering of ulcer area, ulcer index as well as neutrophil infiltration in acetic acid-induced colitis. Antiulcer compound, 9-β-methyl-19-norlanosta-5-ene cucurbitane glycoside, has been isolated from *C. sativus* seeds. The compound showed optimum percentage inhibition by pyloric ligation and water immersion stress in indomethacin-induced ulcer models (Gill & Bali, 2012). The extract of *C. sativus* has shown to possess significant carminative and antacid properties. The extract of *C. sativus* significantly neutralized acid and showed resistance against change in pH and also illustrate good carminative potential when evaluated using the carbondioxide evolution method and Rossette Rice test (Sharma et al., 2012b, 2012c).

**Anticancer:** Tyrosine-phosphorylated signal transducer and activator of transcription (STAT3) plays a pivotal role in human tumour malignancy. Pharmacologically targeting the JAK/STAT3 signaling pathway the anticancer drugs can be developed. Cucurbitacin I potently inhibited the growth in nude mice of A549 tumours, v-Src-transformed NIH 3T3 tumours, invasive NPC cell lines and the human breast carcinoma MDA-MB-468 (Blaskovich et al., 2003). The suppression of STAT3 levels resulted in the inhibition of STAT3 DNA binding in case of Cucurbitacin I. Brief exposure of NPC cells to Cucurbitacin I was sufficient to significantly reduce the in vitro clonogenicity and in vivo tumourigenicity of NPC cells (Lui et al., 2009).

**Hypolipidemic/antiatherogenic:** The levels of atherogenic parameters, the triglyceride level, total cholesterol, HDL and LDL, are far below the borderline level in rats treated with *C. sativus* oils to cause atherosclerosis, indicating that they could be potential good edible oils for reducing cardiovascular illnesses (Achu et al., 2008). The oral administration of the pectin extracted from the fruit of *C. sativus* showed significant hypolipidemic action in normal as well as cholesterol-fed experimental animals (Sudheesh & Vijayalakshmi, 1999). Concentrations of cholesterol, triglycerides, phospholipids and free fatty acids were found to be significantly reduced in the serum and tissues of experimental animals.

**Skin whitening/antiwrinkle:** It is potentially useful skin-whitening agent. Methanolic extracts of leaves and stems inhibited melanin production in B16 cells (Kai et al., 2008). The extracts decreased tyrosinase expression at the protein level suggesting that the depigmenting mechanism of extracts. Trans,cis-2,6-nonadienal, described as a major volatile compound of cucumber, was characterized as a noncompetitive inhibitor against 4-tert-butylcatechol oxidation by mushroom tyrosinase (Gandía-Herrero et al., 2003; Sotiroudis et al., 2010). Cucumber extract, when pharmacologically refined, could be incorporated in first aid treatment of corneal acidburn (Uzodike & Onuoha, 2010). Guinea pigs treated with cucumber bark and pulp extract, which had their cornea induced with acid burn wound, had short healing period than control group. The in vitro Sun Protection Factor of fresh aqueous extract from fruits of *C. sativus* is also determined according to spectrophotometric method (Hogade et al., 2010). The hyaluronidase and elastase

inhibitory assay was performed in reference to oleanolic acid. The lyophilized juice of *C. sativus* fruit showed strong anti-hyaluronidase and anti-elastase activities (Nema et al., 2011). The juice is rich source of ascorbic acid and thereby rationalizes the use of *C. sativus* as potential antiwrinkle agent in cosmetic products (Lee et al., 2003).

A tropical skin-care cream, water in oil emulsion of cucumber extracts, was developed and its effects on skin-melanin, skin erythema, skin moisture, skin sebum and transepidermal water loss were evaluated. Formulation showed significant effects on skin sebum secretion, transepidermal water loss and erythema was increased while skin melanin and skin hydration level was decreased by formulation (Akhtar et al., 2011).

**Antihelminthic:** The ethanolic extracts of the seeds of *C. sativus* exhibited a potent activity against tapeworms which was comparable to the effect of piperazine citrate (Elisha et al., 1987).

**Trypsin inhibitor:** Six amino acid sequences for trypsin inhibitors were isolated from cucumber seeds (Wieczorek et al., 1985).

**Anticockroach:** The compounds (E,Z)-2,6-nonadien-l-al and (E)-2-nonen-l-al that are present in crushed cucumbers were found to repel American cockroaches, *Periplaneta americana* (Scriven & Meloan, 1984).

**Diurectic:** Powdered leaf with sugar acts as a diuretic (Kapoor, 2018).

## 2. *Cyclanthera pedata*

The fruit is a berry (10–20 cm length) with irregular surface, soft spines and longitudinal grooves Figure 9.1b. The young fruits, often mildly tasting of cucumber but not crispy, are eaten raw and older fruits are cooked. The young shoots of this fast growing plant are also edible. Matured fruits can be sun dried or pickled to preserve them and then eat them like vegetables all year round. Their medicinal properties are popularly attributed to anti-inflammatory, hypoglycemic and hypocholesterolemic (Montoro et al., 2005).

## *Bioactive Components*

The fruits and seeds of *C. pedata* are rich in Cucurbitacins. Series of triterpenoid saponins from the MeOH extract of the fruits of *C. pedata* is reported (Table 9.3). In addition, flavonoids O- and C-glycosides were characterized and quantified in the fruits. New malonyl derivatives of flavonoid have been isolated by column chromatography. Flavonoid glycosides present in the methanolic extracts from *C. pedata* fruits was determined using HPLC followed by detection with electrospray ionization mass spectrometry (ESI-MS). A liquid chromatography-mass spectrometry (LC-MS) based method was developed for the characterization of fruits of *C. pedata.* The ripe seeds of *C. pedata* are a rich source of trypsin inhibitors. The procedure employing both affinity chromatography on immobilized chymotrypsin in the presence of high NaCl concentration and native preparative electrophoresis made it possible to effectively isolate seven inhibitors from *C. pedata* seeds.

**Table 9.3.** Different classes of bioactive compounds of *C. pedata*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Cucurbitacins | 3-β-(β-d-Glucopyranosyloxy)-25-acetoxy-16α,20,22,-trihydroxycucurbit-5-en-11-one; 2-[(6-O-β-d-glucopyranosyl-β-d-glucopyranosyl)oxy]-3,16α,20,22,25-pentahydroxy-29-norcucurbita-1,3,5(10)-trien-11-one | (De Tommasi et al., 1996) |
| Saponins | 17-Hydroxy-20(S)-protopanaxatriol-6-O- α-D-xylopyra-nosyl-20-O- α -D-glucopyranosyl-(1f2)-α-D-glucopyranoside | (De Tommasi et al., 1999) |
| Flavonoids | 6-C-Fucopyranosyl-(3-malonyl)-chrysin; chrysin-6-C-fucopyranoside; chrysin-6-C-glucopyranoside; apigenin-6-C-fucopyranoside malonyl derivative | (Montoro et al., 2001, 2005; Macchia et al., 2009; Carbone et al., 2004) |
| Enzymes and protein | Serine proteinase inhibitor CyPTI I-VII; angiotensin I-converting enzyme | (Kowalska et al., 2006; Ranilla et al., 2010) |

## *Pharmacological Properties*

**Antioxidant/anti-inflammatory:** The antioxidant activity was determined by measuring the free radical scavenging activity using the Trolox equivalent antioxidant capacity (TEAC), and the coupled oxidation of β-carotene and linoleic acid methods (Montoro et al., 2001). The isolated flavon glycosides showed antioxidant activity. During evaluation of phytochemical and nutraceutical profiles of *C. pedata* fruits, fresh and dried fruits showed antioxidant activity and inhibitory capacity on lipoxygenase (LOX) (Rivas et al., 2013).

**Hypercholesterolemic:** When the study was designed to determine lipid profiles in postmenopausal women, treatment with Caigua, a natural plant that is administered dehydrated and capsulated, can reverse dyslipidemia in the postmenopausal woman (Gonzales & Villena, 1995). The effects of white wheat bread and white wheat bread added with a bioactive compound mixture (*C. pedata*, *Glycine max*, *Monascus*-fermented red mold rice, *Cynara scolymus* and *Medicago sativa*) were examined on hypercholesterolemic and steatotic mice (Pozzo et al., 2015). Liver histology confirmed lower lipid drop accumulation in the high-fat diet with white wheat bread added mixture group than in the high-fat diet and high-fat diet with white wheat bread groups.

**Antihypertensive:** Caigua inhibited significantly the hypertension relevant angiotensin I-converting enzyme (ACE) (Ranilla et al., 2010).

**Proteinase inhibitor:** New trypsin inhibitors, CyPTI I-VII, were purified from ripe seeds of *C. pedata* by affinity chromatography. All the isolated inhibitors strongly inhibit bovine β-trypsin and, more weakly, bovine α-chymotrypsin (Kowalska et al., 2006).

## 3. *Sechium edule*

*S. edule* is an uprising prerennial plant with tendrils and tuberous roots. An important feature in the species is its broad variation with respect to form and colour of fruits Figure 9.1c. Unlike other cucurbits, the fruit contains only a single large seed. Fruit,

young leaves, shoots, stems and tuberous roots are edible. Chayote fruit are sometimes eaten raw in salads, but are more often cooked by boiling, baking or stuffed, mashed, fried, scalloped or pickled. The fruits are also used in curries. The chayote fruit is harvested and consumed still immature, because it becomes harder and fibrous during the maturation process, due to the decrease of branched arabinan and arabinogalactan contents (Shiga et al., 2015). Oct-1-en-3-ol and hex-3-en-ol contribute characteristic odour to the green fruit (Macleod, 1990). For its high content in aspartic acid, glutamic acid, alanine, proline, serine, tyrosine, threonine and valine, chayote fruit is recommended in hospital diets. There are information mentioning the use of chayote in baby foods (giving consistency) and medicinal use. Because of the softness of the flesh, the fruit has been used for baby and children's food, juices, sauces and pasta dishes. Chayote starch is a good substitute for wheat flours in diverse products, which can be used by people with special nutritional requirements, such as those with celiac disease (Hernandez-Uribe et al., 2014).

## *Bioactive Components*

Chayote edible parts contain a wide diversity of bioactive compounds, such as saponins, phenolic acids, flavonoids, carotenoids, proteins, polysaccharide, cucurbitane triterpenoids and phytosterols (Table 9.4) (Cadena-Iñiguez et al., 2007; Vieira et al., 2019). Flavonoids, including C-glycosyl and O-glycosyl flavones, were detected. The aglycone moieties are represented by apigenin and luteolin, while the sugar units are glucose, apiose and rhamnose. Chayote stems presented higher content of apigenin 6-C-β-D-glucopyranosyl-8-C-β-D-apiofuranoside and diosmetin7-O-rutinoside. Phenolic compounds like trans-cinnamic and phenylacetic acids were present in chayote leaves. Significant and positive correlations observed between antioxidant activity and content of polyphenols and anthocyanidins. Chayote fruits, leaves and tuberous roots contain complex carbohydrates as dietary fiber and starch. Chayote has a high and a low molecular weight polysaccharide fraction containing high amounts of galactose, arabinose and galacturonic acid. Chayote tuber starch had higher peak viscosity than potato starch. The green and wild varieties showed higher concentrations of Cucurbitacin than the yellow varieties, suggesting that the higher Cucurbitacins content may be related to the bitter flavour of chayote. A new ribosome-inactivating protein, sechiumin, with antiproliferative inhibitory activitity was purified from the seeds.

**Table 9.4.** Different classes of bioactive compounds of *S. edule*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Flavonoid | Vicenin-2; vitexin; luteolin-7-O-rutinoside; apigenin-7-O-rutinoside; myricetin; diosmetin-7-O-rutinoside; phlorizidin | (Siciliano et al., 2004; Chao et al., 2014b; Salazar-Aguilar et al., 2017) |
| Polyphenol | Trans-cinnamic acid; phenylacetic acid; cinnamic acid methyl ester; coumaric acid; caffeic acid; kesperetin | (Siciliano et al., 2004; Ragasa et al., 2014; Loizzo et al., 2016; Lombardo-Earl et al., 2014; Yang et al., 2015b) |
| Protein / enzyme | Sechiumin; nicotianamine; trypsin inhibitor; lectin; β-glucosidase | (Wu et al., 1998; Hayashi et al., 2005; Laure et al., 2006; Vozari-Hampe et al., 1992; Mateos et al., 2015) |

| | | |
|---|---|---|
| Starch / Polysaccharide | Glucurono(arabino)xylan; mannan; galactoglucomannan; fucoxyloglucan | (Hernandez-Uribe et al., 2011; Aung et al., 1992; Castro-Alves & do Nascimento, 2016; Hernandez-Uribe et al., 2014; Jiménez-Hernández et al., 2007; Shiga et al., 2015) |
| Cucurbitacin | Cucurbitacins B, D, E, and I; dihydroisocucurbitacin; glycocucurbitacin-I; dihydrocucurbitacin-D | (Cadena-Iñiguez, 2005; Salazar-Aguilar et al., 2017; Iñiguez et al., 2011; Kim & Kim, 2015; CadenaIñiguez & ArévaloGalarza, 2011) |
| Volatiles | Octadeca-9,12-dienoic acid; docosane; oct-1-en-3-ol | (Macleod, 1990) |
| Sterol / Saponin | Desmosterol (cholesta-5,24-dienol); 24-methylcholesterol; 28-isofucosterol; 28-isoavenasterol; avenasterol; peposterol | (Salama et al., 1986; Akihisa et al., 1986; Salama et al., 1987) |
| Triterpene | Euphol; tirucallol; cycloartanol; β-amyrin; butyrospermol; isomultiflorenol | (Akihisa et al., 1986, 1988) |
| Fatty acid | 3-Octadecenoic acid; trilinolenin; α-linolenic acid; methyl of hexadecanoic acid | (Ragasa et al., 2014; Monroy-Vázquez et al., 2009) |
| Gibberellin | 3-Propyl-gibbberellin; 13-hydroxylated gibberellin | (Albone et al., 1984; Aung et al., 1990; Lorenzi & Ceccarelli, 1986) |

## *Pharmacological Properties*

**Antihyperglycemic:** Preventive and therapeutic potentials of fruit juice of *S. edule* in fructose and sucrose-sweetened beverages-induced oxidative stress and impaired glucose tolerance (IGT)-induced other metabolic disturbances in rats were explored. *S. edule* juice prevented development of impaired glucose tolerance-induced by fructose and also significantly reduced two hour glycemic load following oral glucose tolerance test (OGTT) (Tiwari et al., 2013). Treatment of these rats with *S. edule* juice accelerated normalization of oral glucose tolerance ability and decreased oxidative stress, platelet aggregation and accumulation of AGEs in sucrose induced IGT and oxidatively stressed rat. Thus, *S. edule* juice may help to reduce development of hyperglycemia and hyperglycemia induced development of complications. Oral administration of *S. edule* extract also prevents the body weight loss and significantly decreases the blood glucose level on alloxan-induced diabetes in Wistar rats (Maity et al., 2013). Methanol and aqueous extracts of the peel exhibited bile acid binding and α-amylase inhibitory activities (Loizzo et al., 2016; Mateos et al., 2015).

**Antimicrobial:** The antimicrobial properties of *S. edule* alcoholic extracts were tested against bacteria of clinical relevance as nosocomial pathogens *Enterococcus faecalis*, *Staphylococcus aureus*, coagulase-negative *Staphylococci*, *Streptococcus pyogenes* and *Streptococcus agalactiae* (Noumedem et al., 2013; Ordoñez et al., 2003). Ethanolic extracts showed activity against these gram-positive bacteria. In another experiment, a hydrogel with carbopol acrylic acid polymer containing *S. edule* fluid extract acts as antibacterial, antimycotic and antioxidant agent (Ordoñez et al., 2009). When extracted

were tested against the food borne bacteria, different extracts of *S. edule* exhibited antibacterial activity against most of the gram-negative bacteria *E. coli*, *S. typhimurium* and *Shigella flexneri*, but were not able to control the growth of gram-positive bacteria (Sibi et al., 2013).

**Antioxidant:** Biocatalyzer or its byproducts are natural health products made by yeast fermentation of glucose. *Carica papaya*, *Pennisetum pupureum* and *S. edule* may be useful health foods against neural lipid peroxidation, traumatic epilepsy and aging (Santiago et al., 1991). Biocatalyzer and its byproducts scavenge free radicals generated by $FeSO_4$-$H_2O_2$-diethylene triamine pentaacetic acid system. Alcohol impairs erythrocyte (red blood cell) membrane fluidity and lipid composition. Bionormalizer given to alcoholics group showed a significant recovery to control values of either blood viscosity and whole blood filterability and a partial, although significant, improvement of red blood cell membrane fluidity, red blood cell malonyldialdehyde and plasma glutathione, which suggest that an effective antioxidant supplementation is able to improve the hemorrheology in alcoholics (Marotta et al., 2001).

The ethyl acetate extract of *S. edule* showed the highest DPPH free radical scavenging activity. Ethyl acetate fruit extract of *S. edule* had also cupric ion reducing antioxidant capacity and Phosphomolybdenum assays when analyzed by Pearson's method. Pulp was found to be the active in the 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) assay (Chao et al., 2014b; Diré et al., 2007; Fidrianny et al., 2015, 2016; Ibarra-Alvarado et al., 2010; Nagarajaiah & Prakash, 2015; Ordoñez et al., 2006; Sulaiman et al., 2013).

**Cardioprotective/antiobesity/antihypertensive:** Cardioprotective activity of the ethanolic extract of fruits of *S. edule* was determined by the administration of isoproterenol (Neeraja et al., 2015). Histopathological studies of the hearts of isoproterenol treated rats have showed infiltration of inflammatory cells and continuity in muscle fiber. Animals treated with ethanolic extract of *S. edule* showed less degenerative changes. Regular treatment with *S. edule* extract significantly reduced the levels of serum transaminases, alkaline phosphates, lactate dehydrogenase, creatinine kinase, total cholesterol, triglycerides, LDL cholesterol, VLDL cholesterol, and increased the levels of HDL cholesterol.

Water-soluble extracts were prepared from peels and pulps of the fruit and injected into anaesthetised rats. Various cardiovascular parameters were measured including heart rate, mean arterial pressure and several electrocardiogram (ECG) intervals; and extracts tested produced a fall in blood pressure with little change in ECG intervals (Gordon et al., 2000). Different hypertension models were induced with angiotensin II (AG II). The hydroalcoholic extract was tested on an in vitro study of isolated aorta rings denuded of endothelial cells, using AG II as the agonist; this assay proved the vasorelaxant effect of this extract. An angiotensin-converting enzyme (ACE) inhibitor, nicotianamine, was purified from *S. edule* by using some ion-exchange column chromatographies (Hayashi et al., 2005; Ibarra-Alvarado et al., 2010; Lombardo-Earl et al., 2014; Lozoya, 1980).

**Hepatoprotective:** Ethanolic extract of fruits of *S. edule* showed significant hepatoprotective activity against $CCl_4$-induced hepatotoxicity and paracetamol-induced

hepatotoxicity in mice and rats by reducing the levels of alanine transaminase (ALT), aspartate transaminase (AST), alkaline phosphatase (ALP), total billirubin and hepatic lipid peroxidation, and increasing the levels of antioxidants markers like hepatic glutathione, catalase, super oxide dismutase and total protein in a dose dependent manner (Firdous et al., 2012a).

*S. edule* shoots have potential for developing health foods for preventing and remedying fatty liver. The extract of *S. edule* shoots reduces lipid accumulation in oleic acid-treated HepG2 cells. *S. edule* shoots could decrease serum and hepatic lipid contents (e.g., triacylglycerol and cholesterol), and through the AMP-activating protein kinase (AMPK) signaling pathway, the extract could decrease lipogenic relative enzymes, such as fatty acid synthase (FAS), HMG-CoA reductase and sterol regulatory element binding proteins (SREBPs), and increase the expression of carnitine palmitoyltransferase I (CPT-I) and peroxisome proliferators activated receptor α (PPARα). Caffeic acid and hesperetin, the main ingredients of *S. edule* shoot extract, inhibited oleic acid-induced lipid accumulation in HepG2 (Wu et al., 2014a; Yang et al., 2015b).

**Immunomodulatory:** Polysaccharides in chayote modulate macrophage functions. The polysaccharides induced tumour necrosis factor-alpha (TNF-α), nitric oxide (NO) secretion in macrophages and interleukin-6 (IL-6) secretion in activated macrophages (Castro-Alves & do Nascimento, 2016; Salama et al., 1987; Salama et al., 1986).

**Antiulcer:** Ethanolic extract of *S. edule* fruit significantly protected the ulceration induced by aspirin (Sateesh & Rao, 2012).

**Anticancer:** A new ribosome-inactivating protein, sechiumin, was purified from the seeds of edible gourd. It inhibits the protein synthesis of rabbit reticulocyte lysate strongly but has a much lower inhibitory effect on intact human cervical carcinoma (HeLa) cells. The recombinant sechiumin could be used for the preparation of immunotoxin as a potential cancer chemotherapeutic agent (Wu et al., 1998).

*S. edule* extracts showed the strongest inhibitory effect towards the mutagenicity of 2-amino-3-methyl-imidazo[4,5-f]quinoline in *S. typhimurium* TA98 and TA100 (Yen et al., 2001). Fruit of *S. edule* was used in order to assess antiproliferative and cytotoxic activities in two tumoural lines (L-929 and HeLa), and has possibility of blocking proliferation of carcinogenic cells. The in vitro antiproliferative activity of the crude ethanolic extracts from the fruits of *S. edule* was examined using the Crystal violet assay on three cancer cell lines – HeLa, mouse lung fibrosarcoma (L929) and mouse macrophage leukaemia (P388). Different degree of antiproliferative cytotoxicity activity of the extract depended on the cell lines and vareities of *S. edule* used (Cadena-iñiguez et al., 2013; Monroy-Vázquez et al., 2009; Salazar-Aguilar et al., 2017). The methanolic extract, containing mainly cucurbitacin and flavonoids, inhibited the proliferation of HeLa cells, P-388 and L-929 cancer cell lines. The antiproliferative potential of a crude extract from the chayote and its potential for apoptosis induction were assessed in leukaemic cell lines and normal mouse bone marrow mononuclear cells (BM-MNCs). The extract strongly inhibited the proliferation of the P388, J774, and WEHI-3 cell lines. However, the extract had no effect on bone marrow mononuclear cells (Aguiñiga-Sánchez et al., 2015).

**Antiepileptic:** The effect of ethanol extract of fruits of *S. edule* on antiepileptic and central nervous system (CNS) depressant model was studied in rats. The extract significantly reduced the duration of various phases of convulsions in both maximal electroshock (MES)-induce seizures and in pentylenetetrazole (PTZ)-induced convulsion (Firdous et al., 2012b).

**Diuretic:** Chayote, a subtropical vegetable with potent diuretic action, is implicated as the potassium level returned to normal, without recurrence of hypokalemia (Ribeiro et al., 1988; Jensen & Lai, 1986; Rodríguez et al., 1984).

**Enzyme inhibitor:** Several enzyme inhibitor proteins were isolated from *S. edule* seeds like trypsin inhibitors and peroxidase (Flick et al., 1978; Laure et al., 2006).

**Lesive property:** The biodistribution of radiopharmaceutical used in diagnostic imaging can be altered by a wide variety of factors. Stannous chloride ($SnCl_2$) is employed as a reducing agent to obtain technetium-99m-labelled (99mTc) radiopharmaceuticals in nuclear medicine kits, being inject endogenously in humans. If unknown, the drug interaction with radiopharmaceuticals can lead to misdiagnosis. Natural plant extract may induce the generation of activity metabolites with oxidant property with direct action on the labeling process. The extract of *Sechium* was able to reduce the radio labeling in RBC when blood were incubated with $SnCl_2$ and 99mTc in Wistar rats (Gomes et al., 2004; Dire et al., 2001, 2003a, 2003b, 2004, 2007; Feliciano et al., 2002).

**Nephroprotective:** When the aqueous extract of leaves of *S. edule* was evaluated for its protective activity against gentamicin, potassium dichromate-induced nephrotoxicity and STZ-induced diabetic nephropathy in experimental animals, the extract of *S. edule* has significantly decreased the level of blood urea, blood urea nitrogen and serum creatinine, and also significantly increased the serum levels of total protein (Mumtaz et al., 2013).

**Photoprotection:** *S. edule* fruit extract protected keratinocytes against ultraviolet (UVA)-induced cytotoxicity, decreased the intracellular amounts of ROS, and reduced oxidatively induced DNA lesions after UVA exposure. Furthermore, *S. edule* fruit extract decreased the induction of cyclobutane pyrimidine dimer (CPD) lesions in UVA-irradiated keratinocytes, and exhibited increased DNA repair of such photoproducts at 24 hours postexposure (Metral et al., 2018).

## 4. *Luffa cylindrica*

*L. cylindrica* is known as a vegetable sponge or sponge gourd. The fruits of *L. cylindrica* are smooth and cylindrical shaped Figure 9.1d. One mature *Luffa* sponge will produce at least 30 seeds and some will produce many more. It is officially listed in the *Chinese Pharmacopoeia*, and used for treatment of paralytic diseases. In folk medicine, it is used as an antitussive in the treatment of chronic bronchitis. The fruit pulp of *L. cylindrica* has been used to induce hemostasis, resolve phlegm and clear fever in traditional Korean medicine. They are used for bathing, removing toxins and regenerating the skin. They help varicose veins and cellulite by stimulating circulation. The fibrous vascular system inside the fruit, after separating from the skin, flesh and seeds, can be used as bathroom sponge, component of shock absorbers, sound proof linings, utensils cleaning sponge, packing materials, filters in factories, soles of shoes and for making crafts.

*L. cylindrica* seeds were reported to be abortifacient. Since many women in some part of the world depend on the use of this traditional medicine to induce labour, the dilemma can lie in the toxicity and the unspecified dosages that may threaten the life of the unborn baby and the mother (Azeez et al., 2013).

## *Bioactive Components*

Analysis of functional components in *L. cylindrica* has resulted different classes of compounds (Table 9.5) (Azeez et al., 2013; Partap et al., 2012a). The fruit contains triterpenoid and saponins, called lucyosides. Series of luffin proteins were isolated from *Luffa* seed and reported to be a ribosome-inactivating protein. Amino acid analysis revealed that they have very unusual amino acid compositions and are characterized by a predominance of arginine and glutamate residues. Many polyphenols including p-coumaric acid, 1-O-feruloyl-β-D-glucose, diosmetin-7-O-β-D-glucuronidemethyl ester, apigenin-7-O-β-D-glucuronidemethyl ester and luteolin-7-O-β-glucuronide methyl ester have been discovered in *Luffa* pulp. In *Luffa* seed, both oleanolic acid and echinocystic acid were the major triterpene acids present.

**Table 9.5.** Different classes of bioactive compounds of *L. cylindrica*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Polysaccharide | Cellulose; xylan; mannan; galactan; lignin | (Rowell et al., 2000; Mazali & Alves, 2005) |
| Sterol / Triterpene / Saponin | Lucyosides C, E, F, H, J, K, L, M, N, O, P, Q and R; α-spinasterol; lucyin A; 21β-hydroxyoleanoic acid; echinocystic acid; oleanolic acid; cucurbitacin | (Xiong et al., 1994; Ismail et al., 2010; Khajuria et al., 2007; Garai et al., 2018; Kao et al., 2012; Takemoto, 1985; Yoshikawa et al., 1991; Liang et al., 1993, 1994, 1997a, 1997b; Abdel-Salam et al., 2018; El-gengaihi et al., 2015) |
| Flavone glycoside / Phenolic / Flavonoid | Diosmetin-7-O-β-D-glucuronide methyl ester; apigenin-7-O-β-D-glucuronide methyl ester; p-coumaric acid; 1-O-feruloyl-β-D-glucose; 1-O-caffeoyl-β-D-glucose; 1-O-p-coumaroyl-β-D-glucose | (Du & Cui, 2007; Du et al., 2006; Du & Wang, 2007; Hlel et al., 2017; Abdel-Salam et al., 2018; Schilling & Heiser, 1981) |
| Peptide / Protein synthesis inhibitor / Glycoprotein | Arginine, glutamate rich polypeptides; luffacylin; luffins A, B, P and S; protein synthesis inhibitory | (Ishihara et al., 1997; Kimura et al., 1997; Parkash et al., 2002a; Chan et al., 1994; Kamenosono et al., 1988; Kishida et al., 1983; Islam et al., 1990; Watanabe et al., 1990; Ng et al., 1992b, 2011; Li et al., 2003; Au et al., 2000; Wang et al., 2010; Gao et al., 1994; Xiong & Zhang, 1998; Zhang et al., 1998; Liu et al., 2010b; Stirpe & Battelli, 2006; Poma et al., 1999) |
| Chlorophyll | Chlorophyll; pheophytin; hydroxypheophytin | (Kao et al., 2012) |
| Fatty acid | Linoleic acid | (Lucy & Abidemi, 2012) |

## *Pharmacological Properties*

**Antimicrobial/antifungal:** Luffacylin exerted anti-fungal activity against *Mycosphaerella arachidicola* and *Fusarium oxysporum* (Parkash et al., 2002a). The extracts also showed antimicrobial activities against *E. coli*, *S. aureus*, *Salmonella typhi* and *Bacillus subtilis*. Further, ethanolic extract of *L. cylindrica* showed antibacterial and antifungal efficacy against gram-positive and gram-negative bacteria, coliform bacteria in surface water and *Aspergillus fumigates*, *A. niger* and *C. albicans* organisms (Aboh et al., 2012; Ahmad & Khan, 2013; Bulbul et al., 2011; Devi et al., 2009; Garai et al., 2018; Indumathy et al., 2011; Ismail et al., 2010; Muthumani et al., 2010; Oyetayo et al., 2007; Shaheed et al., 2009; Velmurugan et al., 2011). The BuOH fraction of *L. cylindrica* showed significant antifungal activity against *Fusarium solani* and *Trichophyton longifusus*.

**Antiviral:** Luffin P1, the smallest ribosome-inactivating peptide from the seeds of *L. cylindrica*, was found to have anti-HIV activity in HIV-1-infected C8166T-cell lines (Au et al., 2000; Ng et al., 2011). *L. cylindrica* has also antiviral effect of an extract on Japanese B encephalitis virus infection in vivo (Xu et al., 1985a, 1987).

**Antihelminthic:** *L. cylindrica* leaves extract has demonstrated anthelmintic activity against Indian earthworm *Pheritima posthuma* (Tripathi et al., 2016; Partap et al., 2012b).

**Antihyperglycemic:** The methanolic extract of *L. cylindrica* exhibited remarkable antihyperglycemic activity in alloxan-induced hyperglycemic rats (Hazra et al., 2011). It improved the serum biochemical parameters and the activities were found to be dose dependent. Antihyperglycemic activity was evaluated through OGTT in glucose-loaded mice. Methanolic extract of fruits significantly and dose-dependently reduced blood glucose concentrations (Akther et al., 2014; Balakrishnan & Sharma, 2013).

**Bronchodilator:** The compounds isolated from *Luffa* has bronchodilator activity using guinea pig trachea compared to standard aminophylline (Muthumani et al., 2010).

**Hepatoprotective:** The hepatoprotective effect of alcoholic and aqueous extracts of fruits of *L. cylindrica* in paracetamol-induced hepatic injury in experimental animal rats were evaluated (Balakrishnan & Huria, 2011; Pal & Manoj, 2011; Sharma et al., 2014). Hepatoprotective activity of *L. cylindrica* was studied by estimating the serum levels of ALT, AST, ALP, direct and total bilirubin, cholesterol, triglycerides, total proteins and albumin. Treatment with extracts showed significant reduction of paracetamol-induced elevated serum enzyme levels, and increase in total protein and albumin. In another experiment, oral administration of toxic dose of erythromycin estolate was given to rats to induce hepatotoxicity (Shete et al., 2011). The hepatotoxicity was monitored by increased level of serum enzymes like serum glutamate pyruvate transaminase (SGPT) and serum glutamic oxaloacetic transaminase (SGOT), ALP and total bilirubin. Oral administration of hydroalcoholic extract of leaves of *L. cylindrica* prevented the occurrence of erythromycin estolate-induced liver damage.

**Cardioprotective:** *L. cylindrica* protect myocardium against ischemia injury. It reduced the height of T wave in electrocardigram in myocardial ischemia mice and inhibited the decrease in heart rate. It also reduced the content of lactose dehydrogenase in serum and the content of maleic dialdehyde in myocardium and increase in the activity of superoxide dismutase (Guan, et al., 2006).

**Anticancer:** Purified methanolic extract, dose dependently induced apoptosis in leukemia cell line HL-60. Fraction treated HL-60 cells have shown characteristic morphology of apoptosis such as nuclear bebbling and budding of apoptosis bodies, and have shown increased sub G0/G1 population and DNA fragment ladder. Antiapoptotic protein Bcl 2 expression was down regulated whereas, proapoptotic protein Bax was up regulated in fraction treated HL-60 cells. Aqua-alcoholic extracts of *L. cylindrica* was evaluated in colon cancer cells (HT-29 and HCT-15). MTT and LDH assays revealed that the extract decreased the viability of HT-29 and HCT-15 cells in concentration dependent manner. Caspase-3 assay and Annexin V assay also demonstrated maximum efficacy for *L. cylindrical* (Sharma et al., 2015). The triterpenoid sapogenins echinocystic acid, isolated from *L cylindrica*, also possess anticancer property (Garai et al., 2018). The effects of the aqueous ethanol extract of *L. cylindrica* leaves on different types of breast cancer cell lines MCF-7, BT-474, and MDA-MB-231 were analysed (Abdel-Salam et al., 2018). Cell cycle analysis and molecular analysis of apoptotic and proliferative markers have shown that the extract has effective anticancer activity. Antiproliferative potential of *L. cylindrica* fruits collected at two different maturation stages were determined against HeLa cells. Cytotoxicity towards HeLa cells depends on higher contents and more diversity in the phenolic compounds composition. Luffin-a, isolated from *L. cylindrica* seeds, apparently possesses antitumour activity against different human cancer cell lines when evaluated by Cell Counting Kit-8 (CCK-8) assay and flow cytometry (Liu et al., 2010b). Hot water extract of *L. cylindrica* could decrease the ratio of cancer stem cells in blood of hepatocellular carcinoma patients. It has shown cytotoxic activity against circulating tumour cells of hepatocellular carcinoma, especially the cells sub-population $CD133^{+}/CD44^{+}$ (Abdel-Salam et al., 2019; Hlel et al., 2017; Wang et al., 2010).

**Immunomodulatory/macrophage function:** *Luffa* extract plays a very important role in enhancing macrophage function in mice. Acid phosphatase activity in peritoneal macrophage and the engulfing function of peritoneal macrophage increased in the experimental group. Sapogenins isolated from *L. cylindrica* were subjected to immunomodulatory activity in male Balb/c mice (Khajuria et al., 2007). Immune responses to T-dependent antigen SRBCs were observed using parameters like haemagglutination antibody titre, plaque forming cell, delayed type hypersensitivity, lymphocyte proliferation and phagocytosis. It showed significant dose-dependent decrease and increase in Lymphocyte proliferation assay and phagocytic activity of macrophages. Methanoilc extract of *L. cylindrica* resulted in a dose dependent changes in hematological parameter of albino mice. Extract resulted in increased lymphocyte count and platelet count, while neutrophil value was reduced. This plant's leaf extract may therefore have the potentials of being effective in the treatment of diseases caused by thrombocytopenia and lymphocytopenia in mammals (Etim et al., 2018; Mao et al., 2004).

**Analgesic:** The alcoholic extract has produced significant analgesic activity, determined by acetic acid-induced writhing method and tail immersion method. Ethanol extracts produced significant and comparable analgesic effect in Analgesy meter test, a mechanically induced pain model (Velmurugan et al., 2011; Khan et al., 2013b).

**Anti-inflammatory:** Ethanolic extract inhibited the acute inflammation induced by histamine and xylene. The carrageenan-induced edema in rats was significantly reduced

by pre-treatment with extract of *L. cylindrica* fruits (Abirami et al., 2011; El-gengaihi et al., 2015; Muthumani et al., 2010; Khan, et al., 2013c). Anti-inflammatory activity on RAW 264.7 murine macrophage cells were evaluated for ethanol and ethyl acetate extracts of *L cylindrica*. Ethanol and ethyl acetate extracts in peel and pulp decreased production of nitric oxide in LPS-induced RAW 264.7 cells. The extracts significantly inhibited IL-6 production, but remained ineffective in retarding generation of IL-1β and TNF-α. Anti-inflammatory capability is also shown by decreased secretion of IL-8 by IL-8 cytokine assay (Kao et al., 2012).

*L. cylindrica* was evaluated to determine anti-inflammation and antiatopic dermatitis effects. *L cylindrica* can inhibit atopic dermatitis-like skin lesions and reduce the generation of IgE via inhibition of the inflammatory responses. The production of atopic dermatitis-related chemokines (RANTES, TARC) was inhibited in HaCaT cells. In sensitized-NC/Nga mice, the plasma levels of IgE and histamine were suppressed and reduced hemorrhage, hypertrophy and hyperkeratosis of the epidermis, and infiltration of HMC-1 mast cells (Kou et al., 2001).

**Wound healing:** A maximum wound healing activity was found in chloroform extract. In negative pressure wound therapy, dried skeleton of *Luffa* is used for optimal preparation of the wound bed. The mean time to healing was reduced and fresh granulation tissue was observed in all wound beds (Abirami et al., 2011; Zuo & Chen, 2014).

**Anti-allergy:** Ethanolic extract of *L. cylindrica* significantly inhibited homologus passive cutaneous anaphylax in rats, remarkably suppressed heterologus passive cutaneous anaphylax in mice. The extract also markedly inhibited Arthus reaction and suppressed hypersensitivity induced by SRBC-DTH. Thus ethanolic extract has significant antiallergic property (Ha et al., 2015; Kou, et al., 2001).

**Antiemetic:** The antiemetic effect was determined by calculating the mean decrease in number of retching against oral copper sulfate administration. Extracts leaves exhibited statistically significant antiemetic effect (Kanwal et al., 2013; Khan, et al., 2013c).

**Antioxidant:** Antioxidant activity of different concentrations of plant extracts were also found to increase in a concentration dependent manner. Phenolic compounds isolated from *L. cylindrica* were evaluated by the radical scavenging effect on the DPPH radical and had shown potent antioxidant activity (Bulbul et al., 2011; Du et al., 2006; Hlel et al., 2017; Tripathi et al., 2016; Yadav et al., 2017).

**Protein inhibition/interferon inducer:** Protein luffin was purified to homogeneity from the seeds of *L. cylindria*. Luffin exhibited strong inhibitory activity against protein synthesis in rabbit reticulocyte lysate as that of Ricin A-chain, but it showed only a weak cytotoxicity against murine leukemia L1210 cells. Luffacylin isolated from seeds of *L. cylindrica* also inhibited translation in a rabbit reticulocyte lysate system (Kishida et al., 1983; Li et al., 2003; Parkash et al., 2002a).

A novel ribosome inactivating protein, Luffin-S, from the seeds of *L. cylindrica*, were also characterized (Gao et al., 1994). Luffin B, single-chain ribosome inactivating protein, was purified from seeds of *L. cylindrica.* An immunotoxin was constructed with Luffin B and Ng76, a monoclonal antibody to human melanoma cell M(21). Luffin B-

Ng76 showed more cytotoxic to target melanoma cells than free Luffin B (Poma et al., 1999; Zhang et al., 1998). Liposome-incorporated luffin is also a possible alternative to immunotoxins for the treatment of human melanoma in situ. Luffin is incorporated into lecithin/cholesterol and lecithin/cholesterol/dicetylphosphate negatively charged liposomes which resulted in the inhibition of protein synthesis and cell growth; apoptotic cell death. Luffin P1 has also a highly potent inhibitory activity on cell-free protein synthesis. A recombinant hIL-2-Luffin P1 immunotoxin, which strongly inhibited T-cell proliferation in mixed lymphocyte reaction and ConA response, has also been developed (Islam et al., 1990; Xu et al., 1985b).

**Prevention of cataract:** *L. cylindrica* fruit extract can delay the onset and/or prevent the progression of cataract. Hydrogen peroxide induced cataract on isolated goat lenses was investigated. Application of *L. cylindrica* fruit extract opposed in development of dense nuclear opacity (Dubey et al., 2015).

**Abortifacient:** Two immunologically distinct glycoproteins were isolated from seeds of *L. cylindrica*. The proteins were capable of inducing mid-term abortion in mice, inhibiting protein synthesis in a cell-free system and suppressing thymidine uptake by human choriocarcinoma cells (Ng et al., 1992b).

Possible teratogenic activity of proteins, Luffaculin, Luffin-a, Luffin-b and Momorcochin, was tested using cultured mouse embryos. Decreases in embryo somite number and axial length and induced defects in yolk sac circulation, body axis, optic placodes, branchial apparatus, forelimb buds and cranial neural tube varied for different proteins. Thus proteins differ in their potencies as teratogens (Chan et al., 1994; Ng et al., 1992a, 1994).

**Oxytocics:** The in vitro experiments using the rat uterus showed that the aqueous leafy extract of *L. cylindrica* increased rat uterine motility suggesting that they are oxytocics. *L. cylindrica* can be applied as therapeutic uses of herbal remedies in childbirth (Kamatenesi-Mugisha et al., 2007).

## 5. *Luffa acutangula*

Fruits are obovate, cylindrical or club-shaped, pale yellowish-green in colour, tapering towards the base and covered with 8–10 prominent longitudinal ribs on outer surface Figure 9.1e. The young fruits and leaves are used as vegetables. Both the soft pulp and skin of ridge gourd is cooked as a vegetable. It is very nutritive plant and has a bitter taste if taken raw. Ridge gourd has a sweet taste, cooling in nature and easy to digest.

The tea made from fruits of *L. acutangula* had been widely used by women for induction of abortion and as a purgative. Fresh juice is also put in eyes to treat granular conjunctivitis and also to prevent the lids adhering at night from excessive meibomian secretion. Ridge gourd is chopped in small pieces along with the ribbed skin and completely dried in the sun. Once the ridge gourd is fully dried, made into a powder and used to prevent the premature greying of hair (Manikandaselvi et al., 2016). Ridge gourd has certain peptides which are exactly like insulin, alkaloids and charantin which help in reducing the blood sugar and urine sugar levels. Very fine powder of fruits of *L. acutangula* is used as a snuff to protect jaundice.

## *Bioactive Components*

The phytochemical studies have resulted in isolation and identification of various classes of compounds, such as flavonoids, anthraquinones, proteins, fatty acids, saponins, triterpenes and volatile components (Table 9.6) (Shendge & Belemkar, 2018). Oleanane-type triterpene saponins, Acutosides A-G were isolated from the aerial parts. Luffangulin, a novel N-terminal ribosome inactivating peptide, was isolated from the seeds of *L. acutangula.* Anthraquinone derivative was isolated using bioassay-guided approach from the ethanolic extract of the aerial parts. Volatile components from the flowers were isolated using solid-phase microextraction (SPME) coupled with capillary gas chromatography-mass spectrometry (GC-MS). Flavonoids were characterized from the leaves and flowers of different species of *Luffa*. Based on types of flavonoid exsisted, *Luffa* is separable into two groups of species. From GC-MS analysis of *L. acutangula* fraction, it resulted in the identification of pyrone compounds.

**Table 9.6.** Different class of compounds from *Luffa acutangula*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Oleanane-type triterpene, saponin | Acutosides A-G; pipecolic acid | (Nagao et al., 1991a, 1991b) |
| Cucurbitacin | Cucurbitacin B | (Teo et al., 1990) |
| Flavonoid | Apigenin-7-glucoside; luteolin-7-glucoside | (Schilling & Heiser, 1981) |
| Phenolic | Gallic acid; p-hydroxybenzoic acid | (Kalaskar & Surana, 2014). |
| Anthraquinone | 1,8-Dihydroxy-4-methylanthracene-9,10-dione | (Vanajothi & Srinivasan, 2015) |
| Volatiles | Trans-β-ocimene; 3,7,11,15-tetramethyl-2-hexadecen-1-ol; n-hexadecanoic acid; 9,12,15-octadecatrienoic acid methyl ester; citronellyl tiglate | (Fernando & Grn, 2001; Suryanti et al., 2017) |
| Protein | Luffangulin; luffaculins 1 and 2; trypsin inhibitors; lectin; glycoproteins; chitooligosaccharides specific lectin | (Ng, et al., 1992a; Chan et al., 1994; Wang & Ng, 2002; Hou et al., 2006; Lin et al., 2002; Haldar et al., 1996; Anantharam et al., 1985; Yeung et al., 1991) |
| Pyrones | 2,3-Dihydro,3,5-dihydroxy-6-methyl-(4H)-pyran-4-one | (Suryanti et al., 2017) |

## *Pharmacological Properties*

**Antidiabetic:** *L. acutangula* showed significant hypoglycemic activities in modified OGTT with Swiss Webster mice (Quanico et al., 2008). Chloroform and alcoholic extracts of fruits of *L. acutangula* showed significant reduction in blood glucose level in alloxan-induced diabetic Wister and STZ-induced diabetic in rats. Ridge gourd also

reduced triglyceride levels and LDL in alloxan-induced diabetic rats (Sharmin et al., 2012). In an experiment, STZ along with nicotinamide was used to induce non-insulin dependent diabetes mellitus (NIDDM) in rats. Various biochemical markers of blood and tissue origin were estimated after administration of methanolic and aqueous extracts. Dose dependent pronounced antihyperlipidemic and antidiabetic activities were observed (Pimple et al., 2011; Mohan et al., 2012b). Antihyperglycemic activity was also evaluated through OGTT in glucose-loaded mice. Methanolic extract of fruits significantly and dose-dependently reduced blood sugar concentrations. Formulation of hydroalcoholic extract of *L. acutangula* and *Madhuca longifolia* was designed in tablet form and tested for antidiabetic potential in alloxan monohydrate-induced diabetic model. Positive results were obtained for formulation in the observed parameters, thereby favouring the use of the plant in the indigenous system of medicine (Juma et al., 2013; Patil et al., 2010; Singh et al., 2014).

**Hepatoprotective:** The ethanolic and aqueous extracts of *L. acutangula* were examined for antihepatotoxic activity in Druckrey rats by inducing hepatotoxicity with $CCl_4$ and paracetamol (Mishra & Mukerjee, 2017; Mukerjee et al., 2007; Ulaganatha et al., 2010). The extract has shown to possess significant hepatoprotective effect by lowering SGPT, SGOT, ALP and bilirubin. In another study, hepatoprotective activity of hydroalcoholic extract of *L. acutangula* against rifampicin-induced hepatotoxicity in rats was evaluated. It decreased levels of serum marker enzymes viz. AST, ALT, ALP and LDH, and increased total protein including the improvement in histoarchitecture of liver cells and also increased activity of non-enzymatic intracellular antioxidant, glutathione and enzymatic antioxidants, catalase and superoxide dismutase (Ibrahim, 2015; Jadhav et al., 2010).

**Anticancer:** Luffaculins can be used to treat some cancers. The cytotoxicities of Luffaculin-1 and Luffaculin-2 on human leukemia K562 cells were determined and had promising activities (Lin et al., 2002). It could also inhibit germinal vesicle broken-down (GVBD) of ocytes from Bufo gargarizans that showed strong inhibitory activity on protein biosynthesis. Extracts displayed considerable general toxicity towards brine shrimps.

*L. acutangula* is a potential antitumour agent. Fruit methanolic extract showed significant antiproliferative activity on human lung adenocarcinoma epithelial cell line (A-549) (Reddy et al., 2009). Vascular endothelial growth factor (VEGF), matrix metalloproteinases-2 (MMP-2) and matrix metalloproteinases-2 (MMP-9) expressions were significantly inhibited. Further, the anticancer activity of the both extracts was assessed by MTT assay, mitochondrial membrane potential (MMP) alteration, intracellular ROS measurement and nuclear morphology with the appearance of apoptosis in human lung cancer cell line (NCI-H460) (Vanajothi et al., 2012; Vanajothi & Srinivasan, 2015). Leaf extract exhibits high antiproliferative activity against cell line tested, exhibits high dichlorodihydrofluorescein (DCF) fluorescence and significantly increase in mitochondrial depolarization. Anticancer activity of the ethanolic and aqueous extracts of the *L. acutangula* was assessed by evaluating tumour weight and tumour volume in Swiss albino mice against Dalton's lymphoma ascites cells (Dashora & Chauhan, 2015). The extracts showed significant decrease in tumour volume and weight.

**Antiulcer:** Aspirin was administered to induce gastric ulcerations in the diabetic rats. The comparative gastroprotective effect of methanolic extract and aqueous extract of *L.*

*acutangula* were studied. Methanolic extract of *L. acutangula* significantly increased mucosal glycoprotein and antioxidant enzyme level in gastric mucosa of diabetic rats exhibiting better ulcer healing effect (Pimple et al., 2012).

**Immunomodulatory:** Ethanol extract was evaluated for immunomodulatory activity by in vivo phagocytosis using carbon clearance and neutrophil adhesion test. It increased phagocytic index and neutrophil adhesion (Kalaskar & Surana, 2014).

**Hyperlipidemic:** The methanolic extract had dose dependent pronounced antihyperlipidemic activity than aqueous extract (Sharmin et al., 2012).

**Abortifacient:** The tea made from *L. acutangula* fruits has been largely used by women for abortion induction and abortions occurred in ruminants that had ingested the fruits. After administration of *L. acutangula* tea, there was no body weight gain and no sign of maternal toxicity, but it was found reduced fetal weight in pregnant Wistar female rats (Fernandes et al., 2010). The glycoprotein from *L. acutangula* was capable of inducing mid-term abortion in mice and inhibiting protein synthesis in a cell-free system. Ribosome inactivating proteins also differ in their potencies as teratogens when tested using cultured mouse embryos (Chan et al., 1994; Yeung et al., 1991).

**Antibacterial:** Methanolic and aqueous extracts of different plant parts showed antimicrobial activity against *E. coli*, *S. aureus*, *Klebsiella pneumonia*, *Proteus vulgaris*, *C. albicans*, *A. niger* and *Fusarium* species in well diffusion assay (Bulbul et al., 2011; Dandge et al., 2010; . Dixit et al., 1978; Pattusamy et al., 2013; Moideen & Prabha, 2014; Torvi & Hunashal, 2012).

**Anticataleptic:** Anticataleptic efficacy of the ethanolic extract of *L. acutangula* in haloperidol-induced catalepsy in rats was evaluated. Exploratory behaviour in hole board apparatus and locomotor activity in actophotometer showed that the ethanolic extract has protective effect against symptoms of Parkinson's disease (Gandhare, 2012).

**CNS depressant:** The fruit extract exhibited dose-dependent CNS depressant activity when its effect on behavioural changes, exploratory activity and barbiturate sleeping time in mice was studied (Misar et al., 2004).

**Anti-inflammatory/antinociceptive:** The extract showed significant anti-inflammation on carrageenan-induced rat paw edema method and cotton pellet granuloma models (Gill et al., 2011a; Iyyamperumal et al., 2013). In antinociceptive activity tests conducted with intraperitoneally administered acetic acid-induced gastric pain model in mice, the extract cause dose-dependent reduction of the number of abdominal constrictions in mice (Juma et al., 2013).

**Antihelminthic:** The methanolic extract of the aerial part of *L. acutangula* showed moderate anthelmintic activity by in vitro test using earth worm *P. posthuma* (Rahman, 2014).

**Antioxidant:** Extract of *L. acutangula* was tested for it's free radical scavenging activities in the DPPH radical screening assay, reduced glutathione, nitric oxide scavenging method and non-enzymatic inhibition of bovine brain lipid peroxidation. It showed a strong inhibitory activity (Ansari et al., 2005; Dashora & Chauhan, 2015; Gill et

al., 2011a; Iyyamperumal et al., 2013; Shekhawat et al., 2010). Further, the extracts of *L. acutangula* pericarp was evaluated for antioxidant using in vitro for ABTS, superoxides radical, reducing power and phosphomolybdenum assay. The extracts showed potent in vitro antioxidant ability for which the phenolic compounds might be responsible (Kalaskar & Surana, 2014).

**Protein inhibitor:** Ribosome inactivating protein - Luffangulin inhibited cell-free translation but lacked inhibitory activity toward HIV-1 reverse transcriptase (Au et al., 2000).

**Toxicity:** Extracts of *L. acutangula* displayed considerable general toxicity towards brine shrimps. Thus, there is a wide margin of safety for the therapeutic use of *L. acutangula* whole plant (Arunachalam et al., 2012; Bulbul et al., 2011; Rahman, 2014).

## 6. *Cucurbita pepo*

Pumpkin belongs to the family Cucurbitaceae comprises of *C. moschata*, *C. pepo*, *C. maxima*, *C. mixta*, *C. ficifolia* and *Telfairia occidentalis*. Three of these namely *C. pepo*, *C. maxima* and *C. moschata* represent economically important species cultivated worldwide. In the present section, *C. pepo* is considered for description. Fruit of *Cucurbita* is the largest known fruit of all.

The immature fruits are consumed as a vegetable Figure 9.1f. The mature fruit is sweet and used to make confectionery and beverages (roasted or cooked), and can be incorporated into baked goods. *C. pepo* seeds are edible in the same way as those of other cucurbits, either raw or roasted, and consumed as snacks. Pumpkin seed oil is used for cooking or as salad dressing; the oil is generally mixed with other oils because of its robust flavour. The seeds are used as vermifuge, treat problems of the urinary system, benign prostatic hyperplasia and hypertension, prevents the formation of kidney stones, alleviate prostate disesases, and enhance the erysipelas skin infection (Ramak & Mahboubi, 2019). Pumpkin seeds possess high zinc content, which is mega-important for the healthy functioning of the brain, immune system and skin functions (Bombardelli & Morazzoni, 1997; Gutierrez, 2016; Yousaf et al., 2017).

### *Bioactive Components*

Pumpkin seed oil is accepted as an edible oil and as a nutraceutical. Seed oil is a rich natural source of phytosterols, proteins, polyunsaturated fatty acids, carotenoids, and these components are attributed for providing many health benefits (Table 9.7) (Yousaf et al., 2017). The content of vitamin E, especially γ-tocopherol, is very high in seed oil. The greatest concentrations of squalene were found in seed. New phenolic glycosides, Cucurbitosides A-M, were isolated from the seeds of *C. pepo*. The active compounds in *C. pepo* seeds are $\Delta^5$-, $\Delta^7$- and $\Delta^8$-sterols. $\Delta^7$-sterols, which are largely predominant in *C. pepo*, are considered to be the key active constituents of pumpkin seed in the treatment of benign prostatic hyperplasia. Multiflorane-type triterpenoids are also reported in *C. pepo*. Phytochemical study of the fruits of *C. pepo* has led to the isolation of cucurbitane glycosides, proteins, entkaurane-type diterpene glycosides, hydrocarbon derivatives and lignans. Two new ent-kaurane diterpene glycosides were evaluated for their inhibitory effects on macrophage activation.

**Table 9.7.** Different classes of compounds in *C. pepo*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Cucurbitane and its glycoside | Cucurbitacins B, D, E, G, I, L and K; hexanorcucurbitane glycosides; 23,24-dihydrocucurbitacin F; 23,24-dihydrocucurbitacin D; 19-(10→9β)-abeo-10α-lanost-5-ene; cucurbitaglycosides A and B | (Wang et al., 2007, 2008a; Feng et al., 2007; Park et al., 2004; Gill & Bali, 2011; Ren et al., 2012; Konoshima et al., 1995; Duncan et al., 1996) |
| Protein | Lectin; trypsin inhibitors; CPPTI-I and CPPTI-II; serine proteinase inhibitor; endonuclease; ribosome-inactivating protein; aspartic proteinase; cucurmoschin; oxidosqualene cyclise | (Allen, 1979; Otlewski et al., 1984; Otlewski & Wilusz, 1985; Wieczorek et al., 1985; Pham et al., 1985a, 1985b; Yoshinari et al., 1996; Premzl et al., 2001; Wang & Ng, 2003; Shibuya et al., 2004; Rzepecki & Szopa, 1995)) |
| Phenolic | Cucurbitosides F-M; cucurbitosides A-D; 3,4-dihydroxy methyl benzoate; 3,4-dihydroxybenzoic acid; p-coumaric acid; caffeic acid tri-hexoside | (Li et al., 2005; Mohamed et al., 2009; Iswaldi et al., 2013; Peiretti et al., 2017) |
| Carotenoid | Lutein; violaxanthin; luteoxanthin; auroxanthin epimers; lutein epoxide; flavoxanthin; chrysanthemaxanthin | (Matus et al., 1993; Azevedo-Meleiro & Rodriguez-Amaya, 2007) |
| Favonol glycoside | Rhamnazin 3-rutinoside; quercetin-3,4'-O-β-D-glucopyranoside; isorhamnetin; quercetin; myricetin | (Itokawa et al., 1981; Mohamed et al., 2009) |
| Polysaccharide | Pectic polysaccharides; protein-bound polysaccharide; water-soluble polysaccharide | (Nosáľová et al., 2011; Quanhong et al., 2005; Zhang et al., 2013) |
| Sterol | β-Sitosterol; $\Delta^7$-spinasterol; $\Delta^7$-stigmasterol; $\Delta^{7,25}$-stigmastadienol | (Phillips et al., 2005; Garg & Nes, 1986; Bombardelli & Morazzoni, 1997; Kuhlmann et al., 1999; Rabrenović et al., 2014) |
| Multiforane-type triterpenoids | 3α-p-Nitrobenzoylmultiflora-7:9(11)-diene-29-benzoate; 3α-acetoxymultiflora-7:9(11)-diene-29-benzoate | (Tanaka et al., 2013; Appendino et al., 1999) |
| Entkaurane-type diterpene glycoside | 12α-(β-D-glucopyranosyloxy)-7β-hydroxykaurenolide; 7β-(β-D-glucopyranosyloxy)-12α-hydroxykaurenolide | (Kikuchi et al., 2015) |
| Fatty acid | Tetrahydro thiophene; linoleic acid; calotropoleanly ester cholesterol; 13(18)-oleanen-3-ol | (Sabudak, 2007; Murkovic et al., 1996a; Younis et al., 2000; Murkovic & Pfannhauser, 2000; Nakić et al., 2006; Stevenson et al., 2007; Badr et al., 2011; Nawirska-Olszańska et al., 2013; Rabrenović et al., 2014) |
| Hydrocarbon derivative | Dodecane; tetradecane | (Badr et al., 2011) |
| Tocopherol, squalene | Tocopherols | (Stevenson et al., 2007; Murkovic et al., 1996b, 2004; Murkovic & Pfannhauser, 2000; Nakić et al., 2006; Stevenson et al., 2007; Srbinoska et al., 2012; Bharti et al., 2013; Rabrenović et al., 2014; Naziri et al., 2016) |
| Lignan | (+)-Lariciresinol; (−)-secoisolariciresinol | (Murkovic et al., 2004) |

## *Pharmacological Properties*

**Benign prostatic hyperplasia/nocturia:** In a randomised, double-blind study, the preparation, Curbicin, obtained from *C. pepo* and *Sabal serrulata*, was used for treatment of symptoms caused by prostatic hyperplasia (Carbin et al., 1990). Urinary flow, micturition time, residual urine, frequency of micturition and a subjective assessment of the effect of treatment were all significantly improved. In another experiment, effect of oil preparation on the urodynamics was studied and the extract from seeds could remarkably reduce the bladder pressure, increase the bladder compliance and reduce the urethral pressure (Damiano et al., 2016; Nishimura et al., 2014; Xu et al., 1994).

The effect of pumpkin seed oil on testosterone-induced hyperplasia of the prostate of rats was studied. Oral administration of pumpkin seed oil inhibited the prostrate size increment in rats (Gossell-Williams et al., 2006). Pumpkin seed derived compounds, specifically $\Delta^7$-sterols, counteract dihydrotestosterone-implicated benign prostate hyperplasia. They exert clinically positive effects on the prostate, as well as bladder-strengthening effects by inhibition of 5α-reductases, and competitive binding to the androgen receptor mechanisms. The effects of the oil are related to phytoestrogens and unsaturated fatty acids content.

In another experiment, citral was administered orally into stomachs of male rats to induce benign prostatic hyperplasia, and protein binding prostate was determined in ventral prostate gland in order to ensure that benign prostatic hyperplasia has been induced (Abdel-Rahman, 2006). Rats were then fed with pumpkin seeds diet. Pumpkin seeds can alleviate the signs of benign prostatic hyperplasia such as decrease of protein binding prostate levels, weight of ventral prostate size and improve histology of testis that may be beneficial in the management of mild stage of benign prostatic hyperplasia. The study has also undertaken to investigate the effects of pumpkin seed oil alone or combined with Phytosterol-F on testosterone/prazosin-induced prostate growth in rats (Tsai et al., 2006). Rats treated with pumpkin seed oil alone or pumpkin seed oil combined with Phytosterol-F had significantly lower weight ratio for the ventral prostate and significantly lower protein levels. Thus pumpkin seed oil alone or combined with Phytosterol-F can block the testosterone/prazosin-induced increases in prostatic weight-to-body weight ratio and protein synthesis.

The processed food containing a mixture of pumpkin seed extract and soybean germ extract demonstrated a highly favourable effect on various symptoms including nocturia in postmenopausal women. It decreased the frequency of urination during both the night and daytime, and frequency of incontinence also improved in patients (Sogabe & Terado, 2001). In another study, cucuflavone (the combination of pumpkin seed and soy germ extract) can be used as natural alternative to relieve symptoms of over active bladder and to improve quality of life (Shim et al., 2014). There is significant reduction in urination frequency, urgency, incontinence frequency, maximum urgency score, nocturnal urination frequency and over active bladder symptom scale. The safety and effectiveness of a preparation containing a mixture of *C. pepo* seed extract, *Equisetum arvense* and *Linum usitatissimum* - Flax A (CELcomplex®) on stress urinary incontinence was evaluated in female patients. It is highly effective on stress urinary incontinence with minimum adverse events (Gažová et al., 2019).

Pumpkin seed extract showed the cell growth inhibition of hyperplastic and cancer cells, independent of steroid hormone receptors which gives further evidence for the ethnomedical use of pumpkin seeds for a treatment of benign prostate hyperplasia (Medjakovic et al., 2016). Transactivational activity was evaluated for human androgen, estrogen and progesterone receptors with in vitro yeast assays. No transactivational activity was found. Cell viability tests with prostate cancer cells, breast cancer cells, colorectal adenocarcinoma cells and a hyperplastic cell line from benign prostate hyperplasia tissue were performed. A cell growth inhibition was observed for all cell lines. This shows pumpkin seed applications has lack of androgenic activity and can be regarded as safe for the prostate.

**Anthelmintic:** The administration of pumpkin seed was effective in controlling gastrointestinal helminths in naturally infected ostriches (Feitosa et al., 2012). The groups treated with pumpkin seed showed a significant decrease in egg counts per gram of faeces. *C. pepo* seed extracts exhibited a nematidicidal potential in vitro, affecting the survival of *Heligmosoides bakeri* larvae (Grzybek et al., 2016). It also demonstrated a positive effect on *H. bakeri* eggs hatching and marked inhibitory property against worm motility in in vivo studies. A decrease in faecal egg counts was accompanied by a significant reduction in worm burden of the treated mice.

**Anticancer:** Prostate carcinoma cells appear notably sensitive to growth inhibition by Cucurbitacin E. Cucurbitacin E caused marked disruption of the actin cytoskeleton and altered the distribution of vimentin which are associated in prostate carcinoma cells (Duncan et al., 1996). Human PCa DU145, PC3, and LNCaP cells were treated with graded doses of 2,3,24-dihydrocucurbitacin F in vitro, and anti-proliferative, cytotoxic and proteomic effects were determined using (3-(4,5-dimethylthiazol-2-yl)-5-(3-carboxymethoxyphenyl)-2-(4-sulphophenyl)-2H-tetrazolium (MTS) assay, cell cycle analysis, immunofluorescent staining and western blotting (Ren et al., 2012). It inhibited cell growth and induced cell cycle arrest at G(2)/M phase and formation of binucleated cells, and increased levels of apoptosis in all PCa cell lines tested. G-actin depletion, actin aggregation, and rod-like actin fibers, with little effect on microtubule structure, were observed after 2,3,24-dihydrocucurbitacin F treatment.

Cucurbitaglycosides A and B showed cytotoxic activity against the human epithelial carcinoma cell line - HeLa (Wang et al., 2008a). Cytotoxicity of *C. pepo* extract was studied on normal Chinese hamster ovarian cells (CHO), rat fibroblast and cancer (HepG2 and CT26) cell lines by colonogenic assay method. The extract showed cytotoxic properties (Shokrzadeh et al., 2010).

The effect of proteolytic activity on cell invasion was studied by adding aspartic proteinase inhibitors isolated from squash *C. pepo*. Aspartic proteinase inhibitors showed significant inhibition of expression of cathepsins detected by immunofluorescence microscopy in ras-transformed human breast epithelial cells (MCF-10A neoT). Cathepsin D was suggested to support tumour progression (Premzl et al., 2001).

**Antidiabetic:** Pumpkin polysaccharide granules have curative effect on glycemic control. Protein-bound polysaccharide were evaluated for hypoglycemic activity and the effect on serum insulin levels in alloxan-induced diabetic rats (Boaduo et al., 2014; Shi et al.,

2003). Protein-bound polysaccharide can obviously increase the levels of serum insulin, reduce the blood glucose levels and improve tolerance of glucose. Similarly, peel extracts nearly reversed alterations in serum glucose, insulin, triiodothyronine, thyroxine, total cholesterol, triglyceride, HDL, LDL, VLDL, hepatic lipid peroxidation, superoxide dismutase and catalase, which was induced by alloxan suggesting their possible role in ameliorating diabetes mellitus (Quanhong et al., 2005; Xue-min & Jue, 2001). Alloxan-induced diabetic rabbits were injected with a water-soluble polysaccharide to assess effects on pancreatic islet tissue morphology. The polysaccharide had beneficial effects on the improvement in the control of blood glucose, serum lipid and glycosylated hemoglobin levels. It could promote the regeneration of damaged pancreatic islets by stimulating β-cell proliferation (Dixit & Kar, 2010; Sedigheh et al., 2011; Zhang et al., 2013).

The effect of the tocopherol fraction of raw seeds of *C. pepo* was studied in poloxamer-407 (PX-407)-induced type 2 diabetic Wistar rats. The tocopherol fraction of *C. pepo* treated diabetic rats presented a significant amelioration of glycemia, insulinemia and lipid dysmetabolism. A remarkable reduction in oxidative markers and improved glucagon like peptide-1 in cecal and pancreatic characteristics were also observed (Bharti et al., 2013). The results provide pharmacological evidence of *C. pepo* as an antihyperglycemic, mediated by the interaction of various botanicals with multiple targets operating in diabetes mellitus.

**Antigiardial:** The study was carried out to evaluate antigiardial activity of *C. pepo* against *Giaradia lambelia*. In comparision to *C. maxima* and *L. sciceraria*, it showed lowest activity (Elhadi et al., 2013).

**Antimicrobial/antifungal:** A novel antifungal peptide, cucurmoschin, was isolated from the seeds of the black pumpkin. Cucurmoschin inhibited mycelial growth in the fungi *Botrytis cinerea*, *F. oxysporum* and *Mycosphaerella oxysporum*. It inhibited translation in a cell-free rabbit reticulocyte lysate system (Wang & Ng, 2003).

Flavonoids extract and saponin rich extract of *C. pepo* had strong effect and wide diameter of growth inhibition zones against *E. coli*, *S. aureus*, *Serratia marcescens*, *Streptococcus thermophilous*, *F. oxysporium*, *Trichoderma reesei* and *S. typhi* (Jasim et al., 2010; Badr et al., 2011; Chonoko & Rufai, 2011; Dubey et al., 2010; El-Kamali & Mahjoub, 2009; Mohamed et al., 2009; Sood et al., 2012). The application of *C. pepo* cortex extract against human multiresistant urinary tract pathogens has also been studied and may represents a new source as adjuvant to antibiotics for effective treatment of bacterial urinary tract infections (Al-ghazal, 2012; Noumedem et al., 2013). *C. pepo* has also antiparasitic function (Allen, 1979).

**Antioxidant:** DPPH and hydroxyl (HO•) scavenging activities were determined in extracts of *C. pepo* female and male flowers, and the antioxidant capacities of female flowers were found significantly higher than male (Tarhan et al., 2007). Fractions rich in phenolics showed the strongest activity in the DPPH free radical scavenging assay. Similarly, antioxidant activity were performed using 2-4-dinitrophenylhydrazine, TEAC and ferric reducing antioxidant power (FRAP), and the extract had shown strong activities (Kalaiselvi, & Selvi, 2016; Nawirska-Olszańska et al., 2013; Nyam et al., 2013; Peiretti et al., 2017; Xanthopoulou et al., 2009).

Phosphorylation could improve the antioxidant activity of pumpkin polysaccharide both in vitro and in a cell system (Song et al., 2015). $H_2O_2$-induced oxidative damages on rat thymic lymphocyte were also prevented by the derivatives (Nkosi et al., 2006b).

**Anti-inflammatory:** Pumpkin-seed oil was given to rats in which arthritis was induced using Freund's complete adjuvant. Induction of arthritis caused a decrease in serum sulphahydryl groups, increase in serum ceruloplasmin, elevation of blood glutathione in the acute phase, reduction of blood glutathione in the chronic phase, increase in liver glucose-6-phosphate dehydrogenase activity, elevation of activity of serum N-acetyl-β-D-glucosaminidase at the acute phase, while plasma total proteins and albumin were reduced at the chronic phase. Administration of pumpkin-seed oil succeeded in modulating most of the altered parameters affected during arthritis, especially at the chronic phase (Fahim et al., 1995).

Acetone and polar lipid fractions are strongest inhibitors in lipid peroxidation catalyzed by soybean lipoxygenase (Xanthopoulou et al., 2009). Ent-kaurane diterpene glycosides isolated from *C. pepo* have also shown inhibitory effects on macrophage activation by an inhibitory assay of nitric oxide (NO) production (Kikuchi et al., 2015).

**Antihypercholesterolemia:** The study was designed to evaluate the effects of the ingestion a pumpkin-based diet on cholesterol levels. The results showed that dehydrated pumpkin, when administered in high concentration in the diet, reduced the levels of plasmatic and hepatic cholesterol, but may cause relevant lesions in liver (Silveira et al., 1996). The effect of pumpkin seed oil supplementation on the total cholesterol, LDL cholesterol, triglycerides, HDL cholesterol, systolic and diastolic blood pressure in non-ovariectomized and ovariectomized Sprague-Dawley rats were studied (Gossell-Williams et al., 2008; Harvath et al., 1988). Supplementation with pumpkin seed oil resulted in lower systolic and diastolic blood pressures in both non-ovariectomized and ovariectomized rats. Pumpkin seed oil supplementation lowered total cholesterol, LDL cholesterol, triglycerides and increases HDL cholesterol.

**Antihypertensive:** Pumpkin-seed oil may modify the potency of the calcium antagonist, felodipine or ACE-inhibitor, Captopril in spontaneously hypertensive rats. Concomitant administration of felodipine or captopril with pumpkin-seed oil improved the measured free radical scavengers in the heart and kidney (Zuhair et al., 2000).

**Wound healing:** The cold pressed oil, obtained from pumpkin seeds, was studied for their wound healing property. Wounds were induced on the dorsum of rats and oil was applied. It was found efficient in wound healing. Morphometric assessment and histological findings revealed healed biopsies from pumpkin oil and full re-epithelialization with reappearance of skin appendages and well organized collagen fibers without inflammatory cells (Bardaa et al., 2016).

**Hepatoprotective:** The effects of pumpkin seed protein isolate on the activity levels of lactate dehydrogenase, ALT, AST and ALP, catalase, superoxide dismutase, glutathione peroxidase and total antioxidant capacity as well as glucose-6-phosphatase in liver homogenates and lipid peroxidation (LPO-malondialdehyde (MDA)) levels in liver homogenates against $CCl_4$-induced acute liver injury in low-protein fed rats were investigated. $CCl_4$ intoxication resulted in significant increases in the activity levels of

enzymes investigated. The administration of pumpkin seed protein isolate resulted in significantly reduced activity levels of enzymes (Nkosi et al., 2005, 2006a). In another experiment, the administration of protein isolate after acetaminophen-induced acute liver injury in low-protein fed male Sprague-Dawley rats resulted in significantly reduced levels of ALT and AST (Nkosi et al., 2006b).

**Antiulcer:** *C. pepo* fruit pulp extract increase in ALP activity and mucosal thickness along with decrease in ulcer index in aspirin treated stomach and duodenum of albino rats (Sarkar & Guha, 2008). Tetracyclic triterpenoids, isolated from *C. pepo*, have potent antiulcer activity (Gill & Bali, 2011). It showed optimum percentage inhibition by pyloric ligation, water immersion stress and NSAID (indomethacin) induced ulcer method in rats.

**Protein inhibitor:** Varieties of protein inhibitors have been isolated from *C. pepo* as indicated in Table 9.7

**Antitussive:** The pectic polysaccharides obtained from *C. pepo* were tested for antitussive activity by studying the effects of citric acid-induced cough reflex in guinea pigs and reactivity of the airway smooth muscle in vivo conditions in comparison to the narcotic drug codeine. Oral administration of all pectic polysaccharides from pumpkin inhibited the number of coughs induced by citric acid in guinea pigs (Nosáľová et al., 2011). The cough depressive efficacy of polysaccharides was comparable to that of codeine and provoked any side effect which is advantage towards the conventional opioid-derived antitussive agents.

**Immunoregulatory:** Pumpkin extracts have capcity to modulate immunobiochemical pathways induced by cytokinine interferon. Effects were investigated in unstimulated human peripheral blood mononuclear cells and in cells stimulated with the mitogens phytohaemagglutinin and Concanavalin A in vitro. Extracts of pumpkin seeds suppressed mitogen-induced neopterin production and tryptophan degradation in a dose-dependent way (Winkler et al., 2005).

## 7. *Trichosanthes dioca*

*T. dioica* is annual or perennial herbaceous vine, commonly known as pointed gourd. The plant is a perennial, dioecious and grows as a vine. The shape, size and striation pattern of fruit vary greatly Figure 9.1g. The fruit is the edible part of the plant which is cooked in various ways either alone or in combination with other vegetables.

*Charaka Samhita* prescribes its use in treating jaundice and alcoholism. Ayurvedic literature depicts its use as a diuretic, cardiotoinc, antiulcer and laxative (Kumar et al., 2012b). *Patoladi kasaya*, a polyherbal formulation, consisted of 11 herbs viz. Patola, Haritaki, Bibhitaka, Amalaki, Kutaki, Cirayata, Amrta, Pittapapada, Sunthi and Bhrngaraja, exhibited complete improvement and partial improvement with peptic ulcer. Decoction of leaves with *Terminalia chebula* and *Coriandrum sativum* is also taken to treat acidity with constipation. *T dioca* fruit boiled with *C. sativum* seed and *T. chebula* is taken in the treatment of teeth (Akhter et al., 2008). Fruit skin juice mixed with honey is used to remove the bad odour of mouth. Decoction of leaves mixed with *Piper nigrum* fruit powder is used to treat diarrhoea (Sen & Behera, 2008).

## *Bioactive Components*

Different types of bioactive compounds have been identified and isolated from *T. dioica* (Khandaker et al., 2018). The classes of compounds with their respective references are listed in Table 9.8. The seeds of *T. dioica* contain a large amount of peptides, namely trichosanthin and lectin. Trichosanthin is known as a ribosime inactiviating protein and also possess anti-HIV activity (Fang et al., 2011). Lectin, a carbohydrate binding protein, has specific binding property with galactose. The seed peptides have the unique property of being resistant to the action of silver nitrate, a sensitive reagent commonly used to stain proteins. Sterols and tetra- and pentacyclic triterpenes are the most abundant groups of chemical compounds found in *T dioca*, such as Cucurbitacin B, euphol, α-amyrin, β-amyrin, lupeol, taraxerol, betulin and karounidiol. Cucurbitacin B, an oxygenated tetracyclic triterpenoid, has promising anticancer potential. High performance thin layer chromatography (HPTLC) method has been developed to determine the cucurbitacin content in fruit extracts of *T. dioica* (Solomon et al., 2014). Sterols and steroidal saponins, tannins and flavonoids are also present in the plant. The seed extract of *T. dioica* consists of oxidihydrokarounidol-3-benzoate as the most predominant component in the highly polar fraction of the non saponifiable lipid (Akihisa et al., 1997).

**Table 9.8.** Different classes of compounds in *T. dioca*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Tetra and pentacyclic triterpenoids / cucurbitacin | Cucurbitacin B; cucurbita -5,24-dienol; karounidiol; 7-oxodihydrokarounidiol | (Solomon et al., 2014; Khare, 2007; Akihisa et al., 1997) |
| Saponin | 24-α-ethyl-20-ene-7-hydro-stigmast-8β:14β-di-3-O-β-D-xylofuranoside | (Hariti & Rathee, 1995) |
| Protein | Trichosanthin; galactose-specific lectin | (Wong et al., 2014; Kabir, 2000; Sultan et al., 2004; Falasca et al., 1989) |
| Sterol | 24-Methylcholesterol; 28-isofucosterol; avenasterol | (Akihisa et al., 1986, 1988, 1997) |

## *Pharmacological Properties*

**Antidiabetic/antihyperglycemic:** Gum acacia suspension of ethanolic extract of *T. dioica* fed by oral intubation to male albino rats caused significant blood sugar lowering in fasted model (Sekar et al., 1988). Seed powder was fed in raw form along with usual meals to each volunteer without past history of diabetes and to mild diabetic male human subjects. The patients exhibited unexplained weight loss, polyuria, polydipsia and intermittent glycosuria. Effect of oral administration of suspension of alcoholic extract of whole fruit of *T. dioica* lowered the blood sugar, total cholesterol, LDL cholesterol and triglyceride levels, and increased the HDL cholesterol, phospholipid and faecal sterol levels (Adiga et al., 2010; Sharma et al., 1990). In rats with STZ-induced severe diabetes mellitus, aqueous extract of *T. dioica* fruits reduced the levels of fasting blood glucose, postprandial glucose, asparate amino transferase, alanine amino transferase, ALP, creatinine, urine sugar and urine protein. These studies scientifically validate the

traditional use of *T. diocia* in diabetes management and could be developed as an effective oral agent for treating diabetes mellitus and complications associated with it (Rai et al., 2008a, 2008b, 2008c, 2010a, 2013; Sharma & Pant, 1988a).

**Antiulcer:** Ethanolic extract of *T. dioica* fruits was used for gastro protective effects on experimental models in rats, pylorus ligation + aspirin-induced gastric ulcer model, acetic acid-induced gastric ulcer and ethanol-hydrochloric acid-induced gastric ulcer. Estimation of biochemical parameters like total acidity peptic activity, muco-substances, total hexoses, hexosamine, fucose, sialic acid and protein was evaluated. From the study, it showed gastroprotective effect (Singh & Singh, 1985).

**Antimicrobial:** In vitro assessment of antimicrobial activity of different concentrations of the extracts of different parts (leaves, fruits and seeds) of *T. dioica* in clinical isolates of different bacterial strains results inhibition against *Mycobacterium smegmatis* (Rai et al., 2010b). Antifungal activity of the unsaponifiable fraction of the fixed oils of *Trichosanthes* seeds are also reported (Harit & Rathee, 1996).

**Wound healing:** Scientific evaluation for the wound healing potential of the methanolic extract of *T. dioca* fruits showed significant healing in both the wound models when compared with control group. All parameters such as wound contraction, epithelialization period, hydroxyproline content, tensile strength and histopathological studies showed significant changes when compared to control (Shivhare et al., 2010a, 2010b).

**Antihyperlipidemic/cholesterol lowering:** The aqueous fruit extract of *T. dioica* has cholesterol lowering activity (Sharmila et al., 2007). Oral administration of alcoholic extract of the whole fruit of *T. dioica* with the help of catheter along with basal diet lowered the blood sugar, total cholesterol, LDL cholesterol and triglyceride levels, and increased the HDL cholesterol, phospholipid and faecal sterol levels (Sharma & Pant, 1988b; Sharma & Pant, 1992).

**Cytotoxicity/chemopreventive/antitumour:** In vitro cytotoxic effect of dichloromethane, methanol and aqueous extracts of *T. dioica* root was evaluated using *Allium cepa* root meristems (Bhattacharya & Haldar, 2010). All the extracts and Cucurbitacin enriched extract significantly demonstrated concentration-dependent inhibition of root length and number, and reduction in mitotic index indicating antimitotic activity. The cytotoxic activity of *T. dioca* against Ehrlich ascites carcinoma cells was assessed in vitro by Trypan blue cell viability assay and MTT cell proliferation assay. The hydroalcoholic extract of *T. dioica* root demonstrated significant antiproliferative effect at lower concentrations against Ehrlich ascites carcinoma cells, thus suggesting the feasibility of its possible promise as natural anticancer agent. *T. dioca* exhibited dose dependent and significant decrease in tumour weight, tumour volume, packed cell volume and viable cell count, and extended the life span of Ehrlich ascites carcinoma bearing hosts (Bhattacharya et al., 2011; Bhattacharya & Haldar, 2012f). The extracts also showed moderate cytotoxicity against brine shrimp.

*T. dioica* root possessed remarkable ameliorative effect against arsenic-induced organ toxicity in male albino rats (Bhattacharya & Haldar, 2012a, 2013d). *T. dioca* was administered orally to rats before oral administration of sodium arsenite. The body weight, organ weight, haematological profile, serum biochemical profile, hepatic and renal

antioxidative parameters and DNA fragmentation were evaluated. Pretreatment with *T. dioca* markedly and significantly normalized organ's weight and other parameters (Bhattacharya & Haldar, 2012g). In another study, *T. dioica* fruit possesses a remarkable ameliorative effect against arsenic-induced brain toxicity in male albino rats and cardiotoxicity in Wistar albino rats (Bhattacharya et al., 2014; Bhattacharya & Haldar, 2013c).

Hydroalcoholic extract of the *T. dioica* root exhibited the chemopreventive property against 3-methylcholanthrene-induced carcinogenesis in Swiss albino mice. *T. dioca* treatment markedly reduced tumour incidence and prolonged the life span of sarcoma-bearing mice (Bhattacharya & Haldar, 2012b).

Trichosanthin manifested anti-proliferative and apoptosis-inducing activities in both estrogen-dependent human MCF-7 cells and estrogen-independent MDA-MB-231 cells (Fang et al., 2012e; Li et al., 2010a; Sha et al., 2013). Trichosanthin treated nude mice bearing MDA-MB-231 xenograft tumours exhibited significantly reduced tumour volume and tumour weight, due to the potent effect of trichosanthin on tumour cell apoptosis as determined by the increase of caspase-3 activation, PARP cleavage and DNA fragmentation. Considering the clinical efficacy, it opens up new therapeutic avenues for patients with estrogen-dependent and/or estrogen-independent breast cancers.

Tricosanthin significantly inhibited the growth of both CNE1 and CNE2 nasopharyngeal carcinoma cell lines. Its anticancer effects were associated with induction of apoptosis and, at least partially, with suppression of telomerase activity (Kang et al., 2013). Apoptosis of CNE1 and CNE2 cells was determined by the terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL) method and telomerase activity by the tartrate resistant acid phosphatase - enzyme-linked immunosorbent (TRAP-ELISA) assay. Recombinant trichosanthin is a potential agent with high in vitro and in vivo anti-tumour activity on PC3 cells (Li et al., 2016a). Recombinant trichosanthin combined with IL-2 is a promising strategy in treating patients with prostate cancer.

**Anti-inflammatory:** *T. dioca* extract showed a dose-dependent and significant anti-inflammatory (carrageenan-induced paw edema in rats) and antipyretic effect (Brewer's yeast induced pyrexia) (Alam et al., 2011; Fulzule et al., 2001; Kharbanda et al., 2015). Antinociceptive activity was evaluated by acetic acid-induced writhing and tail flick methods in Swiss albino mice. Further root extract was evaluated for anti-inflammatory activity in experimental acute (carrageenan-, histamine- and serotonin-induced paw edema) and chronic models (cotton pellet-induced granuloma) in Wistar albino rats (Bhattacharya & Haldar, 2012e). In all the anti-inflammatory models, root extract exhibited promising anti-inflammatory activity in a dose-dependent manner. The triterpenoid enriched fraction from *T. dioica* root demonstrated significant reduction of ascitic fluid formation in a dose-dependent manner against experimentally induced acute inflammatory ascites in Wistar albino rats by intraperitoneal administration of formalin solution (Bhattacharya & Haldar, 2013b).

**Neuroprotective:** *T. dioica* root possessed prominent antinociceptive as well as depressant actions on the CNS, as manifested by neuropharmacological properties in mice. It revealed significant and dose-dependent antinociceptive, locomotor depressant,

muscle relaxant and sedative potentiating effects by a phenobarbitone-induced sleep (Bhattacharya & Haldar, 2012c, 2013a).

**Antidiarrhoeal:** Diarrhoea induced with castor oil and magnesium sulphate in mice were used to evaluate antidiarrhoeal activity and the extract in different solvent reduced the frequency and severity of diarrhoea in both animal models. *T. dioica* root significantly and dose-dependently increased all the excretory bowel activities and gastrointestinal transit in both naive and constipated mice. *T. dioica* root demonstrated stimulant laxative activity in Swiss mice validating its traditional usage in India (Akter & Imam, 2011; Bhattacharya & Haldar, 2012h, 2012d).

**Antioxidant:** Antioxidant activity of aqueous extract of *T. dioica* fruits was studied for its free radical scavenging property in different in vitro methods as DPPH, nitric oxide, reducing power assay and hydrogen peroxide radical methods. It showed significant concentration dependent free radical scavenging property in all the methods (Akter & Imam, 2011; Alam et al., 2011; Dixit & Kar, 2009; Sharma et al., 2009; Yadav et al., 2016; Yogesh et al., 2010).

**Hepatoprotective:** Liver damage was induced in Wistar rats by administering ferrous sulphate. The pretreatment with extracts showed profound histopathological protection to liver cells as evident from histopathological studies (Ghaisas et al., 2008). Hepatoprotective activity of the ethanolic and aqueous extracts of *T. dioica* was also evaluated against paracetamol-induced hepatic damage in rats. The ethanolic and aqueous extracts of *T. dioca* at different doses, administered orally, showed decrease in the levels of AST, ALT, total bilirubin, ALP and increase in total protein. In vivo hepatoprotective effect of methanolic fruit extract of *T. dioica* was also evaluated in simvastatin-induced hepatotoxicity in experimental animals (Gupta et al., 2018). The treatment with *T. dioca* significantly and dose-dependently reversed simvastatin-induced elevation in serum level of SGOT, SGPT, ALP and total bilirubin, and restored the total protein and albumin levels.

**Immunomodulatory:** An oral administration of the aqueous extract of *T. dioica* showed immunomodulatory effect in rat. The aqueous extract of *T. dioica* showed increasing antibody production in dose-dependent manner. It enhances the production of RBC, WBC and haemoglobin (Bhadoriyal & Mandoriya, 2012).

**Wormicidal:** In vitro activities of defatted methanol extract of the leaves from *T. dioica* and its ethyl acetate and n-butanol fractions were evaluated against *P. posthuma* (Annelida) and *Ascaridia galli* (Nematoda). All the extracts demonstrated concentration dependent paralytic and lethal effects on *P. posthuma* and *A. galli* (Bhattacharya et al., 2010).

**Skin disorder:** Trichosanthin, purified from the pointed gourd, is a potent inhibitor against HIV-1 replication. The seed contains haemagglutinating activity due to lectin, which is inhibited by galactose (Bhujbal, 1999).

## 8. *Momordica dioca*

*M. dioica* Roxb. is a perennial, dioecious climber included in Cucurbitaceae family. It is commonly known as spine gourd. Fruit is shortly beaked, obtuse with inner red kernel, densely echinate with soft spines, green and yellow at maturity (Figure 9.1h).

The juice of root is a domestic remedy for the inflammation caused by contact with the urine of the house lizard (Jha et al., 2017; Talukdar, 2014). The protective role of the leaves against chronic skin diseases is also reported. A preparation called '*Panchatikta ghrita*' is made by boiling 800 g each of neem bark, leaves of *M. dioica*, *Solanum surattense*, *Tinospora cordifolia* and bark of *Adhatoda vasica*, in 5–6 L of water up to its reduction to quarter and then adding of 3.5 L of butter and about 3 kg myrobalans, and is recommended as one tablespoonful with little hot milk, internally twice daily, in chronic skin diseases. Tender fruits are rubbed on skin for pimples and acne. Seeds are roasted and taken for eczema and other skin problems. The powder or infusion of the dried fruits, when introduced into the nostrils, produces a powerful errhine effect and provokes a copious discharge from the schneiderian mucous membrane. Mucilaginous tubers of female plants used in bleeding piles and bowel infections. The juice of the leaves are mixed with coconut, pepper, red sandalwood and so forth in order to form an ointment, and applied to the head to relieve pain.

## *Bioactive Components*

It is the highest amount of carotene (162 mg/100 g of edible portion) container amongst the cucurbitaceous vegetables. *M. dioca* fruit aril memebrane and seed pericarp contains highly valuable source of carotenoids and responsible for yellow, orange and scarlet red colour of ripen fruit. Tirmizi et al. (2007) screened it as a potential source of chromium and zinc. *M. dioica* (peeled) contained 0.27 mg/kg of chromium and 4.91 mg/kg of zinc, and *M. dioica* (unpeeled) contained 0.26 mg/kg of chromium and 11.0 mg/kg of zinc. The presence of secondary metabolites of fruits include steroids, triterpenoids, aliphatic compounds, phenolics, flavonoids, peptides and saponins (Table 9.9) (Talukdar, 2014). Polypeptides may be a contributing factor in controlling sex mechanism of dioecious *M. dioica*. Trypsin inhibitor proteins were characterized from *M. dioca.*

**Table 9.9.** Different classes of compounds in *M. dioca*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Steroid | α-Spinasterol; pleuchiol; momodicaursenol | (Luo et al., 1998; Ali & Srivastava, 1998) |
| Triterpene | Oleanolic acid; gypsogenin; hederagenin; bryonolic acid; 3β-O-benzoyl-11-oxo-ursolic acid | (Lei & Zuqiang, 1997; Luo et al., 1998; Zuqiang, 1999; Ali & Srivastava, 1998) |
| Saponin | Charantin; 3-O-β-D-glucuronopyranosyl gypsogenin; 3-O-β-D-glucopyranosyl hederagenin | (Shanmugapriya & Poornima, 2014; Jha et al., 2019b) |
| Aliphatic compound | 6-Methyl tritriacont-5-on-28-ol; 8-methyl hentriacont-3-ene | (Ali & Srivastava, 1998) |
| Flavonoid / phenolic | Rutin; daidzein; hydroxycinnamic acids; hydroxybenzoic acids | (Shreedhara & Vaidya, 2006a; Kale & Laddha, 2012; Chung et al., 2017; Nagarani et al., 2014) |
| Polypeptide / Protein | Trypsin inhibitor protein; lectin | (Sinha et al., 2001; Varghese & Gajbhiye, 2016; Ghosh et al., 1981; Shruthi et al., 2016; Du et al., 2019) |

## *Pharmacological Properties*

**Hepatoprotective:** The hexane and methanolic extracts of the fruit pulp of *M. dioica* were evaluated for anti-hepatotoxic activity induced by administering paracetamol in rats (Ilango & Maharajan, 2004). In another experiment, the flavonoidal fraction from ethanolic extract and saponin fraction of fruits of *M. dioica* were evaluated for hepatoprotective activity in Wistar strain of albino rats against $CCl_4$-induced hepatic damage (Firdous et al., 2008; Jain et al., 2008). The extracts exhibited a significant therapeutic effect by lowering SGOT, SGPT, ALP and serum bilirubin, and increasing the serum protein level (Kushawa et al., 2005; Kushwaha et al., 2006; Sato et al., 2011; Shreedhara & Vaidya, 2006b).

**Antioxidant:** In vivo antioxidant and free radical scavenging activities were also screened which were positive for both ethanolic and aqueous extracts (Jain et al., 2008). DPPH and nitrous oxide method were used to evaluate antioxidant activities of the extract. Similarly, the extract showed its ability to scavenge free radicals in a concentration dependent manner in ABTS radical scavenging, iron chelating activity, total antioxidant capacity and haemoglobin glycosylation assays (Shreedhara et al., 2011). Increase in the levels of thiobarbituric acid reactive substances and hydroperoxide, and decrease in the levels of non-enzymatic antioxidants and activity of enzymatic antioxidants were observed in liver, kidney, pancreas, and serum of diabetic rats when compared with normal healthy rats. It showed the protective role of the extract of *M. dioca* on liver, kidney and pancreas in severe diabetic rats supporting for its antidiabetic use in folk medicine (Shreedhara & Vaidya, 2006b; Shrinivas, 2009).

**Anithyperglycemic:** *M. dioica* fruits possess potential antidiabetic activity. Various extracts were tested for their antidiabetic activity in alloxan-induced diabetic rats (Ilango et al., 2009; Reddy et al., 2006a, 2006b; Singh et al., 2011). In the diabetic rats, the elevated blood glucose level, total cholesterol and triglycerides were reduced to the normal values by both the hexane and methanolic extracts of *M. dioica*. Similarly, *M. dioica* extract treatment markedly reduced serum glucose, and increased serum insulin and urea levels in STZ-induced diabetic rats. The methanolic extract of *M. dioica* seeds also showed significant inhibition of α-amylase activity in STZ-induced diabetic rats (Haimed et al., 2019; Poovitha et al., 2017; Sailaja & Krishna, 2015). Saponin isolated from the methanolic extract of fruits of *M. dioica* was tested against STZ-induced diabetic mellitus type I in rats. Saponin extract treated diabetic group showed significant decreased in the HbA1c level and showed reversible beta cell degeneration. Saponin was also found to possess insulinotropic activity when rat insulinoma cell line was treated with it (Fernandopulle et al., 1994; Gupta et al., 2011; Jha et al., 2019a).

**Hypolipidemic:** Extracts of *M. dioica* fruits possess good hypolipidemic and antiobesity activities. The effect of dietary kakrol on lipid metabolism in rats was studied. Dietary kakrol reduced liver lipids by inhibiting lipid absorption (Sato et al., 2011). Results showed significantly lowered liver cholesterol and triacylglycerol levels in rats. Faecal lipid excretion increased in rats fed the kakrol diet, and lymphatic transport of

triacylglycerol and phospholipids decreased in rats fed the kakrol diet after permanent lymph cannulation. Atherogenic diet alone treated animals have developed hyperlipidemia and obesity when compared with normal animals. Extract of *M. dioca* significantly reduced the elevated levels of total cholesterol, serum triglyceride, LDL cholesterol, VLDL cholesterol, AST and ALT, and elevate the decreased level of HDL-cholesterol (Ilango et al., 2009).

**Analgesic:** Different extracts exhibited analgesic activity when evaluated by non-narcotic models like acetic acid-induced writhing syndrome test and narcotic models like hot plate (Ilango et al., 2003; Rakh & Chaudhari, 2010a; Rakh et al., 2012; Shreedhara & Vaidya, 2003).

**Anti-inflammatory:** Hexane and methanolic extracts exhibited significant analgesic and anti-inflammatory activities in mice and rats. The alcoholic extract also significantly reduced carrageenan-induced paw edema when administered orally (Ilango et al., 2003; Shreedhara & Vaidya, 2006b).

**Nephroprotective:** The ethanolic extract of the fruits of *M. dioica* exhibited nephroprotective and curative effects against gentamicin-induced acute renal injury in albino rats. The extract showed significant reduction in the elevated blood urea and serum creatinine intoxicated with gentamicin (Jain & Singhai, 2010a). The ethanol extract of *M. dioica* fruit extract was studied for nephroprotective and curative activities in cisplatin-induced nephrotoxicity. Administration of extract has shown significant recovery in the levels of these biochemicals like blood urea and serum creatinine (Jain & Singhai, 2010b). *M. dioica* extract protects kidney in severe diabetes. Antioxidant enzyme activity of kidney was increased, while thiobarbituric acid reactive substances were reduced in *M. dioica* extract treated diabetic rats (Gupta et al., 2011).

**Antiallergic:** Extracts of fruit pulps shows antiallergic activity in all three models of milk-induced leukocytosis, milk-induced eosinophilia and differentia leukocytes count in mice. The antiallergic activity of *M. dioica* fruit pulp may be due to polar constituents present in the fruit pulp (Rakh et al., 2012). The inhibitory effect of the extract of kakrol on histamine release in human basophilic KU812 cells showed the inhibitory effect on histamine release. The dietary kakrol flesh water extract alleviated the development of skin lesions in ears accompanied by lower IgE levels and inflammatory cytokines levels in serum in picryl chloride-treated NC/Nga mice (Gupta et al., 1993).

**Anticancer:** The $CHCl_3$ extract of *M. dioica* roots and isolated constituents showed anticancer activity in L1210, CCER-CEM and Ls174T cell lines (Luo et al., 1998). The methanolic extract of seeds of *M. dioica* was tested against human lung carcinoma (A549) and breast carcinoma (MCF-7) cell lines at various concentrations (Chandra et al., 2019). The results showed that the extract of *M. dioca* inhibited the growth of A549 and MCF-7 cells.

**Antifeedant:** The methanolic extract of the fruit pulp of *M. dioica* exhibited moderate and concentration dependent antifeedant activity against *Spodoptera litura* (Narasimhan

et al., 2005). Seed oil of *M. dioca* was found to be satisfactory natural insecticide. Oil was evaluated against mustard aphid, *Lipaphis erysimi*, in the farm of mustard crop and was found very effective (Mishra et al., 2006). No further spray was given to crop and also no further infestation of aphid found in the vegetable oil treated crop. Oil of *M. dioca* seed evaluated as grain protectant against *Callosobruchus chinensis* on the stored legume-pulse grains and was found effective as legume-pulse grain protectant (Deokule, 2012; Mishra et al., 2007).

**Antimicrobial/antimalarial:** Methanolic extract showed more promising antimicrobial acitivity when screening of antimicrobial activity was done using disc diffusion method on common gram-positive and gram-negative bacteria (Arekar et al., 2013; Ilango et al., 2012; Shrinivas, 2009). Extract of fruit pulp of *M. dioica* had also a potential antimicrobial activity against *S. typhi* and *Shigella dysenteriae* investigated by cup-plate agar diffusion method. Alcoholic extracts of *M. dioica* were found to possess schizontocidal activity in vivo and in vitro for antimalarial activity against the NK 65 strain of *Plasmodium berghei* (Misra et al., 1991).

**Antifertility:** Aqueous and ethanolic extracts of *M. dioca* were found to be most effective in causing significant abortifacient activity. Histological studies of the uterus were carried out to confirm estrogenic activity (Shreedhara, 2001).

**Antiulcer:** Estimation of $H^+$-$K^+$ ATPase activity and gastric wall mucous were performed in ethanol- and aspirin-induced ulcer models, antioxidant enzyme activity was carried out in cold-restraint stress-induced ulcer model, and various gastric secretion parameters like volume of gastric juice, acid output and pH value were estimated in pylorus ligation-induced ulcer model (Fernandopulle et al., 1996; Vijayakumar et al., 2011). A significant reduction in lesion index was observed in ulcer-induced animals pretreated with the extract. A significant decrease occurred in the level of $H^+$-$K^+$ ATPase, volume of gastric juice and acid output. Gastric wall mucus and pH were increased significantly. The results indicate that *M. dioica* extract possess antiulcerogenic effect, that attributable to augmentation of gastric defense mechanisms.

**CNS depressant:** The methanolic and aqueous extracts of *M. dioica* fruits pulp possess a wide range of CNS activities using neuropharmacological experimental models (muscle co-ordination and locomotor activity) in mice (Rakh & Chaudhari, 2010b).

**Cardioprotective:** The cardioprotective activity of *M. dioca* fruit extract on doxorubicin-induced cardiotoxicity on rats was evaluated by serum (CK-MB, LDH and AST) and nonserum parameters like endogenous antioxidants, ECG and histological studies. The rats pretreated with extract have produced the reversed toxicity produced by doxorubicin (Shamala & Krishna, 2013).

**Protein inhibitor:** *M. dioica* seeds were found to possess serine protease inhibitor protein. The purified protein from *M. dioica* seeds showed trypsin activity inhibition. The inhibitory effect of purified protein on trypsin activity was characterized by enzyme kinetic study (Du et al., 2019; Varghese & Gajbhiye, 2016).

## 9. *Benincasa hispida*

Young *B. hispida* fruit is fleshy, succulent and hairy while the mature fruit has thickly deposited hairs with easily removable waxy bloom (Figure 9.1i). It is a perennial, large trailing gourd climbing with tendrils and resembles the pumpkin in appearance. Fruits contain numerous white coloured embedded seeds. The fruit is harvested immature, half-ripe and usually cooked and eaten as vegetables. The fleshy pulp is also processed into pickles and sweet candies. In Western Nepal, the vegetable is used to prepare a candy called *Petha*. One of the unique characters of the fruit is that if there is no injury to the fruit, it can even be stored for a year in cool and dry place. Ash gourd has a mild to bland flavour and juicy texture and is mainly used in soups, curries and stews, but can also be stuffed with a flavour some filling and baked. As this fruit apparently contains appreciable amounts of thickening agents; a potential exists for exploration of food-grade thickeners for commercial applications.

The oil from the seeds is soporific, good for the brain and liver, and also useful in the treatment of syphilis. The fruit is an important ingredient of *Kusmanda lehyam* (an Ayurvedic medicine). It has been widely used for the treatment of epilepsy and other nervous disorders. In Ayurvedic system of medicine, *B. hispida* fruits are used for the treatment of schizophrenia and other psychologic disorders (Al-Snafi, 2013; Gupta et al., 2019; Zaini et al., 2011). The methanolic extract of *B. hispida* fruit has been demonstrated to possess nootropic, antidepressant and anxiolytic like effects, which suggests that *B. hispida* influences various neurotransmitter systems including serotonergic system. *Haidonghua powder*, made up of *Laminaria japonica* and *B. hispida*, was found to have antiobesity activity.

### *Bioactive Components*

*B. hispida* contains various mineral elements and vitamins, with a relatively high level of potassium and low sodium, with low heat energy and no fat. Proximate analysis of the seeds revealed the total dietary fiber as the principal component. The high content of total dietary fiber is associated with lowering blood cholesterol level and incidence of coronary heart diseases, and bowel disorders. The seeds of *B. hispida* contain a high proportion of essential fatty acids like linoleic acid accounting for 67.37% of total fatty acids. The beverage prepared from this vegetable has a different aroma, and the analysis of the volatile compounds indicated the presence of pyrazine, which is believed to be formed by the Maillard reaction during the extraction of juices. The major odour active compounds of *B. hispida* were acetoin, octanal and nonanal. The waxy coating on fruits of *B. hispida* was found to consist mainly of triterpenes. The major wax constituent isolated and identified was isomultiflorenol acetate. The polysaccharide present in the juice was isolated and characterized by its sugar composition, mainly arabinogalactans. It contained galacturonic acid and neutral sugars, mainly galactose, arabinose and glucose. Phytochemical constituents reported in *B. hispida* fruit reveal the presence of triterpenes, sterols, glycosides, pyrazines, aminocompounds, phenolics, flavonoids and proteins (Table 9.10) (Zaini et al., 2011). The triterpenes, alnusenol and multiflorenol from the gourd, are active histamine release inhibitors.

**Table 9.10.** Different classes of compounds in *B. hispida*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Polysaccharide | Arabinogalactans; homogalacturonan | (Mazumder et al., 2001, 2004, 2005; Kumar et al., 2012a) |
| Volatiles | E-2-Hexenal; n-hexanal; n-hexyl formate; acetoin | (Maarse, 2017; Wu et al., 1987; Sharma et al., 2010a; Sikorski, 2006) |
| Pyrazine | 2,5-Dimethylpyrazine; 2,6-dimethylpyrazine; 2,3,5-trimethylpyrazine; 2-methylpyrazine; 2-ethyl-5-methylpyrazine | (Sikorski, 2006; Wu et al., 1987) |
| Triterpene | Isomultiflorenol acetate; α-amyrin; alnusenol; multiflorenol | (Wollenweber et al., 1991; Yoshizumi et al., 1998; Battu et al., 2007) |
| Sterol | β-Sitosterol | (Battu et al., 2007; Yoshizumi et al., 1998) |
| Amino compound | 2-Aminohexanoic acid; 2-amino-3-cyano-propanoic acid; 2-aminobutanoic acid; 2-amino-4-hexenoic acid; 3-cyclohexenyl-1-glycine | (Dong et al., 1995) |
| Phenolic / flavonoid | Quercetin; astilbin; catechin; naringenin; gallic acid | (Du et al., 2005; Yoshizumi et al., 1998; Battu et al., 2007; Fatariah et al., 2014) |
| Protein / enzyme / peptide | Cucumisin likeserine protease; osmotin-like proein; chitinase; serine proteinase inhibitor; laccase; beneincasins | (Shih et al., 2001a; Uchikoba et al., 1998; Atiwetin et al., 2006; Churiyah & Darusman, 2009; Mitra et al., 2017; Devaki et al., 2015) |
| Acids | Uronic acid; malic acid; citric acid | (Kumazawa et al., 1985; Wills et al., 1984) |

## *Pharmacological Properties*

**Anticonvulsant/nootropic/anxiolytic/antidepressant:** As mentioned in Ayurvedic medicine, fruit juice is used for treating a range of ailments including insanity and epilepsy. Experiment on activities on mouse CNS and guinea-pig ileum muscle validate its reported pharmacological properties (Ramesh et al., 1989). Methanol extract of *B. hispida* was evaluated using chemo-convulsive agents such as pentylenetetrazole, strychnine and picrotoxin, and maximal electro seizures model in mice. The extract significantly inhibited the hind limb extension induced by maximal electro seizures and the extract significantly increased the latency of convulsion and death induced by pentylenetetrazole and strychnine (Kumar & Ramu, 2004; Nimbal et al., 2011b). However, the extract failed to protect the convulsion induced by picrotoxin. When anticonvulsant activity of methanolic extract of *B. hispida* was measured by supramaximal electric shock-induced convulsions using phenytoin as a reference standard, it showed significant reduction in duration of tonic flexion and tonic extension as compared to control group ( Rachchh et al., 2010).

*B. hispida* may be useful in the treatment of obsessive-compulsive disorder characterized by persistent thoughts (obsessions), which are ego-dystonic and associated with seemingly purposeful behaviours. Methanolic extract of *B. hispida* fruit was investigated on the marble-burying behaviour of mice compared with the effect of fluoxetine as standard antiobsessive-compulsive disorder agent (Girdhar et al., 2010).

When anxiolytic activity of the methanolic extract of *B. hispida* was measured by Elevated plus maze model using lorazepam as a reference standard, it showed significant increase in time spent in open arm and also increase the latency period for entry into close arm as compared to control group. In light-dark transition test and spontaneous motor activity, the ethanolic extract increase the time spent in the illuminated side. However, the extract was not able to modify the spontaneous motor activity measured in actophotometer (Kumar & Nirmala, 2003; Maciuk et al., 2002; Nimbal et al., 2011a; Rukumani et al., 2003). The extract significantly potentiated the barbiturate-induced hypnosis (Babu et al., 2003). *B. hispida* was studied for its effect on motor coordination, locomotor activity, cognitive behaviour, anxiolytic activity, haloperidol-induced catalepsy and anticonvulsant activity. The extract showed significant decrease in locomotor activity and exploratory behaviour but no effect on motor-coordination (Ambikar, 2013). The dose-dependent protective effect of water extract of *B. hispida* pulp on colchicine-induced experimental rat model of Alzheimer's disease was studied and it has shown protective effect on colchicine-induced Alzheimer's disease (Roy & Ghosh, 2008). In mouse forced swim test, the study showed the antidepressant-like effect of the methanolic extract (Dhingra & Joshi, 2012).

**Antihistamine/antiallergic:** The fruits of *B. hispida* was found to show inhibitory activity on the histamine release from rat exudate cells induced by antigen-antibody reaction (Babu et al., 2003; Kumar & Ramu, 2002; Yoshizumi et al., 1998). Alnusenol and multiflorenol triterpenes isolated from *B. hispida*, were found to potently inhibit the histamine release. The effects of an extract of *B. hispida* on allergic inflammation were examined in terms of histamine and β-hexosaminidase release, serum IgE level and inflammatory cytokine level. The *B. hispida* extract inhibited the release of histamine and β-hexosaminidase, a degranulation marker, from rat basophilic leukemia cells (RBL-2H3) (Park et al., 2009).

**Gastroprotective/prebiotic activity:** Vegetables are also rich source of insoluble and soluble dietary fibres. Prebiotic ability of dietary fibre from *B. hispida* was studied using pure cultures as well as mix culture of *E. coli*, *Lactobacillus fermentum*, *Bifidobacterium breve* and *Clostridium acetobutilicum* species in in vitro fermentation for total short chain fatty acid production. *B. hispida* fibres with a 48 hr fermentation period produced highest amount of total short chain fatty acid, among other tested vegetables (Sreenivas & Lele, 2013). A comparative study on the growth of *Lactobacillus* and *E. coli* on media supplemented with the carbohydrate was done. The results showed a higher growth rate in *Lacto bacillus* when compared to *E. coli*, which confirmed with a positive prebiotic activity. These prebiotics from the gourd seeds were incorporated into chocolates for colour, texture and sensory acceptability (Pallavi et al., 2018).

Anti-ulcerogenic activity of different extracts of *B. hispida* was studied in aspirin plus restraint and swimming-stress, and indomethacin plus histamine- and serotonin-induced ulcers in rats and mice. The extract significantly reduced the ulcer index produced by various ulcerogens (Gill et al., 2011b; Grover et al., 2001a; Shetty et al., 2008). In another study, there was an apparent decrease in ulcer index in animals treated with the fruit extract. There was significant decrease in malondialdehyde with concomitant decrease in superoxide dismutase and vitamin C levels in the treated rats when compared to those not treated with the fruit extract. The antiulcer activity of *B. hispida* fruit was also evaluated in rats against ethanol-induced gastric mucosal damage, pylorus ligated (PL) gastric ulcers, and cold restraint-stress induced gastric ulcer models (Rachchh & Jain, 2008). The extracts produced significant reduction in ulcer index in all the models and the results were comparable with that of omeprazole-treated group.

**Anthelmintic:** *B. hispida* fresh leaves extracts exhibited anthelmintic activity significantly when compared with standard piperazine citrate using *P. posthuma* as the test worm (Bhattacharjee et al., 2010; Bhattacharjee et al., 2011; Muley et al., 2012).

**Antidiarrheal:** The methanolic extract of fruit treated animals showed significant inhibitory activity against castor oil-induced diarrhea and inhibited PGE2-induced enter pooling in rats. It also showed significant reduction in gastro intestinal motility following charcoal meal in rats (Mathad et al., 2005).

**Antiobesity:** A rat model of hypothalamic obesity induced by monosodium glutamate (MSG) was used for antiobesity. Haidonghua powder has the effect of antiobesity, without any influencing on the function of thyroid gland and metabolism of water and salt. The mechanism is related to the reduction of fat cell size and the accumulation of fat (Wang et al., 2000; Zhang, 1996).

**Anoretic effect:** Fasted mice were administered with various doses of the methanolic extract of *B. hispida* and the food intake was measured. The extract significantly reduced the cumulative food intake. The percentage of gastric emptying was determined after the administration of the methanolic extract but was not significantly influenced. It reveals a possible anorectic activity of *B. hispida*, most probably mediated through the CNS without affecting the gastric emptying (Kumar & Vimalavathini, 2004).

**Hypoglycemic:** Diabetes was induced in the male rats by intravenous injection of STZ dissolved in citrate buffer (Lim et al., 2003). Rats were fed a AIN-93 diet with the ash gourd powder. The levels of glucose, insulin, cholesterol, HDL-cholesterol, triglyceride and free fatty acids in plasma and levels of glycogen in liver and muscle were analyzed. The plasma glucose levels, plasma cholesterol level and plasma free fatty acids were significantly lowered. The plasma insulin levels and plasma level of triglyceride were higher. These results the possibility of therapeutic or preventive use of wax gourd to the diabetes mellitus (Kim, 2004; Lim, 2007; Lim & Kim, 2004; Lim & Lee, 2005). The hypoglycemic of alcoholic extract of *B. hispida* were investigated in normal and alloxan-induced diabetic rats. A oral administration of alcoholic extract of *B. hispida* produced a significant blood glucose reduction in a dose-dependent manner (Battu et al., 2007; Mohana & Mohan, 1997). In another study, hypoglycemic activity of *B. hispida* stem extract was evaluted in normal male Wistar rats and its activity was compared with

control and standard drug glybenclamide (Jayasree et al., 2011a). It shows maximum reduction in blood glucose level with stem extract in comparision to control group. In an experiment, supplementation of ash gourd with curry leaves had also shown significant hypoglycemic and hypolidemic effects, and it had reduced the blood glucose level in the group of diabetic patients (Amirthaveni & Priya, 2011). Supplementation of fermented beverage showed significant improvement in body mass index (BMI) grades, heamoglobin and reduced blood glucose level, triglycerides and improved HDL cholesterol level in geriatric population. The preventive and therapeutic potentials of fruit juice of *B. hispida* and *S. edule* in fructose and sucrose-sweetened beverages-induced IGT, oxidative stress and IGT-induced other metabolic disturbances in rats were explored (Tiwari et al., 2013). Treatment of theses rats with juice of *B. hispida* and *S. edule* accelerated normalization of oral glucose tolerance ability and decreased oxidative stress, platelet aggregation and accumulation of advanced glycation end products (AGEs) in sucrose induced-IGT and oxidatively stressed rat.

**Hyperlipidemic:** The effect of the extract of wax gourd peel on metabolic disorders in diet-induced C57BL/6 obese mice was studied. The extract of wax gourd peel blocked body weight gain and lowered serum total cholesterol, LDL cholesterol, liver triglyceride and total cholesterol contents, and fasting blood glucose in mice fed with a high-fat diet (Gu et al., 2013). Further gene expression analysis showed that extract of wax gourd peel could inhibit peroxisome proliferator-activated receptor γ (PPARγ) transactivities and could decrease mRNA levels of PPARγ and its target genes, and HMG-CoA reductase was downregulated in the mouse liver (Amirthaveni & Priya, 2011; Zhang, 1996).

**Antioxidant:** The effect of oral treatment of aqueous pulp extract was studied in Holtzman strain adult albino rats. The antioxidant level superoxide dismutase, catalase, reduced glutathione level and lipid peroxidation level were studied in different brain areas in colchicine-induced experimental Alzheimer's rat model (Roy & Ghosh, 2008). The pulp extract significantly decreased lipid peroxidation level, significantly increased superoxide dismutase and catalase, and reduced glutathione level in the different parts of the brain demonstrating that the antioxidant property. Free radical scavenging potential of the methanolic extract was evaluated by DPPH and hydrogen peroxide methods. Methanolic extract of *B. hispida* seeds showed significant free radical scavenging activity in a dose-dependent manner when compared with ascorbic acid (Gill et al., 2010, 2011; Mandana et al., 2012; Nagarajaiah & Prakash, 2015; Rana & Suttee, 2012). The essential fatty acids including linoleic acid and linolenic acid in seed extracts might play important roles in antioxidant activity (Bimakr et al., 2012). The antioxidant capacity of skin, pulp and seed of wax gourd extracts were measured by three different assays such as scavenging activity, ferric reducing activity and carotene bleaching assays (Abdullah et al., 2012). Among them the seed extract of wax gourd showed the highest antioxidant capacity. Various extracts of *B. hispida* fruit was subjected to quantitative analysis for total phenols, total flavonoids, total antioxidant and free radical scavenging activity by various methods like DPPH, nitric oxide, superoxide, hydroxyl radicals and hydrogen peroxide scavenging activity and reducing capacity. All the extracts showed significant activities in all the assays in a dose-dependent manner (Nadhiya & Vijayalakshmi, 2014; Singh et al., 2016).

**Anti-inflammatory:** The extract showed significant anti-inflammatory activity on carrageenan-induced (acute inflammation) and formalin-induced (chronic model) hind paw edema models (Babu & Umamageshwari, 2002; Gill et al., 2010). In the study of mechanism of anti-vascular inflammatory activity of the aqueous extract of *B. hispida*, it reduces high glucose-induced cell adhesion molecules activation by inhibiting monocyte adhesion, reactive oxygen species, and NF-kappaB in human umbilical vein endothelial cells. The results suggest the effective role of extract on high glucose-induced vascular inflammation of human umbilical vein endothelial cells (Moon et al., 2009).

In another study, in histamine-induced paw edema test, the extract showed maximum inhibition as compared to control group, which were comparable with that of standard drug cetirizine. However, extracts showed slight reduction in granuloma tissue formation in cotton pellet implanted rats, which were not significant with that of standard drug diclofenac sodium (Grover & Rathi, 1994; Rachchh et al., 2011).

The antinociceptive activity of the methanolic extract of *B. hispida* was studied using acetic acid-induced writhing and hot plate methods in mice. The methanolic extract of *B. hispida* showed percentage of protection from writhing and significant dose-dependent prolongation of the response latency. These results suggest that the methanolic extract possesses antinociceptive activity. Extract was used to study antipyretic effect. Brewer's yeast was used to induce pyrexia in rats, and the extract significantly decreased yeast-induced pyrexia in rats (Qadrie et al., 2009).

**Antiasthamatic/broncospasm:** The effects of crude oil on the smooth and skeletal muscles contraction and pain were investigated. The crude oil caused complete inhibition of histamine-induced smooth muscle contraction, while producing only a partial inhibition of acetylcholine-induced contraction in rat duodenum and frog rectus abdominis muscle (Kumar & Ramu, 2002).

**Anti-urolithiatic:** The study was designed to investigate the ameliorating effect of the ethanolic extract of *B. hispida* seeds in hyperoxaluria and renal cell injury. Ethylene glycol feeding resulted in hyperoxaluria as well as increased renal excretion of calcium. Supplementation with the extract of *B. hispida* seeds significantly reduced the elevated urinary oxalate showing a regulatory action on endogenous oxalate synthesis (Patel et al., 2011). Moreover, elevated serum levels of sodium, creatinine, calcium and phosphorus were significantly reduced. The aqueous pulp extract showed significant hepatoprotective effect through the modulation of antioxidant-mediated mechanism by altering SGOT, SGPT, ALP, superoxide dismutase and catalase activities, and reduced glutathione and lipid peroxidation levels against nimesulide-induced hepatotoxicity model in rats.

**Diuretic:** The *B. hispida* rind (pericarp) extract possesses a significant diuretic activity with a potassium sparing effect (Jayasree et al., 2011b). The extract produced a significant increase in the urinary volume. There was a significant increase in the sodium and chloride excretion, and a decrease in the potassium excretion in guinea-pigs experiment comparing to standard drug hydrochlorothiazide.

**Nephroprotective:** *B. hispida* had significant protection and blocking effects upon the kidney injure caused by mercuric chloride (Dong et al., 1995). Its extract could increase urination quantity, reduce the degree of pathological changes of kidney disease caused by mercuric chloride, and significantly decrease blood serum creatinine content. The effects of hydro alcoholic extract of *B. hispida* on paracetamol-induced nephrotoxicity were examined. Treatment with the extract prevented the paracetamol-induced nephrotoxicity and oxidative impairments of the kidney, as evidenced by a significantly reduced in kidney weight, blood urea, blood creatinine, urinary glucose, urinary potassium level and also increased body weight, urine volume, urinary creatinine and blood total protein level. The hydroalcoholic extract of *B. hispida* also had a protective effect on nephrotoxicity induced by cisplatin (Bhalodia et al., 2009; Varghese et al., 2013).

**Hepatoprotective:** Hepatotoxicity in rats was caused by nimesulide. The aqueous pulp extract of *B. hispida* was administered orally to rats. The biochemical changes produced by nimesulide were restored to normal by the aqueous extract (Das & Roy, 2012).

**Antimicrobial:** The methanol extract of wax gourd was found to significant inhibition against *C. albicans*. 1:1 combination of fixed oil of seeds of *B. hispida* and *Nigella sativa* was used for antimicrobial test. It showed a good activity against all the tested pathogens i.e. *Micrococcus luteus*, *E. coli*, *S. aureus*, *Pasteurella multocida*, *Pseudomonas aeruginosa* and *B. subtilis* (Lubna et al., 2016; Natarajan et al., 2003).

**Antitumour:** Radiosensitizing and antitumour effects of the hot water extract derived from the seeds of *B. hispida* were investigated and showed maximum survival rate against L1210 cells implanted in BDF1 mice (Choi et al., 2003). The seed extract of *B. hispida* decreased basic fibroblast growth factor (bFGF)-induced endothelial cell proliferation and tube formation in a dose-dependent manner. bFGF is a potent angiogenic factor found in various tumours (Kumazawa et al., 1985; Lee et al., 2005).

**Cytotoxicity:** Toxicity of the proteins, isolated from different parts of plant, was analyzed through the brine shrimp lethality test, followed with cytotoxicity test using HeLa and K-562 cancer cell lines. All proteins were found toxic on brine shrimp lethality test and the proteins also inhibited proliferation of HeLa cell (Churiyah & Darusman, 2009).

**Antimorphine:** The juice of *B. hispida* showed significant activity against symptoms of morphine withdrawal, such as jumping response and diarrhoea, in mice (Grover et al., 2000).

**Angiotensin converting enzyme inhibition:** A study was carried to investigate inhibition of angiotensin-converting enzyme (ACE) activity of wax gourd pulp, core, seed and peel prepared by different extraction methods. Angiotensin converting enzyme inhibition activity may provide protective effects against cardiovascular diseases and cancers (Huang et al., 2004).

**Protein inhibition:** The protease inhibitors were obtained from wax gourd (Atiwetin et al., 2006; Shih et al., 2001b; Uchikoba et al., 1998).

## 10. *Lagenaria sciceraria*

*L. siceraria* is widely cultivated as a vegetable crop in tropical countries and has a fleshy fruit and seeded pepo. It is a climbing or trailing herb with bottle, oval or dumbbell shaped fruit (Figure 9.1j).

The therapeutic potential of *L. siceraria* fruit is reported in the *Ayurvedic Pharmacopeia of India.* It is used as general tonic, cardioprotectant, hypolipidemic, aphrodisiac, purgative and diuretic. The regular intake (4–6 months) of *L. siceraria* fruit juice is claimed to relieve cardiovascular disorder (Ahmad et al., 2011; Roopan et al., 2016). In Punjab, the pulp is applied to the soles of the feet of those with burning feet. The pulp of the fruit is considered cool, diuretic, antibilious, and useful in coughs and as antidote to certain poisions. The Gutti Koya tribals use the bottle gourd as a cure for headache (external application) by mixing the seed oil with castor oil. The Koya community uses the fruits of the wild types for medicinal purposes (purgatives). Probably, the bitter principle found in the wild bottle gourds is responsible for the purgative property. Leaf juice is widely used for baldness. Topical application of a mixture of *L. sciceraria* juice and sesame oil on scalp gives beneficial results in baldness (hair loss). In Curacao, a leaf decoction is taken for flatulence. Decoctions containing a combination of *L. siceraria* and *Rivina humilis* are given for gas in pregnancy. Incombination with garlic, a decoction is taken for gas pain in the heart area. Leaves with salt or coconut oil are often used as poultices for mange, skin irritation and tumours. A poultice of the crushed leaves has been applied to the head to treat headaches. Taken with *Achyranthes* spp., the seed is used to treat aching teeth and gums, boils, etc. Pulverized seed kernels are taken to expel intestinal worms. The traditional use of seeds of *L. siceraria* as an anthelmintic is further supported by experiments. Mucilage from *L. siceraria* fruit is used as a binding, thickening, emulsifying, suspending and stabilizing agent in cosmetics, food and pharmaceutical industries. Seeds are also used in dropsy, worm infection and as nutritive. Ripe seeds are having a 45% yield of clear limbid oil which have cooling effect and can be applied in migraine type headache.

### *Bioactive Components*

The fruit is reported to contain the triterepeniod (Cucurbitacins B, D, G, H and 22-deoxy cucurbitacin, the bitter principle of cucurbitaceae), sterols (fucosterol and campesterol), terpene (bryonolic acid, an allergic compound), flavone-C glycosides, a ribosome inactivating protein and lagenin (Table 9.11) (Aman & Ramchandran, 2009). It also contains a high level of choline (a lipotropic factor), which is required for brain function. The fruit was reported to have higher amount of soluble dietary fibres than insoluble fibres. Pectin was found as the predominant component of soluble dietary fibres which showed a profound effect in lowering serum cholesterol. Aliphatic aldehydes such as octanal, nonanal and decanal with fruity, floral and citrus odours dominated the volatile profile of bottle gourd. Additionally, glycosidic precursors of bottle gourd including 1,4-benzenediol, 2-pentadecyn-1-ol, 9,12-octadecadienal and fatty acids such as palmitic acid and stearic acid that dominated the volatile aroma profile may also contribute to the fatty odour of the vegetable. This constituted the first report of bound aroma precursors being present in the fruit.

**Table 9.11.** Different classes of compounds in *L. sciceraria*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Volatiles | Octanal, nonanal; decanal | (Chatterjee et al., 2009) |
| Phenolic | Protocatechuic acid; gallic acid; caffeic acid; 3,4-dimethoxy cinnamic acid; (E)-4-hydroxymethyl-phenyl-6-O-caffeoyl-β-D-glucopyranoside; di-caffeoylquinic acid derivatives | (Mohan et al., 2012a; Calabrese et al., 1999) |
| Flavonoid / 4-C-glycosylflavone | Isoquercitrin; kaempferol; vitexin; orientin; isoorientin; 7-O-glucosyl-6-C-glucoside apigenin; 6-C-glucoside apigenin; saponarin | (Gangwal et al., 2009, 2010; Mali et al., 2012; Mirlosawa & Cisowski 1995; Krauze-Baranowska & Cisowski, 1994) |
| Ellagitannin | Ellagitannins | (Deshpande et al., 2007) |
| Sterol | Oleanolic acid; β-sitosterol; campesterol; fucosterol; campesterol | (Gangwal et al., 2009, 2010; Shirwaikar & Sreenivasan, 1996) |
| Triterpene | 3-β-O-(E)-feruloyl-D:C-friedooleana-7,9(11)-dien-29-ol; 3-epikarounidiol; 3-oxo-D:C-friedoolena-7,9(11)-dien-29-oic acid; bryonolol; bryononic acid; 20-epibryonolic acid; bryonolic acid | (Chen et al., 2008b; Gangwal et al., 2009, 2010; Tabata et al., 1993) |
| Cucurbitacin | 22-Deoxocurcubitacin; 22-deoxoisocurcubitacin; cucurbitacins B, D, G and H | (Enslin et al., 1956; Sturm & Stuppner, 2000) |
| Polysaccharide / mucilage / dietary fibre | Methyl-D-galacturonate; 3-O-acetyl methyl-α-D-galacturonate; pectin | (Ghosh et al., 2008, 2009; Shah et al., 2010; Chang, 1998) |
| Enzyme / protein | Ascorbate oxidase; elaterase; ribosome-inactivating protein; lagenin | (Chauhan et al., 2010; Enslin et al., 1956; Shirsat & Kadam, 2015; Kumari et al., 2015; Wang & Ng, 2000; Ogunbusola et al., 2010; Teugwa et al., 2013) |

## *Pharmacological Properties*

**Antihyperglycemic:** Hyperglycemia was induced by STZ in rats. Methanolic extract of *L. sciceraria* aerial parts was administered to evaluate the antihyperglycemic activity. Significant reduction in fasting blood glucose levels was observed with treatment duration. Antioxidant (lipid peroxide, catalase and glutathione) and biochemical parameters (SGPT, SGOT, ALP, total cholesterol and triglycerides) were significantly improved (Saha et al., 2011b). *L. sciceraria* pulp extract and seed extract treatment exerts therapeutic protective effect in diabetes by preserving pancreatic cell integrity and significant activity extract against the pancreatic damage from alloxan-induced diabetes in

rats (Bhattacharya & Das, 2012) *L. siceraria* induced significant reduction in blood glucose and increasing of serum insulin.

To evaluate the neutraceutical potential of bottle gourd juice in the management of human diabetes and associated dyslipidemia, freshly prepared bottle gourd juice was given to human participants with an empty stomach. Biochemical markers of carbohydrate and lipid metabolism plus kidney and liver functions were monitored at monthly intervals during the course of bottle gourd juice administration. A notable reduction in blood glucose level, total cholesterol, serum triglycerides, LDL cholesterol and VLDL cholesterol were observed. Significant elevations in superoxide dismutase, catalase activities and glutathione levels were also observed indicating that *L. siceraria* juice may be used as an alternative treatment in disorders associated with carbohydrate and lipid metabolism in human diabetes and associated dyslipidemia (Katare et al., 2013; Shah et al. , 2011).

The evaluation of hypoglycaemic property of globulins extracted from *L. sciceraria* was performed on male Wistar rats by the OGTT. Globulins possess significant anti-hyperglycaemic activity (Teugwa et al., 2013).

**Antihyperlipidemic:** The antihyperlipidemic effect of different extracts from bottle gourd in triton-induced hyperlipidemic rats was examined. Oral administration of the extracts in rats dose-dependently inhibited the total cholesterol, triglycerides, LDL level, and significantly increased the HDL level (Ghule et al., 2006b; Mohale et al., 2008). In another study, methanolic extract of *L. siceraria* fruits was administered to the high fat-diet-induced hyperlipidemic rats to evaluate its antihyperlipidemic activity. The results obtained suggest marked antihyperlipidemic of *L. sciceraria* fruit extracts (Ghule et al., 2009).

Rats were fed with high cholesterol atherogenic diet and in addition supplemented with ethanolic extract of fruits of *L. siceraria.* The blood samples were evaluated for serum lipid profile, and atherosclerotic lesion area was measured in cross-sections of the aortic root. Treatment of rats with ethanolic extract of fruits of *L. siceraria* significantly lowers the risk of atherosclerosis by lowering percentage plaque area in aorta. It also lowers serum cholesterol, triglyceride, LDL cholesterol, VLDL cholesterol and increased HDL cholesterol levels. The extract also induced lipoprotein lipase activity and significantly decreased cholesterogenesis in liver by reducing HMG-CoA reductase activity in hypercholeaterolemic rats. Thus ethanolic extract of fruits of *L. siceraria* ameliorates the atheromatous lesions in rat aorta and lowers the risk of atherosclerosis in hypercholesterolemic rats (Rajput et al., 2014).

Effects of semi-purified dietaray fibers, isolated from *L. siceraria*, on faecal steroid excretion in rats were examined. In the absence of cholesterol, faecal excretions of several secondary bile acids and total bile acids were affected by the type of dietary fibres. The lithocholic acid (LCA)/deoxycholic acid (DCA) ratio was significantly lowered in the test dietary fibre groups (Chang, 1998; Sannoumaru et al., 1996).

**Cardioprotective:** *L. siceraria* possessed cardioprotective effect against doxorubicin-induced cardiotoxicity in rats. Male Wistar rats were randomly divided into three groups according to different diet (i.e. gum acacia 2%, doxorubicin and doxorubicin + *L. sciceraria*). When blood samples were analyzed, significant decrease in serum CK-MB,

AST and LDH were observed. There was significant increase in the level of glutathione and nonsignificant increase in SOD, whereas lipid peroxidation was inhibited. Further histopathological study showed protection against myocardial toxicity induced by doxorubicin (Deshpande et al., 2008; Fard et al., 2008; Singh et al., 2012a).

The cardioprotective activity of *L. siceraria* fruit powder in isoprenalin-induced cardiotoxicity in rats were evaluated. In *L. sciceraria* pretreated rats, isoprenalin neither increased heart rate nor produced the hypotensive effect. Further the histopathology of the heart showed lower myocardial damage in *L. sciceraria* and isoprenalin pretreated rats (Mali & Bodhankar, 2010; Upaganlawar & Balaraman, 2011; Vijayakumar et al., 2010). Pretreatment with *L. siceraria* fruits significantly elevated activities of cardiac mitochondrial enzymes and significantly lowered the activities of lysosomal enzymes in heart tissues of isoprenalin-induced rats.

**Enzymatic activity:** An ascorbate oxidase, purified from *L. siceraria* fruit, was immobilized onto egg shell membrane. The membrane consisting of ascorbate oxidase was mounted over an Au electrode to construct a working electrode for ascorbate biosensor (Chauhan et al., 2010). Lagenin, a novel ribosome-inactivating protein with ribonucleolytic activity from bottle gourd seeds were isolated (Koffi et al., 2010; Shirsat & Kadam, 2015; Wang & Ng, 2000).

**Antioxidant:** Free radical scavenging activity of *L. siceraria* fruit were determined by DPPH assay. The maximum antioxidant activity was observed in the acetone extract of fruit epicarp (Deshpande et al., 2007; Erasto & Mbwambo, 2009; Kalpna et al., 2011). Chemical investigation revealed that radical scavenging activity may be due to the presence of ellagitannins present in the acetone extract of epicarp (Antia et al., 2015). The antioxidant activities of of fruits of *L. siceraria* were also determined by reducing power ability, hydrogen peroxide scavenging assay, ABTS, FRAP, iron chelating ability, β-carotene bleaching assay and thiocyanate method. It has shown effective antioxidant activity in all the assay techniques (Agrawal et al., 2015; Bor et al., 2006; Chanda et al., 2015; Deore et al., 2009; Deshpande et al., 2008; Jiwajinda et al., 2002; Mayakrishnan et al., 2013; Sharma et al., 2012a; Sharma et al., 2013). Phenolic glycoside isolated from *L. sciceraria* were tested in different in vitro assay systems such as free radical scavenging assay, MTT reduction assay, superoxide scavenging activity, reducing power assay and linoleic acid peroxidation assay. It showed promising antioxidant activity (Mohan et al., 2012a; Singh et al., 2012b).

**Antihypertensive:** N(G)-Nitro-L-arginine methyl ester (L-NAME) was induced for hypertension in rats. L-NAME causes increase in systolic blood pressure, elevates cholesterol and inflammation, and develops necrosis in heart. On treatment with *L. sciceraria* extract, all these parameters were reduced showing its antihypertensive effect. Antioxidant activity of orientin and isoorientin appears to reduce the L-NAME induced damage (Mali et al., 2012).

**Antimicrobial:** The antimicrobial activity of the extracts of the leaves, seeds and fruit-flesh of *L. siceraria* were determined by agar-well diffusion method. The study revealed that the extracts have activity against *S. aureus*, *P. aeruginosa* and *S. pyogenes* (Sood et al., 2012). Dietary cucurbits (like *L. sciceraria*) showed appreciable antioxidant activity

and enhance antimicrobial and barrier function of mucosa by *Lactobacillus rhamnosus* and impart protection to gut without any toxic effects. When antimicrobial activity of *L. rhamnosus* measured through generation of inhibition zone against *E. coli*, it was amplified maximally in presence of *L. sciceraria*. So, *L. sciceraria* has therapeutic prebiotic potential to ameliorate such threat from pathogens in gastro-intestinal tract (Menpara et al., 2014; Sharma et al., 2012a). The silver nano particles synthesized by using *L. Sciceraria* also exhibited antimicrobial property against different strains of microorganisms like *K. pneumoniae*, *E. coli*, *S. aureus* and *Clostridium acetobutilicum* bacteria (Anandh et al., 2014; Nalwade et al., 2013). The methanolic and ethyl acetate extracts of the fruit pedicle also showed potency against *Achromobacter xylosoxidans*, *P. aeruginosa*, *Citrobacter freundii*, *Bacillus megaterium*, *Stenotrophomonas maltophilia*, *K. pneumoniae*, *Enterobacter cloacae,* and *Enterobacter aerogenes* (Ahmed & Ashiq, 2018; Goji et al., 2007; Kumar et al., 2014).

**Antihelmintic:** The antihelmintic efficacy of *L. sciceraria* against *Hymenolepis nana* (tapeworm) and *Aspicularis tetraptera* (pinworm) infections in mice was evaluated utilizing piperazine citrate as a reference substance (Elisha et al., 1987). The ethanolic extracts of the seeds of *L. siceraria* exhibited a potent activity against tapeworm. Anthelmintic potential of crude extracts of seeds of *L. siceraria* using *P. posthuma* as test worm was evaluated. Methanol and benzene extracts significantly demonstrated paralysis, and also caused death of worms (Kumar & Pratap, 2012; Thube et al., 2009).

**Hepatoprotective:** The antihepatotoxic activity of different fractions of the ethanolic extract of *L. siceraria* fruit, administered orally to different groups of rats was evaluated using the $CCl_4$-induced hepatotoxicity test and showed significant activity (Shirwaikar & Sreenivasan, 1996). Petroleum ether and ethanol extracts were evaluated for their hepatoprotective and antioxidant activities against paracetamol-induced hepatotoxicity. Both extracts exhibited a significant hepatoprotective effect (Panchal et al., 2013). Hepatoprotective effect of *L. siceraria* in carbamazepine-induced hepatotoxicity in rabbits was studied. Blood samples were analyzed for liver enzymes and total proteins in animals of different groups administered with various diets. Histopathological study was also performed on liver specimen collected from animals to see morphological and pathological changes in the tissue. *L. siceraria* fruit extract significantly reduced liver enzymes, SGPT, ALP, γ-glutamyltransferase (γ-GT) and total proteins. Results of liver tissue histology did not show necrosis and cholestasis. Hepatoprotective potential of *L. siceraria* suggested its use to prevent elevation of hepatic enzymes due to long term administration of carbamazepine (Owais & Mehjabeen, 2018).

**Lung protection:** The effect of *L. siceraria* on acute lung injury, induced by oleic acid in rats, was studied. Oleic acid has been administered intravenously to induce acute lung injury in experimental studies. Levels of protein carbonyl, malondialdehyde, superoxide dismutase, catalase and glutathione peroxidase levels were measured in tissue samples. Levels of TNF-α, IL-10, IL-6 and total tissue oxidant status and total tissue antioxidant status were measured in serum samples. *L. sciceraria* decreased the total lung injury score, decreased the thickness of the fused basal lamina and TNF-α, IL-6 in serum and MDA in tissue were higher (Yetisir et al., 2012).

**Anticancer:** The effects of dietary fiber of *L. scineraria* on colonic carcinogenesis in mice were examined. Mice were given intraperitoneal injection of 1,2-dimethylhydrazine to induce carcinogenesis and were fed with diet containing *Lagenaria* powder. Dietary fiber from *L. sciceraria* suppressed 1,2-dimethylhydrazine (DMH)-induced colonic carcinogenesis in mice by lowering the bile acid concentration and pH in the colon (Furukawa et al., 1995; Wynder & Reddy, 1977). Anticancer activity of the methanolic extract of *L. siceraria* aerial parts was evaluated on Ehrlich's ascites carcinoma (EAC) model in mice (Saha et al., 2011a). Evaluation of the effect of drug response was made by the study of tumour growth response and the studies of hematological parameters, biochemical estimations and antioxidant assays of liver tissue. Experimental results revealed that *L. siceraria* possesses significant anticancer activity. In an experiment to study to evaluate antimutagenic activity in TA98 and TA100 strains of *S. typhimurium* using direct (sodium azide) acting mutagens, the extract of plant exhibited varying level of antimutagenicity in the Ames test (Jalaram et al., 2013). It implies chemopreventive pharmacological importance of *L. siceraria* fruit.

**Cytotoxicity:** D:C-friedooleanane-type triterpenes, isolated from the methanolic extract of the stems, showed significant cytotoxic activity against SK-Hep 1 cell line. Polysaccharide showed cytotoxic activity in vitro against human breast adenocarcinoma cell line (MCF-7). n-Butanol and n-hexane extracts of *L. siceraria* fruit powder shows the promising cytotoxicity against brine shrimp (Ghosh et al., 2009; Killedar et al., 2012; Sen et al., 2013).

**Immunomodulatory:** n-Butanol and ethyl acetate soluble fractions of successive methanolic extract of *L. siceraria* possess promising immunomodulatory activity. Oral administration of the fractions significantly inhibited delayed type hypersensitivity reaction in rats. A dose-dependent increase in both primary and secondary antibody titres was observed. Fractions also significantly increased the WBC and lymphocyte count (Gangwal et al., 2008).

*L. sciceraria* extract was evaluated for its possible immunomodulatory activity in rats using different immunomodulatory protocols such as haemagglutination antibody titre, carbon clearance and cyclophosphamide-induced myelosuppression. The extract was found to increase antibody titre significantly. It also enhanced rate of carbon clearance from animal's blood indicating increased phagocytosis. A significant increase in WBC count was observed in methanol extract-treated rats as compared to cyclophosphamide treatment alone. Futher oleanolic acid and isoquercitrin, isolated from *L. sciceraria*, augment humoral immune response, suppress cellular immune response and activate macrophage-induced phagocytosis (Gangwal et al., 2009; Sankari et al., 2010).

**Anti-inflammatory/analgesic:** Ethanolic extract of *L. siceraria* seeds possess good therapeutic potential in the treatment of inflammation and pain when experiment was performed for anti-inflammatory activity by carrageenan-induced rat paw edema and analgesic activity by the Tail immersion and Hot plate methods. Analgesic potential of ethanolic extract of *L. siceraria* root by tail flick method in albino mice was also evaluated (Ghule et al., 2006a; Gill et al., 2012b; Manasa & Dayana, 2019).

**Antidiuretic:** Different parameters viz. total urine volume, urine concentration of electrolytes such as sodium, potassium and chloride have been evaluated for its diuretic activity in albino rats. The rats treated with vacuum dried *L. siceraria* juice extract and *L. siceraria* methanol extract showed higher urine volume. Both the extracts have exhibited dose-dependent increase in the excretion of electrolytes (Ghule et al., 2007; Jayasree et al., 2014).

**Adaptogenic/antistress:** *L. siceraria* possess antistress and adaptogenic properties. Pretreatment with the extract at different doses significantly ameliorated the stress-induced variations in thess biochemical parameters - serum glucose, triglyceride, cholesterol, blood urea nitrogen (BUN) and cortisol levels, blood cell counts, and organ weights in these stress models. The extract treated animals also showed increase in swimming endurance time (Lakshmi & Sudhakar, 2009). Antidepressant activity of the methanolic extract of *L. siceraria* fruits was studied using forced swim (behaviour despair) models (Prajapati et al., 2011). The extract showed dose-dependent significant reduction in duration of immobility.

**Hyperthyroidism:** The potential of *L. siceraria* peel extract in the regulation of lipid peroxidation, hyperthyroidism and hyperglycemia have been evaluated in mice. The antithyroidal, antiperoxidative and glucose inhibitory potential of the peel extract were tested in T4 induced hyperthyroid animals. A decrease in the concentrations of serum thyroid hormones, glucose as well as in hepatic lipid peroxidation with a parallel increase in antioxidants such as superoxide dismutase, catalase and glutathione indicated the efficacy of the test peel in the amelioration of hyperthyroidism, hyperglycemia and hepatic lipid peroxidation (Dixit et al., 2008).

## 11. *Trichosanthus cucumerina*

Fruits are very slender, long and cylindrical berry, often twisted, greenish-white when immature, dark red when mature (Figure 9.1k). Two varieties are distinguished within *T. cucumerina*; wild var. *cucumerina* and cultivated var. *anguina.* The young fruit is cooked as a vegetable often in curries. The leafy tendril shoots and leaves are also consumed as greens after cooking.

The extract from the snake gourd leaves is quite effective in dealing with the treatment of hair and scalp disorders like alopecia, which usually leads to partial and sometimes even complete hair loss. For this specific treatment, you need to apply the juice topically to the affected area (Devi, 2017).

It is one among the constituents in various Ayurvedic formulations used for the treatment of liver disorders.

### *Bioactive Components*

The chemical constituents present in *T. cucumerina* are cucurbitacins (cucurbitacin B, cucurbitacin E, isocucurbitacin B, 23,24-dihydroisocucurbitacin B, 23,24-dihydrocucurbitacin E), sterols (β-sitosterol, stigmasterol), hydrocarbon derivatives and isoflavone glycosides (Table 9.12) (Sandhya et al., 2010). The seeds of the plant *T. anguina* contain a type I ribosome-inactivating protein, designated trichoanguin and galactose-specific lectin.

**Table 9.12.** Different classes of compounds in *T. cucumerina*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Triterpene / cucurbitacin | 23,24-Dihydrocucurbitacin D; cucurbitacin B; cucurbitacin E; isocucurbitacin B; α-amyrin; bryonolic acid; bryononic acid | (Jiratchariyakul & Frahm, 1992; Buaprom, 2006; Chandra & Sastry, 1990; Kongtun et al., 2009; Kummalue et al., 2009; Devendra et al., 2012) |
| Sterol | β-Sitosterol; stigmasterol; luteolin-7-glucoside | (Buaprom, 2006; Chandra & Sastry, 1990) |
| Isoflavone glycoside | 5,6,6'-Trimethoxy-3',4'-methylenedioxyisoflavone 7-O-β-D-(2"-O-p-coumaroylglucopyranoside | (Yadava & Syeda, 1994) |
| Protein | Galactose-specific lectin; isolectins; ribosome-inactivating protein; trichoanguina | (Komath et al., 1996, 1998, 2000, 2001; Chow et al., 1996, 1999; Komath & Swamy, 1998; Kenoth & Swamy, 2003; Anuradha & Bhide, 1999; Padma et al., 1998; Kenoth et al., 2000, 2003; Azeez & Morakinyo, 2004; Kabir et al., 2012) |
| Long chain hydrocarbon derivatives | Hentriacontane; ceryl alcohol | (Chandra & Sastry, 1990) |
| Fatty acid | Free fatty acids | (Ekam, 2003) |
| Carotenoid | α-Carotene; β-carotene | (Adebooye, 2008) |

## *Pharmacological Properties*

**Hair growth promoting:** The leaves of *T. cucumerina* are a potent hair growth promoter which supports the traditional claim (Sandhya et al., 2012a). It was observed that the hair growth completion, length of hair, percentage of hair follicles and diameter of bald patch and concentration of minerals in the blood for the test animals applied was comparable with that of the animals treated with minoxidil. Polyherbal phyto-complex hair growth promoting cream incorporated with aqueous extracts of *T. cucumerina* and *Abrus precatorius* was formulated for enhancing the hair growth. The preclinical studies showed that the formulated polyherbal phyto-complex hair growth promoting cream was an effective hair growth promoter and percentage of hair follicles in the anagen phase increased (Sandhya et al., 2012b). The formulation has also been developed by using *Reetha*, *Shika kai* and snake gourd to enhance anti-dandruff activity (Vishal & Prashant, 2014).

**Antioxidant:** *T. cucumerina* aerial parts can exert significant antioxidant activity in vivo and in vitro (Adebooye, 2008; Ademosun, 2013; Badejo et al., 2016; Liyanage et al., 2016; Stellus & Nair, 2015). Treatment with a hot water extract and a cold ethanolic extract of *T. cucumerina* aerial parts prevented the accumulation of lipid peroxidation products in liver tissues. In vitro antioxidant assays (DPPH, thiobarbituric acid reactive substances (TBARS)) and carotene-linoleic acid assays) also demonstrated its antioxidant potential (Arawwawala et al., 2011). Juice blend made from the mixture of snake gourd

and pineapple (*Ananas comosus*) fruits has been used to make a healthy juice blend. The addition of snake gourd juice increased the antioxidant property of the juice blends (Bamidele & Fasogbon, 2017).

**Hypolipidemic:** The effects of the hot water extract of *T. cucumerina* aerial parts on lipid profile of STZ-induced diabetic rats were investigated. There was a significant decrease in total cholesterol, LDL and triglycerides levels, and a significant increase in HDL (Arawwawala et al., 2012). In another study, high-fat diet-mediated elevation in the levels of conjugated dienes, lipid hydroperoxides, malondialdehyde, protein carbonyl and DNA fragmentation in rat liver was dose-dependently lowered by the extract of *T. cucumerina* (Ajiboye et al., 2014).

**Nephroprotective:** Nephrotoxicity was induced in male Wistar rats by administration of cisplatin. Nephroprotective activity was assessed by estimating serum markers and urinary functional parameters supported by antioxidant studies and histopathological aspects. Increased levels of serum markers and urinary functional parameters were reversed by the extract in dose-dependent manner. It provided the scientific evidence for the use of seeds of *T. cucumerina* in nephrotoxicity (Prasanthi & Adikay, 2017).

The potential of aqueous extract of *T. cucumerina* in preventing renal abnormalities in diabetic rabbits was investigated. Oral administration of aqueous extract of *T. cucumerina* caused adverse effects showing the preventive role in renal abnormalities. Urine urea, creatinine, glucose level, serum urea, creatinine, urea and creatinine clearance were determined. Diabetes significantly reduces body weight gain and kidney weight, urine urea and creatinine level, and creatinine clearance increases. Oral administration of the aqueous extract of *T. cucumerina* reduces these diabetic adverse effects (Adeeyo et al., 2011).

**Antidiabetic/hypoglycaemic:** Aqueous extract of *T. cucumerina* significantly decreased the elevated blood glucose of NIDDM induced rats, induced by administering STZ (Kirana & Srinivasan, 2008). Glycogen content of insulin dependent tissues such as liver and skeletal muscle was found to be improved. Studies revealed that *T. cucumerina* possess antidiabetic activity. Further in normoglycemic rats, hot water extract mediated a dose-dependent reduction in fasting blood glucose levels and a significant improvement of glucose tolerance (Arawwawala et al., 2009). The stronger inhibition of α-glucosidase and α-amylase activities also showed its potential effect in diabetes (Ademosun, 2013). Comparative hypoglycaemic activity of Indian medicinal plants in alloxan diabetic rats was evaluated. *T. cucumerina* possess blood glucose lowering effect (Kar et al., 2003).

**Hepatoprotective:** The methanolic extract of whole plant of *T. cucumerina* was evaluated for the hepatoprotective activity against $CCl_4$-induced hepatotoxicity in rats. The levels of serum total and conjugated bilirubin as well as AST, ALT and ALP, glutathione and malondialdehyde activities were determined to study hepatoprotective property of *T. anguina*. The extract shown decreased necrotic zones and hepatocellular degeneration in histopathological study (Kumar et al., 2009; Ojiako & Igwe, 2008). This study demonstrates the hepatoprotective activity of *T. cucumerina* and thus scientifically supports the usage of this plant in various Ayurvedic preparations and traditional medicine for the treatment of liver disorders.

**Cardioprotective:** Methanolic extract of fruit of *T. cucumerina* in doxorubicin-induced cardiotoxicity in rats was examined. The methanol extract of *T. cucumerina* significantly decreased LDH and CK-MB, reduced ST, QT interval and QRS complex, increased heart rate, restored blood pressure and left ventricular function (Shah et al., 2012).

**Anti-inflammatory/analgesic:** The effect of hot aqueous extract of root and tubers of *T. cucumerina* exhibited significant anti-inflammatory activity against carrageenan-induced mouse's hind paw edema (Arawwawala et al., 2010b; Kolte et al., 1996). Inhibition of nitric oxide (NO) production and membrane stabilization activities are probable mechanisms by which *T. cucumerina* mediates its anti-inflammatory actions. Ethanolic extract showed potential analgesic activity by Eddy's hot plate method (Gill et al., 2012a).

**Anticancer/cytotoxicity:** The root extract of *T. cucumerina* and bryonolic acid as well as the fruit juice and Cucurbitacin B were tested for cytotoxicity against four human breast cancer cell lines (SKBR3, MCF7, T47D and MDA-MB435), two lung cancer cell lines (A549 and SK-LU1), and one colon cancer cell line (Caco-2). The root extract had higher inhibition activity than bryonolic, and the fruit juice had higher inhibition activity than Cucurbitacin B, which were isolated from the root extract (Kongtun et al., 2009).

The inhibition of proliferation of Cucurbitacin B on human lung cancer cell lines (LK87 and QG95), human colon adenocarcinoma cell lines (HCT15 and HT29), renal cancer cell line (A498) and pancreatic cancer cell line (NOR-P) was observed in a dose-dependent manner (Kongtun et al., 1999; Kummalue et al., 2009). The viability of cells was assessed by using WST-8, which is based on detection of LDH released from damaged cells that reacts with WST-8 to form a yellow colour. This study showed direct toxic effect of Cucurbitacin B to these cell lines.

Cucurbitacin B inhibits growth and telomerase activity in the three breast cancer cell lines (T47D, SKBR-3 and MCF-7) and a mammary epithelium cell line (HBL-100) (Duangmano et al., 2010). It exerts an obvious inhibitory effect in the estrogen receptor-negative breast cancer SKBR-3 cells. The expression of human telomerase reverse transcriptase and c-Myc protein were also inhibited by Cucurbitacin B. Thus Cucurbitacin B exerts an anticancer effect by inhibiting telomerase via down regulating both the hTERT and c-Myc expression in breast cancer cells.

A lectin was purified from the snake guard seeds. The lectin showed inhibition against Ehrlich ascites carcinoma (EAC) cells in vivo in mice thus possess antitumour activity. The lectin reduced the tumour burden of EAC cells and significantly increased the hemoglobin and RBC. It enhanced the number of macrophages remarkably in the normal mice (Kabir et al., 2012).

**Gastroprotective:** *T. cucumerina* exerts a significant protection against ethanol or indomethacin-induced gastric damage (Arawwawala et al., 2010a). *T. cucumerina* possesses significant and dose-dependent gastroprotective effect in terms of the length and number of gastric lesions mediated in the alcohol and indomethacine model. The hot water extract significantly increased the amount of mucus produced by the rat gastro mucosa and reduced the gastric acidity.

**Antiulcer:** Oral administration of ethanolic extract of fruits of *T. cucumerina* was evaluated in rats against ethanol, aspirin and pylorus ligated gastric ulcers as well as cysteamine-induced duodenal ulcers (Galani et al., 2010). The extract showed significant antiulcer activity in ethanol-induced and aspirin-induced gastric ulcer models as well as cysteamine-induced duodenal ulcers. Significant reduction in ulcer index, total acidity and pepsin activity was observed. Mucosal defensive factors such as pH, mucin activity and gastric wall mucous content was found to be increased. In another study, ethanolic extract of *T. cucumerina* causes inhibition of ulcer in non steroidal anti-inflammatory drugs induced model and ethanol induced model.

**Larvicidal:** Extracts of *T. anguina* were tested against the late third larval age group of *Culex quinquefasciatus* (Prabakar & Jebanesan, 2004). The larval mortality was observed after 24 hr of exposure. In another study, extracts showed moderate larvicidal effects against the early fourth instar larvae of *Aedes aegypti*. This is an ideal eco-friendly approach for the control of the dengue vector, *A. aegypti*, and the lymphatic filariasis vector, *C. quinquefasciatus* (Rahuman & Venkatesan, 2008).

**Antifertility/prostatic hyperplasia:** Ethanolic extract of whole plant of *T. cucumerina* showed antiovulatory activity in adult rats. The ethanolic extract given orally affected the normal estrous cycle showing a significant increase in estrus and metestrus phases, and decrease in diestras and proestrus phases (Kage et al., 2009). The extract also significantly reduced the number of healthy follicles and corpora lutea, and increased the number of regressing follicles. The protein and glycogen contents in the ovaries were reduced and cholesterol level was increased. The methanolic extract of *T. Cucumerina* seed has also effect on experimentally increased prostate specific antigen in adult Wistar rats (Akinsola et al., 2012a; Akinyemi et al., 2012).

**Hormone-influenced seminal vesicle weight:** The effect caused by the methanolic extract of *T. cucumerina* on hormone influenced seminal vesicle weight in adult Wistar rats was determined. The seminal vesicle weight increase was achieved by the simultaneous induction of estradiol and testosterone (Akinsola et al., 2012b). To appreciate the weight increase of seminal vesicle, the extract treated group was compared with other control group. The experimentally induced enlargement was able to be reversed back to normal due to the effect of the methanolic extracts of *T. cucumerina* seed.

**Agglutination:** The agglutination activity of *T. cucumerina* seed lectin was studied (Kenoth et al., 2003; Komath et al., 1998, 2000, 2001). The galactose-specific lectin present in the seeds of snake gourd has been further characterized. The interaction of several free-base porphyrins and their corresponding copper(II) and zinc(II) derivatives with the galactose-specific lectin from snake gourd seeds has been investigated by absorption and fluorescence spectroscopic techniques.

**Antibacterial:** The antibacterial activities of various extracts of the leaves of *T. cucumerina* were screened against various pathogenic bacteria such as *B. cereus*, *Enterobacter faecalis*, *Salmonella paratyphi*, *S. aureus*, *E. coli*, *Streptococcus faecalis*, *P. vulgaris*, *K. pneumoniae*, *P. aeruginosa* and *S. marcescens* by the Agar well diffusion method and exhibited pronounced activity against these organisms (Reddy et al., 2010; Soladoye & Adebisi, 2004).

**Antihelminthic:** *T. cucumerina* produced a potent anthelmintic activity against the *P. posthuma* (Murthy et al., 2012).

**Diuretic:** The methanolic extract exhibited significant diuretic activity as evidenced by increased total urine volume and the urine concentration of $Na^+$, $K^+$ and $Cl^-$ (Murthy et al., 2012).

## 12. *Momordica charantia*

*M. charantia* also known as bitter melon, is a monoecious climber or scrambling harbaceous vine. The fruit is oblong shaped with a distinct warty exterior (Figure 9.1l). The cross sections show hollow interior with a thin layer of flesh covering a central seed cavity contained large, flat seeds and pith. *M. charantia* shoots, leaves and fruits are often consumed as vegetables for cooking, while fruit extracts are also utilized in tea preparations. Fruit is eaten when it is green or just starts turning yellow in colour. All parts of *M. charantia* are bitter, especially ripened fruit.

The bitter gourd tea, which is known as *Gohyah* or herbal tea made from dried slices, is applied mainly for medicinal purposes (Thent et al., 2018). In Indian medicinal systems, *M. charantia* is reported to possess antidiabetic, abortifacient, antihelminthic, antimalarial and laxative properties, while it is also used for the treatment of dysmenorrhea, emmenagogue, eczema, gout, galactagogue, kidney stone, jaundice, leucorrhea, leprosy, pneumonia, piles, rheumatism and psoriasis (Abascal & Yarnell, 2005; Chaturvedi, 2012; Efird et al., 2014; Fang & Ng, 2011; Joseph & Jini, 2013; Krawinkel & Keding, 2006; Singh et al., 2011; Wang et al., 2017; Yin et al., 2014). It is applied externally for wound healing and treatment of peptic ulcers in traditional Turkish medicine (Grover & Yadav, 2004).

### *Bioactive Components*

The major chemical constituents are tetracyclic triterpenoids and their glycosides, most of which are referred to as cucurbitanes, and are well-known for their bitterness and toxicity (Table 9.13). The bitter component consists of cucurbitane glycosides such as Momordicoside K, Momordicoside L, Momordicine I, and Momordicine II. *M. charantia* mainly contains two classes of saponins known as cucurbitane- and oleanane-type triterpenoids. More than 50 cucurbitane-type triterpenoids have been isolated from *M. charantia* (Haque et al., 2011; Lee et al., 2009). The pulp around the seeds of the mature ripe fruit is a rich source of the carotenoid, lycopene. Lutein and carotene were the major pigments of the immature fruit. Later, cryptoxanthin become the principal pigment of the ripe fruit which accumulated rapidly at the onset of ripening (Rodriguez et al., 1976). Many types of proteins and peptides have been isolated from different parts of *M. charantia*, such as ribosome inactivating proteins, lectin, Momorcharin, MAP30, MC1, polypeptide-P, peroxidase, cyclic peptides, trypsin inhibitors and cystine knot peptides. Polysaccharides present in *M. charantia* are classified as heteropolysaccharide and are composed of galactose, glucose, arabinose, rhamnose and mannose. Properties of *M. charantia* polysaccharides have a great relationship with molecular weight, purity, monosaccharide compositions and ratios of the monosaccharide compositions. Other

important components of *M. charantia* are flavonoids and phenolic compounds. The most abundant flavonoids were quinic acid and catechin. Eleostearic acid is a conjugated linolenic acid that makes up approximately 60% of bitter melon seed oil.

**Table 9.13.** Different classes of compounds in *M. charantia*

| Class of compounds | Some representative compounds | References |
|---|---|---|
| Protein/peptide | Ribosome inactivating proteins; charantin; insulin receptor-binding protein; peroxidise; RNase MC2; lectin-galactose-specific glycoprotein; polypeptide-p; guanylate cyclase inhibitor; MAP 30; α-momorcharin; β-momorcharin; acidic amino acid-specific endopeptidases; momordin; trypsin inhibitor MCTI-II' and BGI; elastase inhibitors; MRK20; MCha-Pr; BG-4 | (Puri et al., 2009; Parkash et al., 2002b; Lo et al., 2016; Fatima & Husain, 2008; Fang et al., 2012c, 2012d; Huang et al., 2008; Khanna et al., 1981; Vesely et al., 1977; Licastro et al., 1980; Lee-Huang et al., 1990; Tsao et al., 1990; Ogata et al., 1991; Chan et al., 1992; Porro et al., 1993; Husain et al., 1994; Hamato et al., 1995; Miura & Funatsu, 1995; Fong et al., 1996; Wang & Ng, 1998; Tse et al., 1999; Jiratchariyakul et al., 2001; Ou et al., 2003; Pitipanapong et al., 2007; Yuan et al., 2008; Tanaka et al., 2009; Patel et al., 2010; Ronny et al., 2010; Li et al., 2012b; Meng et al., 2014; Zhang et al., 2015a; Dia & Krishnan, 2016; Jabeen & Khanum, 2017; Lo et al., 2016) |
| Sterol | Acylglucosylsterols | (Agrawal & Tyagi, 2015; Wang et al., 2012a, 2012b; Lin et al., 2011; Guevara et al., 1989, 1990) |
| Pentacyclic triterpene / saponin / cucurbitane | Karavilagenins A, B, C, D and E; Karavilosides I-XI; Momordicosides A, B, C, F1, F2, G, I, K, L, M, N, O, P, U, V and W; Goyaglycosides-a, b, c, d,e,f, g and h; Goyasaponins I, II and III; Kuguaglycosides A–H; Kuguacins F–S; Kuguasaponins A–H; Charantosides I–VIII; pentanorcucurbitane triterpenes; Charantagenins A and E; Taiwacins A and B; Octanorcucurbitacins A–D; Momordicines I–III; momordicin; momordicinin; momordicilin; momordenol; momordol; momordin | (Raghavan, 2015; Lolitkar & Rao, 1966; Okabe et al., 1980, 1982; Miyahara et al., 1981; Xie et al., 1998; Murakami et al., 2001; Chang et al., 2004, 2006, 2008; Kimura et al., 2005; Nakamura et al., 2006; Li et al., 2007a, 2007b, 2016; Akihisa et al., 2007; Matsuda et al., 2007; Chen et al., 2008a, 2009, 2010; Liu et al., 2008, 2009, 2010; Nhiem et al., 2010a; Chang et al., 2010; Ma et al., 2010, 2014; Yasuda et al., 1984; Fatope et al., 1990; Begum et al., 1997; Lee et al., 1998, 2009; Choi et al., 2002; Xu & Dong, 2005; Harinantenaina et al., 2006; Mekuria et al., 2006; Kashiwagi et al., 2007; Tan et al., 2008; Ling et al., 2009; Cao et al., 2011; Hsu et al., 2011; Keller et al., 2011; Pitchakarn et al., 2011; Lin et al., 2011; Wang et al., 2012a, 2012b; Zhang et al., 2012, 2014, 2016; Cheng et al., 2012; Tabata et al., 2012; Hsiao et al., 2013; Zhao et al., 2014; Yen et al., 2014) |

| | | |
|---|---|---|
| Pyrimidine nucleoside | Vincine; mycose; Momorcharaside A and B | (Xie et al., 1998; Zhu et al., 1990) |
| Phenol / Flavonoid | Gallic acid; gentisic acid; catechin; chlorogenic acid; epicatechin; momordicatin; apigenin-7-O-glycoside; luteolin-7-O-glycoside; Monordicophenoide A | (Horax et al., 2005; Kenny et al., 2013; Chen et al., 2008b; Budrat & Shotipruk, 2008; Horax et al., 2010; Gupta et al., 2010; Güder, 2016; Li et al., 2009b; Huang et al., 2015) |
| Fatty oils | Eleostearic acid; 1-monopalmitin; conjugated octadecatrienoic fatty acid; 1-α-linolenoyl-lysophosphatidylcholine; 2-α- linolenoyl-lysophosphatidylcholine | (Grossmann et al., 2009; Yuwai et al., 1991; Suzuki et al., 2001; Konishi et al., 2004; Chuang et al., 2006; Pubali et al., 2007; Fu et al., 2009; Liu et al., 2010c; Xu et al., 2016; Kobori et al., 2008a; Habicht et al., 2011) |
| Carotenoid | Cryptoxanthin; β-carotene; zeaxanthin; lycopene; lutein | (Rodriguez et al., 1976; Hsu et al., 2012a) |
| Polysaccharide | Trehalose; MCP; D-chiro-inositol; water-soluble polysaccharides BP1 and BP2; pectic polysaccharide | (Tan & Gan, 2016; Matsuura et al., 2002; Gong et al., 2015; Xia & Wang, 2007; Li et al., 2010b; Guan, 2012; Deng, et al., 2014; Panda et al., 2015; Fan et al., 2015a; Liu et al., 2014; Xu et al., 2006) |
| Volatiles | Trans-nerolidol,apiole; cis-dihydrocarveol; Germacrene D | (Braca et al., 2008) |

## *Pharmacological Properties*

**Antidiabetic:** More than over 100 studies using modern techniques have authenticated use of *M. charantia* in diabetes and its complications (nephropathy, cataract, insulin resistance, etc.). It enhances insulin secretion by the islets of Langerhans, reduces glycogenesis in liver tissue, enhances peripheral glucose utilisation and increases serum protein levels, restores the altered histological architecture of the islets of Langerhans (Leung et al., 2009).

When karela juice was given to normal and diabetic rabbits by injecting alloxan, there was a slow and steady fall of blood sugar in both groups (Batran et al., 2006; Chandrasekar et al., 1989; Fernandes et al., 2007; Han et al., 2008; Jiang et al., 2016; Kar et al., 2003; Nkambo et al., 2013; Reyes et al., 2006; Sharma et al., 1960; Singh et al., 1989; Srivastava et al., 1993; Tripathi & Chandra, 2010; Welihinda et al., 1986; Xu et al., 2015). The hypoglycaemic property of *M. charantia* water extract was tested on alloxan diabetic rats and cyproheptadine-induced hyperglycaemic mice (Akhtar et al., 1981; Çakici et al., 1994; Choudhary et al., 2012; Day et al., 1990). A fall of blood sugar on treatment with aqueous extract of fruits was found to be significant (Anila & Vijayalakshmi, 2000; Shibib et al., 1993). *Diamed* is a herbal formulation composed of the aqueous extracts of three medicinal plants (*Azardirachta indica*, *Cassia auriculata* and *M. charantia*). Oral administration of *Diamed* resulted in a significant reduction in blood glucose, glycosylated haemoglobin, and an increase in plasma insulin and total haemoglobin showing its antihyperglycaemic action (Dans et al., 2007; Pari et al., 2001). Ethanolic extract of *M. charantia* plant significantly lowered blood sugar in fasted model and depressed the peak value in glucose loaded model (Ahmad et al., 1999; Ali et al.,

1993; Boone et al., 2017; Leatherdale et al., 1981; Platel & Srinivasan, 1997; Raman & Lau, 1996; Vikrant et al., 2001; Virdi et al., 2003; Zhu et al., 2012). The antidiabetic activity of *M. charantia* was investigated in KK-Ay mice, with type II diabetes with hyperinsulinemia. The water extract of the fruit of *M. charantia* reduced the blood glucose of KK-Ay mice after oral administration and also significantly lowered the serum insulin of KK-Ay mice (Akhtar, 1982; Karunanayake et al., 1984; Kasbia et al., 2009; Miura et al., 2001).

Oleanolic acid-3-O-glucuronide and Momordin Ic, given orally, exhibit their hypoglycemic activity by suppressing the transfer of glucose from the stomach to the small intestine and by inhibiting glucose transport at the brush border of the small intestine (Mahomoodally et al., 2004; Matsuda et al., 1998). The fruit of *Momordica*, at all ripening stages, was found to contain inhibitory compounds; one against hexokinase activity and the other against glucose uptake by rat intestinal fragments. During diabetes, structural and functional changes in the alimentary tract are known to take place resulting in increased absorption of intestinal glucose and alterations in the activities of brush border disaccharidases. Feeding bitter gourd has positive influence on intestinal and renal disaccharidases (Shetty et al., 2005b; Wu et al., 2014b; Yousaf et al., 2016). Bitter gourd supplementation causes reduction in maltase and lactase activity.

A hypoglycemic peptide, polypeptide-p, has been isolated from fruit, seeds, and tissue of *M. charantia*. The purified protein extract was obtained from fruits of *M. charantia* as active hypoglycaemic principle. This extract was homologous to insulin obtained from animal pancreas (Baldwa et al., 1976, 1977; Chang et al., 2015; Khanna et al., 1981; Ng et al., 1986b; Wang et al., 2014; Yang et al., 2015a; Yibchok-Anun et al., 2006). The average fall in blood sugar level due to vegetable insulin was found to be statistically significant. Slow acting protein extract from fruit pulp of *M. charantia* exerted both insulin secretagogue and insulinomimetic activities to lower blood glucose concentrations in vivo (Yibchok-Anun et al., 2006). In perfused rat pancreas, the proteins extract increased insulin secretion, but not glucagon secretion. Incubation of L6 myotubes with either the lyophilised juice or its chloroform extract of *M. charantia* resulted in time-dependent increases in 3H-deoxy-D-glucose and 14C-Me-AIB uptakes. Incubation of either insulin or the juice in the presence of Wortmannin (a phosphatidylinositol 3-kinase inhibitor) resulted in a marked inhibition of 3H-deoxyglucose by L6 myotubes. The results indicated that *M. charantia* fruit juice acts like insulin to exert its hypoglycaemic effect (Cummings et al., 2004).

The triterpenes have insulin-sensitizing and insulin-substitution functions, which are likely correlated with their effects on inhibiting protein-tyrosine phosphatase-1B (PTP 1B) and activating AMPK, respectively (Cheng et al., 2008; Ma et al., 2010; Sridhar et al., 2008; Tan et al., 2008). Saponin-rich fraction and isolated compounds from *M. charantia*, stimulate insulin secretion in an in vitro static incubation assay (Keller et al., 2011). PTP 1B is the physiological antagonist of the insulin signaling pathway. The saponin fraction and the lipid fraction reduced PTP 1B activity in skeletal muscle cytosol. Inhibition of PTP 1B increases insulin sensitivity and demonstrate the possible biochemical mechanism underlying the antidiabetic effects (Klomann et al., 2010; Welihinda et al., 1983).

Cerasee, a wild variety of *M. charantia*, traditionally prepared as a tea, improved glucose tolerance in STZ diabetic mice but did not significantly alter plasma insulin concentrations (Bailey et al., 1985; Higashino et al., 1992; Karunanayake et al., 1990; Kedar & Chakrabarti, 1982; Meir & Yaniv, 1985; Mishra et al., 2015; Grover, & Vats, 2002; Sarkar et al., 1996; Sekar et al., 2005). The mechanism of action of *M. charantia* could be partly attributed to increased glucose utilization in the liver rather than an insulin secretion effect (Ahmed et al., 2004; Roffey et al., 2007; Shetty et al., 2005a; Welihinda & Karunanayake, 1986; Zhang et al., 2014). Further, it also reduced the STZ-induced apoptosis in RIN cells indicating the mode of protection of bitter gourd fruit juice on RIN cells, islets and pancreatic β-cells (Sitasawad et al., 2000).

Cataract formation was found to be dependent on blood sugar levels. Treatment with *Momordica* delayed cataract formation in rat (Rathi et al., 2002a, 2002b; Srivastava et al., 1988). *M. charantia* and *Andrographis paniculata* could restore impaired estrous cycle in alloxan-induced diabetic rats. *M. charantia* and *T. foenum graecum* are useful in controlling the blood glucose levels and also have antioxidant potential to protect vital organs such as heart and kidney against damage (Czompa et al., 2017; Raish et al., 2016; Yadav et al., 2010). Thickening of the glomerular basement membrane is well characterized in diabetic nephropathy. Changes in glomerular basement membrane mainly include reduction and undersulphation of heparan sulphate, and laminin with accumulation of type IV collagen (Kumar et al., 2008). Decrease in sulphate content in the glycosaminoglycan metabolism during diabetes was ameliorated by bitter gourd feeding. Sulphate groups in glycosaminoglycan perform pivotal functions in many biological events. Bitter gourd and spent turmeric were tested for their efficacy on glycosaminoglycan metabolism in various tissues viz. liver, spleen, lungs, heart and testis in control, diabetic and treated rats. Bitter gourd and spent turmeric have beneficial effects in glycosaminoglycan metabolism (Kumar et al., 2006; Vijayalakshmi et al., 2009). Improvement is due to slow release of glucose by fiber in the gastrointestinal track and short-chain fatty acid production from fiber by colon microbes. The renoprotective nature of *M. charantia* polysaccharides mitigates the progression of STZ-induced diabetic nephropathy in rats by suppression of oxidative stress and amelioration of the HO-1/Nrf2 pathway.

The effect of *M. charantia* fruit juice on the distribution and number of α, β and δ cells in the pancreas of STZ-induced diabetic rats using immunohistochemical methods was investigated. Oral feeding of *M. charantia* fruit juice may have a role in the renewal of β cells in STZ-diabetic rats or alternately may permit the recovery of partially destroyed β cells (Abdollahi et al., 2011; Ahmed et al., 1998; Hafizur et al., 2011; Singh & Gupta, 2007; Xiang et al., 2007). Treatment of STZ-induced diabetic rats with *M. charantia* juice normalised the structural abnormalities of peripheral nerves. The cell reparative effects of *M. Charantia* boiling water extract on the HIT-T15 hamster pancreatic β-cells was investigated. It indicated, *M. charantia* boiling water extract has significant repairing effects on HIT-T15 cells against superoxide anion radicals and stimulate insulin secretion. Further, histopathological studies revealed that administration of rosiglitazone with *M. charantia* increased the volume of islet cell in pancreas and prevented the hepatic damage (Nivitabishekam et al., 2009).

There was a significant increase in plasma non-esterified cholesterol, triglycerides and phospholipids in STZ-induced diabetic rats, accompanied by a decrease in HDL-cholesterol. The treatment of diabetic rats with *M. charantia* fruit extract returned these levels close to normal (Ahmed et al., 2001; Chaturvedi et al., 2004; Chaturvedi, 2005; Grover et al., 2001b; Jayasooriya et al., 2000; Nerurkar et al., 2008). Oral administration of seed extracts showed a significant decrease in fasting blood glucose, hepatic and renal thiobarbituric acid reactive substances and hydroperoxides. The treatment also resulted in a significant increase in reduced glutathione, superoxide dismutase, catalase, glutathione peroxidase and glutathione-s-transferase in the liver and kidney of diabetic rats (Chaturvedi & George, 2010; Sathishsekar & Subramanian, 2005b, 2005a). The liver of the diabetic rats showed involvement of the hepatocytes with features of inflammation. Liver damage in the diabetic animals was healed with administration of the *M. charantia* extract (Teoh et al., 2009a). The blood glucose and serum neutral fat-lowering effects of *M. charantia* were closely associated with its inhibitory activity against disaccharidase and pancreatic lipase (Hsieh et al., 2013).

The modulation of xenobiotic metabolism and oxidative stress in various tissues may be related to altered metabolism of endogenous substrates and hormonal status during diabetes. Karela juice feeding modulates the enzyme expression and catalytic activities in a tissue and isoenzyme-specific manner (Arafat et al., 2016; Güder, 2016; Raza et al., 2000; Tripathi & Chandra, 2009). The accumulation of advanced glycation endproducts (AGEs) and oxidative stress underlie the pathogenesis of diabetic complication. Lysozyme mixed with methylglyoxal and after incubation forms crosslinked AGEs. Aqueous extracts of *M. charantia* flesh extracts inhibited the formation of crosslinked AGEs and carboxymethyllysine in a dose-dependent manner (Aljohi et al., 2016).

Peroxisome proliferator receptors are ligand-dependent transcription factors that belong to the steroid hormone nuclear receptor family and control lipid and glucose homeostasis in the body. The nuclear receptors PPARα and PPARγ are therapeutic targets for hypertriglyceridemia and insulin resistance. 9cis,11trans,13trans-conjugated linolenic acid was identified as a PPARα activator in wild bitter gourd (Chuang et al., 2006). Bitter melon increased the expression of PPARγ in white adipose tissue and increases the mRNA expression and protein of glucose transporter 4 (GLUT4) in skeletal muscle (Chao & Huang, 2003; Shih et al., 2008, 2009). Conversely, bitter melon decreased the expression of leptin in white adipose tissue.

α-Glucosidase inhibitory activity was found in aqueous methanol extracts of the seeds of *M. charantia* (Deng et al., 2014a; Oishi et al., 2007). On further purification, the active principle for its activity was identified as trehalose. Cucurbitane-type triterpene glycosides also possess α-glucosidase inhibitory activity (Nhiem et al., 2010b; Poovitha & Parani, 2016). Total anthocyanins from bitter melon fruit showed very influential inhibitory activity against α-amylase and moderate inhibitory activity against α-glucosidase. Similarly, the protein extract from bitter melon inhibited the activity of α-amylase and α-glucosidase through competitive inhibition. Polypeptide k and seed oil showed potent inhibition of α-glucosidase enzyme and α-amylase (Ahmad et al., 2012).

Development of insulin resistance is closely related to chronic inflammation induced by factors such as TNF-α. A triterpenoid compound purified from *M. charantia* was

found to activate AMPK and have a hypoglycaemic effect in TNF-α-treated FL83B cells (Cheng et al., 2012). It might repress TNF-α-induced inflammation via AMPK. Bitter melon exerted preventive effects against insulin resistance and diabetes through the modulation of NF-κB and Jun N-terminal kinases (JNK) pathways (Yang et al., 2015c). There is strong evidence that increased adipose 11β-HSD1 activity may be an important aetiological factor in the current obesity and diabetes type II epidemics. *M. charantia* extract contain ingredient with selective 11β-HSD1 inhibitory activity. Hence inhibition of 11β-HSD1 can be a promising antidiabetic strategy (Blum et al., 2012).

**Anticancer:** The studies have shown its efficacy in various cancers (lymphoid leukemia, lymphoma, choriocarcinoma, melanoma, breast cancer, skin tumour, prostatic cancer, squamous carcinoma of tongue and larynx, human bladder carcinomas and Hodgkin's disease) (Terenzi et al., 1996).

Extract of *M. charantia* inhibited the germination of maize, cotton and broad bean seeds, as well as the formation of adventitious roots on *Bryophyllum* leaves (West et al., 1971). The neutralized acidic fraction also inhibited the division of sea urchin eggs and foetal development in rats. It caused a slight increase of the life expectancy of mice bearing tumours of Sarcoma 180, and suppressed the growth of Her2 cells in tissue culture.

α-Momorcharin, a glycoprotein isolated from seeds of the bitter gourd, inhibited incorporation of [3H]thymidine, [3H]leucine and [3H]uridine into P388 (mouse monocyte-macrophage), J774 (Balb/c macrophage), JAR (human placental choriocarcinoma) and sarcoma S180 cell lines (Jilka et al., 1983; Ng et al., 1994a, 1994b; Zhu et al., 1990). D-galactose-specific lectin of *M. charantia* seeds showed growth inhibitions against Ehrlich ascites carcinoma cells (Kabir et al., 2015). The antimutagens, acylglucosylsterols, were extracted from the green fruits (Guevara et al., 1989). The mixture reduced the number of micronucleated polychromatic erythrocytes induced by the well-known mutagen Mitomycin C. Ingestion of acylglucosylsterols may result in their absorption in the plasma membrane lipid bilayer which could adversely affect the membrane permeability towards Mitomycin C and disrupt the cellular activity of the latter (Guevara et al., 1990). α- and β-momorcharin can effect of on viability, caspase activity, cytochrome C release and on cytosolic calcium levels in different cancer cell lines (Manoharan et al., 2014).

Guanylate cyclase inhibitor blocked the activation of guanylate cyclase by nitroso chemical carcinogens, and therefore, may be useful in studying mechanisms of chemical carcinogenesis (Takemoto et al., 1982a; Vesely et al., 1977). The effect of the aqueous extract containing guanylate cyclase inhibitor on an undifferentiated adenocarcinoma of the rat prostate and concanavalin-A-stimulated [3H]thymidine incorporation into cultured splenic lymphocytes were examined (Claflin et al., 1978; Takemoto et al., 1980). The extract of the *M. charantia* blocks both the growth of the rat prostatic adencarcinoma in vitro and [3H]thymidine incorporation into DNA. The anti-invasive effect of bitter melon leaf extract on a rat prostate cancer cell line (PLS10) in vitro and in vivo was investigated. The leaf extract significantly inhibited the migration and invasion of cells in vitro. It inhibited the secretion of matrix metalloproteinase and urokinase plasminogen activator from PLS10 and markedly increased the mRNA level of tissue inhibitor of

metalloproteinase (Pitchakarn et al., 2010). Oral administration of bitter melon extract inhibits prostate cancer progression in transgenic adenocarcinoma of the mouse prostate (TRAMP) mice by interfering cell-cycle progression and proliferation (Ru et al., 2011). Kuguacin J, a triterpenoid from *M. charantia* leaf, induces G1 arrest and apoptosis in androgen-dependent human prostate cancer (Pitchakarn et al., 2011; Pitchakarn et al., 2012b). MCP30 selectively induces prostatic intraepithelial neoplasia and PCa apoptosis and inhibits histone deacetylase-1 activity (Su et al., 2009).

The proliferation of human colorectal carcinoma LoVo cells were significantly suppressed by MAP30 in time- and dose-dependent manners. MAP30 can thus induce the apoptosis of the human colorectal carcinoma LoVo cells (Fan et al., 2008). A novel bioactive peptide BG-4 isolated from *M. charantia* has the potential therapeutic property against colon cancer HCT-116 and HT-29 cells. The apoptosis inducing property of BG-4 is due to reduced expression of Bcl-2 and increased expression of Bax leading to increased expression of caspase-3 and affecting the expression of cell cycle proteins p21 and CDK2 (Dia & Krishnan, 2016). Methanolic extracts of bitter melon inhibit colon cancer stem cells by affecting energy homeostasis and autophagy. Fruit extract reduced cellular ATP levels coupled with activation of AMPK.

Seed oil from bitter melon inhibited the development of azoxymethane-induced colonic aberrant crypt foci (ACF) (Kohno et al., 2004). Administration of the oil in diet enhanced expression of PPARγ protein in the nonlesional colonic mucosa and alters lipid composition which consequently helps on the development of colonic neoplasms. The anti-proliferative and apoptosis-inducing effects of free fatty acids, obtained from the oil, was studied against colon cancer Caco-2 cells. It remarkably reduced the cell viability of Caco-2 through up-regulation of GADD45, p53 and PPARγ (Yasui et al., 2006; Yumiko et al., 2005). Bitter melon effects on anticancer activity and bioavailability of doxorubicin in colon cancer cells. It enhanced the effect of doxorubicin on cell proliferation and sensitized the cells toward doxorubicin upon pretreatment (Kwatra et al., 2013). The anticlastogenic and anticarcinogenic effects of bitter gourd against clastogens, cyclophosphamide and dimethylbenz(a)anthracene, in mice, using the in vivo erythrocyte micronucleus assay and azoxymethane-induced colon carcinogenesis in rats were examined (Kupradinun et al., 2011). Bitter gourd resulted in a significant reduction in micronucleated peripheral reticulocytes (MNRETs) induced by only cyclophosphamide. However, no preventive potential against azoxymethane-induced colon carcinogenesis was observed.

Peptide, RNase MC2 demonstrated both cytostatic and cytotoxic activities against MCF-7 breast cancer cells. Treatment of MCF-7 cells with RNase MC2 caused nuclear damage ultimately resulting in apoptosis associated with activation of mitogen-activated protein kinases (MAPKs) and induction of caspase pathways (Fang et al., 2012a; Zhang et al., 2014). RNase MC2 significantly suppressed the growth of Hep G2 xenograft-bearing nude mice by inducing apoptosis. α-Eleostearic acid has been shown to possess antitumour activity in breast cancer cells. α-Eleostearic acid inhibited cell growth and induced apoptosis in the SKBR3 and T47D breast cancer cell lines (Li et al., 2016b; Zhuo et al., 2014). The antitumour activity of α-eleostearic acid is mediated by reduction of the HER2/HER3 heterodimer protein level, activation of the Akt/BAD/Bcl-2 apoptotic

pathway and inhibition of the Akt/GSK-3β survival pathway. A cucurbitane-type triterpene, isolated from wild bitter gourd, induced apoptotic death in breast cancer cells through PPARγ activation (Weng et al., 2013). α-Eleostearic acid also inhibited proliferation of both MDA-wt and MDA-ERα7 human breast cancer cells (Grossmann et al., 2009). Bitter melon extract treatment of breast cancer cells MCF-7 and MDA-MB-231 resulted in a significant decrease in cell proliferation and induced apoptotic cell death (Cao et al., 2011, 2015; Ray et al., 2010). Apoptosis was accompanied by increased poly (ADP-ribose) polymerase cleavage and caspase activation. Treatment of MDA-MB-231 breast cancer cells with MAP30 resulted in inhibition of cancer cell proliferation as well as inhibition of the expression of HER2 gene in vitro (Lee-Huang et al., 1995a, 2000; Sun et al., 2001). Almost 70% of breast cancers are estrogen receptor α positive. Cucurbitane-type triterpenoids has property with partial agonist/antagonist potential for estrogen receptors (Hsu et al., 2011). α-Momorcharin also exerts effective anti-human breast tumour activity, but due to its obvious toxicity, α-momorcharin has a relatively narrow therapeutic window (Muhammad et al., 2017; Tsao et al., 1990).

The anti-leukemic activity of the bitter melon extract is due to the activation of natural killer (NK) cells in the host mouse. This anti-leukemic activity was associated with an activation of murine lymphocytes (Cunnick et al., 1990). Seeds of *M. charantia* suppressed the proliferation of three adult T-cell leukaemia cell lines (Su9T01, HUT-102 and Jurkat). Adult T-cell leukaemia preventative bioactive compounds may thus exist in *M. charantia*. α-Eleostearic acid is one of the responsible compound for suppression of the proliferation of adult T-cell leukaemia cell (Kai et al., 2011). The immunotoxin, anti-CD5 monoclonal antibody linked to the plant toxin momordin, was evaluated as the inhibition of protein and/or DNA synthesis on isolated peripheral blood mononuclear cells (PBMC) and on human T cell leukemia Jurkat (Dinota et al., 1989; Kai et al., 2014; Porro et al., 1993). A significant inhibition of the tumour development in the animals treated with the immunotoxin was observed. A haemagglutinin (lectin) and protein inhibitor purified from the seeds of *M. charantia* inhibited protein and subsequently DNA synthesis in normal (mitogen-stimulated) and leukaemic human peripheral blood lymphocytes (Licastro et al., 1980; Takemoto et al., 1982b). The lectin inhibits protein synthesis by a rabbit reticulocyte lysate (Barbieri et al., 1980). α-Eleostearic acid strongly inhibited the growth of some cancer and fibroblast cell lines, including those of HL60 leukemia and HT29 colon carcinoma (Ohnishi-Kameyama, et al., 2008; Tsuzuki et al., 2004).

Immunotoxins were prepared by linking the type I ribosome-inactivating proteins momordin I to monoclonal antibody and then tested on human bladder carcinoma cell lines, and showed maximum inhibition of protein synthesis by T24 cells (Battelli et al., 1996; Bolognesi et al., 1996). Further chemical modification of ribosome-inactivating proteins such as by polyethylene glycol (PEGylated ribosome-inactivating proteins) might have prominent anti-tumour activity (Bian et al., 2010; Li et al., 2009a, 2012a). Full-length MAP30 gene was successfully expressed in *E. coli* BL21 strain and MAP30 recombinant protein inhibited the growth of bladder cancer 5637 cells by inducing apoptosis of target cells in a dose- and time-dependent manner (Lin et al., 2016).

Protein P-B and pentatricopeptide repeat-containing protein have anticancer activity on the human gastric cancer cell line SGC-7901 (Li et al., 2012a). Bitter melon fruit

extract was tested against 3,4-benzo(a)pyrene-induced fore stomach papillomagenesis in Swiss albino mice. A significant decrease in tumour burden was observed in short and long-term treatment (Deep et al., 2004; Kusamran et al., 1998). The inhibitory potential of *M. charantia* peel, pulp, seed and whole fruit extract on mouse skin papillomagensis was studied. The results suggest the maximum chemopreventive potential is in the *Momordica* peel (Singh et al., 1998). *Momordica* fruit and leaf extracts have also chemopreventive effect on dimethylbenz(a)anthracene-induced skin tumourigenesis, melanoma tumour and cytogenicity. The extract afforded protection from the development of skin tumour and increased life expectancy (Agrawal & Beohar, 2010). Biotransformation system enzymes may be the cause of this reduced papillomagenesis. Carcinogen-induced lipid peroxidation in liver and DNA damage in lymphocytes were found to be reduced following treatment with *Momordica* (Ganguly et al., 2000).

It exhibited marked inhibitory effects in Epstein−Barr virus early antigen induction by 12-O-tetradecanoylphorbol-13-acetate in Raji cells, 7,12-dimethylbenz[a]anthracene- and peroxynitrite ($ONOO^-$)-induced mouse skin carcinogenesis tests. Cucurbitane-type triterpenoids have been isolated which showed potent inhibitory effects on Epstein-Barr virus induction (Akihisa et al., 2007; Zhang et al., 2012).

The anticancer effect of Kuguaglycoside C against human neuroblastoma IMR-32 cells was investigated. In the MTT assay, Kuguaglycoside C induced significant cytotoxicity against the IMR-32 cells. Kuguaglycoside C induced caspase-independent cell death of neuroblastoma cells (Tabata et al., 2012).

Momordins inhibit both activater protein 1 (AP-1) function and cell proliferation. The mechanism of anticancer activity of Momordin I comes from its inhibitory effect on the protein-DNA interaction (Lee et al., 1998). These compounds reduced the Jun/Fos-DNA interaction which is crucial factor in transmitting the tumour promoting signal from the extracellular environment to nuclear transcription machinery.

The effects of chronic treatment with hot water extract of bitter melon on spontaneous mammary tumourigenesis were examined in SHN mice strain virgin mice. The development of mammary tumours was significantly inhibited (Nagasawa et al., 2002).

MAP30 protein from bitter gourd seeds promotes apoptosis in liver cancer cells in vitro and in vivo. *M. charantia* lectin manifests antitumour activity towards hepatocellular carcinoma (Fang et al., 2012a, 2012b). *M. charantia* lectin treatment induced G2/M phase arrest, autophagy, DNA fragmentation, mitochondrial injury and subsequently cell apoptosis in hepatocellular carcinoma cells (Huang et al., 1999; Wang et al., 2012a; Zhang et al., 2015b).

*M. charantia* extracts had ability to modulate the function of P-glycoprotein (P-gp) and the MDR phenotype in the multidrug-resistant human cervical carcinoma KB-V1 cells (Limtrakul et al., 2004). The monoglyceride 1-monopalmitin also played an important role in the inhibition of P-gp activity in Caco-2 cells (Konishi et al., 2004). The overexpression of the P-gp causes a reduction in drug accumulation in the cancer cells. Kuguacin J modulates the function of P-gp by directly interacting at the drug-substrate-binding site, and it appears to be an effective inhibitor of P-gp activity in vitro and thus

could be developed as an effective chemosensitizer to treat multidrug-resistant cancers (Pitchakarn et al., 2012a).

*M. charantia* lectin evinced potent cytotoxicity toward nasopharyngeal carcinoma CNE-1 and CNE-2 cells. It induced apoptosis, DNA fragmentation, G(1)-phase arrest and mitochondrial injury in both types of nasopharyngeal carcinoma cells (Fang et al., 2012b). *M. charantia* induces apoptosis in several human lung adenocarcinoma CL1 cells through caspase- and mitochondria-dependent pathways (Hsu et al., 2012b; Li et al., 2012a). α-Momorcharin reduced cell viability and inhibited clonogenic formation of human NPC CNE2 and HONE1 cells under normoxia and cobalt chloride-induced hypoxia (Pan et al., 2014).

The effects of α-MMC and MAP30 on human lung adenocarcinoma epithelial A549 cells were determined. The results revealed that A549 cells were sensitive to α-MMC and MAP30 cytotoxicity assays in vitro. Cell proliferation was significantly suppressed in a dose- and time-dependent manner (Fan et al., 2015b).

Bitter melon extract suppresses adrenocortical cancer cell proliferation through modulation of the apoptotic pathway and decreasing the key proteins involved in steroidogenesis. Bitter melon reduces head and neck squamous cell carcinoma growth by targeting c-Met signaling. Bitter melon extract modulates the regulatory T cell (Treg) population and enhance the NK-cell killing activity in head and neck squamous cell carcinoma (Bhattacharya et al., 2016, 2017; Rajamoorthi et al., 2013).

Bitter melon extract inhibits tumourigenicity and overcomes cisplatin-resistance in ovarian cancer cells. Co-treatment with bitter melon extract and cisplatin markedly attenuated tumour growth in vitro and in vivo. Studies of the molecular mechanism demonstrated that bitter melon extract activates AMPK (Yung et al., 2016). Bitter melon juice activates cellular energy sensor AMPK causing apoptotic death of human pancreatic carcinoma cells (Kaur et al., 2013).

**Hypotensive:** Acute intravenous administration of *M. charantia* extract produced dose-dependent, significant reductions in systemic arterial blood pressure and heart rates of normal, and hypertensive Dahl salt-sensitive rats (Ojewole et al., 2006). A bitter melon extract was investigated for the potential to reduce cell viability, reduce lipid accumulation in differentiating 3T3-L1 cells and affect subsequent adiponectin expression. Bitter melon extract reduced preadipocyte proliferation by a G2/M arrest of the cell cycle and reduced lipid accumulation of the adipocyte (Popovich et al., 2010). The effects of bitter gourd leaf extracts on enzyme linked with hypertension (angiotensin-I-converting enzyme) and some pro-oxidants in rat kidney homogenates were studied. The extract rich in phenolics had significant angiotensin-I converting enzyme inhibitory activity (Shodehinde et al., 2016).

Polysaccharide of *M. charantia* has effect on endothelial dysfunction in myocardial infarction. Pretreatment with *M. charantia* polysaccharides significantly inhibited myocardial infarction induced in rats using isoproterenol (Czompa et al., 2017; Raish, 2017).

**Antimicrobial:** The extracts from the leaves of *M. charantia* have antimicrobial property against the test organisms *E. coli*, *S. paratyphi*, *S. dysenterae, Ruminococcus albus, Ruminococcus flavefaciens*, methicilin-resistant *S. aureus*, etc. (Abalaka et al., 2011; Costa et al., 2010; Coutinho et al., 2010; Jagessar et al., 2008; Kang et al., 2017; Khan & Omoloso, 1998; Lu et al., 2011; Mada et al., 2013; Mahomoodally et al., 2010; Mwambete, 2009; Ogata et al., 1991; Omoregbe et al., 1996; Patel et al., 2010; Saeed & Tariq, 2005; Yaldiz et al., 2015; Yeşilada et al., 1999; Zhang et al., 2011). The essential oil obtained from the seeds of *M. charantia* also possess antimicrobial and antifungal properties (Braca et al., 2008). Extracts from *M. charantia* could be used as a source of plant-derived natural products with resistance-modifying activity. *M. charantia* seed extracts has also antimicrobial activity against mammalian and poultry pathogens (Mahmood et al., 2012). α-Momorcharin could inhibit the mycelial growth of *F. solani* and *F. oxysporum* (Santos et al., 2012; Wang et al., 2016). The seed extract led to deformation of cells with irregular budding, loss of integrity of cell wall, as well as disruption of the fungal cell membrane (Wang et al., 2012b). Protein MCha-Pr had inhibitory effect towards a variety of fungal species like *Alternaria brassicae*, *Cercospora personata*, *F. oxysporum*, *Mucor* sp., and *Rhizoctonia solani* (Zhang et al., 2015a). Antibacterial peptide obtained from seeds of *M. charantia* may be used as an alternative natural biopreservative source for minced meat products (Jabeen & Khanum, 2017).

**Gut microbiota:** Bitter melon formulation effects on gut microbiota of type II diabetic rats. Bitter melon formulation can significantly modify the proportions of particular gut microbiota in diabetic rats without disturbing the normal population diversity (Bai et al., 2016; Yousaf et al., 2016; Zhu et al., 2016). The effects of *M. charantia* polysaccharide on ruminal fermentation and cellulolytic bacteria in vitro were investigated. *M. charantia* polysaccharide had the ability to enhance the total volatile fatty acids production, modulate the rumen fermentation pathway and influence the number of cellulolytic bacteria population (Kang et al., 2016, 2017).

**Antiobesity:** Bitter melon decreased adiposity in rats. It is resulted from lower metabolic efficiency, a consequence of increased lipid oxidation and mitochondrial uncoupling. It elevated activities of hepatic and muscle mitochondrial carnitine palmitoyl transferase-I (CPT-I) and acyl-CoA dehydrogenase (Chan et al., 2005). A proteomic approach was used to identify proteins differentially expressed in the white adipose tissue of mice fed diets with bitter melon seed oil (Hsieh et al., 2013). Long-term bitter melon seed oil administration was characterized by reduced caveolae formation, increased ROS insult, tissue remodeling/repair, mitochondria uncoupling and stabilization of the actin cytoskeleton (Xu et al., 2016). The anti-adiposity effect of bitter melon seed oil is associated with white adipose tissue delipidation, inflammation and browning. Bitter gourd prevents inflammation and oxidative stress, modulates mitochondrial activity and inhibits lipid accumulation during the development of obesity-associated fatty liver (Xu et al., 2014). *M. charantia* extracts have anti-obesity effect and ability to modulate lipid prolife of mice fed a high-fat diet by suppressing body weight gain, visceral tissue weight, plasma and hepatic lipid concentrations, and lipid peroxidation along with increasing lipid metabolism (Alam et al., 2015; Chen & Li, 2005; Jayasooriya et al., 2000; Ng et al., 1986a; Senanayake et al., 2004b; Wang & Ryu, 2015).

**Antihyperlipidemic:** *M. charantia* fruits and seeds contained components that resembled insulin in inhibiting hormone-induced lipolysis (Chen et al., 2003; Shih et al., 2008; Sridhar et al., 2008; Wong et al., 1985). A saponin fraction was isolated from *M. charantia* seeds. The saponin containing fraction, inhibited both lipolysis and 3H-glucose incorporation into lipids (Wong, et al., 1987). The saponin acted as a noncompetitive inhibitor of corticotropin, glucagon and epinephrine in lipolysis in isolated rat adipocytes, and it also antagonized dibutyryl cAMP induced lipolysis.

Dietary effect of conjugated α-eleostearic acid level on blood lipid and nonenzymatic in vitro lipid peroxidation in rats was studied. Nonenzymatic liver tissue lipid peroxidation was significantly lower in the group of rats fed with α-eleostearic acid. The effect of dietary bitter melon on lipid parameters of the serum and liver was studied in rats fed diets supplemented with and without cholesterol. HDL-cholesterol level tended to decrease by dietary cholesterol, while they were consistently elevated by dietary bitter melon both in the presence and absence of dietary cholesterol, indicating an antiatherogenic activity of bitter melon (Chaturvedi, 2005; Mahwish et al., 2017; Noguchi et al., 2001; Platel et al., 1993; Senanayake et al., 2004a). Bitter gourd alters hepatic gene expression of cholesterol- and bile acid-regulating proteins to improve blood cholesterol profiles. Bitter gourd decreases the re-absorption of bile acids into the intestine and also increases the conversion of cholesterol to bile acids by CYP7A1 up-regulation through the down-regulation of the hepatic farnesoid X receptor/SHP pathway (Matsui et al., 2013; Saad et al., 2017).

Conjugated linolenic acid isomers showed potent hypolipidemic and hypocholesterolemic activities against biochemical perturbations (Dhar et al., 1999). Administration of sodium arsenite caused alteration in erythrocyte membrane fluidity due to increase in cholesterol and decrease in phospholipid content (Saha et al., 2012). These altered parameters were reversed by conjugated linolenic acid isomers present in *M. charantia* seed oil. When bitter melon seed oil was administered to rat with an obesity model established by feeding C57BL/6J mice a high fat diet, it restored the balance between lipid intake and metabolism, which was probably mediated by leptin's variation (Bao et al., 2013; Chaturvedi et al., 2004). The effects of treatment of *Momordica* fruit extract and sodium orthovanadate, separately and in combination, on serum and tissue lipid profile and on the activities of lipogenic enzymes in alloxan-induced diabetic rats were examined. The lipogenic enzymes showed decreased activity in the diabetic liver, while in kidney, they showed an increased activity. This shows that *Momordica* fruit extract and sodium orthovanadate exhibit hypolipidemic effect in diabetic rats (Yadav et al., 2005).

The bitter gourd extract was able to act on a natural PPARα signaling pathway in the cell line (Barish et al., 2006; Chao et al., 2011; Chao & Huang, 2003; Gadang et al., 2011; Sasa et al., 2009). PPARα is a ligand-dependent transcription factor that regulates the expression of genes involved in lipid metabolism and transport.

Bitter melon juice is a potent inhibitor of apoB secretion and triglyceride synthesis, and secretion that may be involved in the plasma lipid- and VLDL-lowering effects observed in animal studies. Human hepatoma cells, HepG2, treated with bitter melon juice reduced apoB secretion with and without the addition of lipids and decreased microsomal triglyceride transfer protein (MTP) mRNA expression (Ching et al., 2011;

Nerurkar et al., 2008, 2005). Bitter melon treatment of 3T3-L1 cells resulted in a decreased in lipid accumulation and significantly decreased intracellular triglyceride amount (Ahmed et al., 2001; Nerurkar et al., 2006, 2010; Popovich et al., 2010). It reduced preadipocyte proliferation by a G2/M arrest of the cell cycle and reduced lipid accumulation of the adipocyte.

**Antioxidant:** Conjugated octadecatrienoic fatty acid is potentially effective antioxidant that can protect plasma, LDL and erythrocyte membrane from oxidation which may be effective in reducing the risk of coronary heart disease in diabetes mellitus (Dhar et al., 2007). Based on different antioxidant activities like DPPH radical-scavenging activity, hydroxyl radical-scavenging activity, β-carotene-linoleate bleaching assay and FRAP assay, the plant extract showed prominent antioxidant property. The water-soluble polysaccharides and phenolics also possess antioxidant property (Aljohi et al., 2016; Aminah & Anna, 2011; Bajpai et al., 2005; Budrat & Shotipruk, 2008; Ghosh et al., 2014; Güder, 2016; Horax et al., 2010; Kenny et al., 2013; Kubola & Siriamornpun, 2008; Li et al., 2010b; Lu et al., 2013; Myojin et al., 2008; Padmashree et al., 2011; Panda et al., 2015; Shan et al., 2012; Tan & Gan, 2016; Tan et al., 2014; Tripathi & Chandra, 2009, 2010; Wu & Ng, 2008).

Cucurbitane-type triterpene glycoside were tested for antioxidant property and significantly displayed superoxide ($O_2^-$) scavenging activity in the relative oxygen radical absorbance capacity (ORAC) and ABTS radical cation scavenging activity (Deng et al., 2014b; Lin et al., 2011; Liu et al., 2010a).

*M. charantia* inhibited stress-induced lipid peroxidation by increasing the levels of reduced glutathione and activities of catalase (Chaturvedi, 2009). Bitter gourd possessed protective effect against chronic alcohol-induced liver injury in mice (Deng et al., 2017; Lu et al., 2014). *M. charantia* fruits was assayed by radical-scavenging methods and cytoprotective effects on hydrogen peroxide- and hypoxanthin-xanthin oxidase-induced damage to rat cardiac fibroblasts (RCFs), NIH 3T3 and keratinocyte (A431). A dose-dependent relationship of oxidant toxicity was observed (Kumar et al., 2010b).

Hyperammonemia was induced in adult male Wistar rats by intraperitoneal injection of ammonium chloride. Hyperammonemic rats showed a significant increase in the activities of thiobarbituric acid reactive substances, hydroperoxides and liver markers. Treatment with *M. charantia* fruit extract normalized the above-mentioned changes in hyperammonemic rats by reversing the oxidant-antioxidant imbalance (Thenmozhi & Subramanian, 2011).

Animals subjected to acute stress and chronic unpredictable stress resulted in significant elevation of plasma corticosterone levels and brain monoamine levels. Pretreatment with *M. charantia* significantly countered acute stress-induced changes and attenuated the chronic unpredictable stress (CUS)-induced changes (Kavitha et al., 2011).

**Anti-inflammatory:** Plant extracts and Momordine Ic were active in the rheumatoidal rat induced Freund's complete adjuvant reagent (Choi et al., 2002). *M. charantia* peroxidase was purified from fruits of *M. charantia*. The peroxidase catalyzed the oxidation of ferulic acid to dehydrodimer (FA-2). FA-2 was a potential inhibitor on inflammation through interference with immune response in the process of inflammation (Ou et al., 2003).

Bitter gourd pulp induced interferon-gamma (IFN-γ) production and show its promise as a means of effective immunestimulatory therapy specific for Th1 cells and IFN-γ production (Ike et al., 2005). The extract of the pulp induced specific immunoglobulin isotype (IgG2a) antibody of the mice serum inoculated with immunogen.

Bitter gourd extract suppressed lipopolysaccharide-induced TNF-α production in RAW 264.7 macrophage-like cells. Components responsible for the activity are identified as 1-α-linolenoyl-lysophosphatidylcholine and its derivatives (Kobori et al., 2008a; Lii et al., 2009).

Phytol and lutein, isolated from bitter melon fruit, potently suppressed pro-inflammatory cytokine and matrix metalloproteinase (MMP)-9 levels in propionibacterium acnes-stimulated THP-1 cells in vitro. Bitter melon reduced adipose tissue inflammation in diet-induced obese mice. It lowered mast cell recruitments in epididymal adipose tissues, and depressed pro-inflammatory cytokine monocyte chemotactic protein-1 (MCP-1) expression in epididymal adipose tissues and brown adipose tissues as well as IL-6 and TNF-α expression in epididymal adipose tissues (Chao et al., 2014a). *Propionibacterium acnes* is a key pathogen involved in acne inflammation. Total phenolic extract significantly attenuated *P. acnes*-induced ear swelling in mice along with microabscess (Hsu et al., 2012a; Huang et al., 2015) Further, phenolics isolated from bitter melon significantly suppressed *P. acnes*-induced IL-8 production in vitro. Bitter gourd in diets promoted lipid metabolism, reducing fat accumulation and improving low blood glucose in sepsis. In addition, bitter gourd can reduce inflammation biochemical markers and pro-inflammatory cytokines in the body, hence improving the inflammation responses in mice with sepsis (Hsieh et al., 2013).

**Analgesic, antipyretic:** Analgesic and antipyretic effects were determined using acetic acid-induced writhing and tail-immersion tests in mice, and yeast-induced pyrexia in rats. *M. charantia* showed significant activities (Biswas et al., 1991; Patel et al., 2010).

**Immunomodulatory:** *Momordica* saponins can improve immune function of senile mice by modulating the ratio of T cell subpopulation (Wang et al., 2001). *Momordica* saponins could increase splenocyte to secrete IL-2, enhance peritoneal macrophage to secrete TNF. A water soluble pectic polysaccharide was isolated from the aqueous extract of the green fruits of *M. charantia*. It showed splenocyte, thymocyte as well as macrophage activation (Juvekar et al., 2015; Panda et al., 2015).

The immunological activity of *M. charantia* inhibitor and of pokeweed antiviral protein was investigated in mice. In vitro, *M. charantia* inhibitor and pokeweed antiviral protein at non-cytotoxic concentrations inhibited lymphoid cell responsiveness to phytohemagglutinin and concanavalin A, but not to lipopolysaccharide, and markedly enhanced macrophage-dependent cytotoxicity (Spreafico et al., 1983; Zheng et al., 1999).

Dietary bitter gourd induced both intestinal and systemic anti-inflammatory responses. It induced a decrease in the intestinal secretion of IL-7 and an increase in the secretions of TGF-β and IL-10, these effects reflecting the bitter gourd-induced changes in systemic immunity (Manabe et al., 2003).

Cervical cancer patients have a defective immune system. There is a decrease of total WBC count including lymphocytes and NK cells (Pongnikorn et al., 2003). Bitter melon can stimulate lymphocyte activity in vitro and in vivo. Bitter melon could stimulate the increase of NK cells percentage and P-gp level on the membrane in blood samples from cervical cancer patients. Lectin of *M. charantia* is a T cell-independent B cell activator and a polyclonal immunoglobulin inducer. Proliferation assays showed that lectin selectively stimulates the B cell subset of splenocytes in a dose- and time-dependent manners, and thess activation proceed without the involvement of T cells (Huang et al., 2008; Leung et al., 1987).

Intragastric administration polysaccharide of *M. charantia* significantly increased the carbolic particle clearance index, serum haemolysin production, spleen index, thymus index and NK cell cytotoxicity to normal control levels in cyclophosphamide-induced immunosuppressed mice (Deng et al., 2014a).

**Antithrombin:** *M. charantia* trypsin inhibitor-II prolonged the prothrombin time of human plasma and has effect on serine proteases of the blood coagulation system (Hayashi et al., 1994). Oral administration of aqueous extract of *M. charantia* causes a decrease in haemoglobin concentration which can lead to anaemia (Dar et al., 2014; Temitope, 2014).

**Antihelmintic:** Lyophilized *M. charantia* extracts had anthelmintic activity against *Caenorhabditis elegans* (Beloin et al., 2005; Poolperm & Jiraungkoorskul, 2017; Sujon et al., 1970). Bitter gourd seeds contain several squash-type serine proteinase inhibitors, which inhibit the digestive proteinases of the polyphagous insect pest *Helicoverpa armigera* (Telang et al., 2009). The methanolic extract of *M. charantia* leaves showed strong oviposition deterrent activity against *Liriomyza trifolii* and *Liriomyza sativae* females on the host plant leaf (Kashiwagi et al., 2007; Ling et al., 2009; Mekuria et al., 2005, 2006).

**Antileishmanial/antiprotozoal:** Aqueous extract *M. charantia* and Momordicatin were evaluated in vitro and in vivo against kala-azar caused by *Leishmania donovani* (Gupta et al., 2010). Both extract and compound exhibited inhibitory effect against *Leishmania promastigotes* in vitro. Parasite clearance was achieved in the hamster model of visceral leishmaniasis. *M. charantia* could be a source of plant-derived natural products with antiepimastigote. In in vitro antiepimastigote activity, *Trypanosoma cruzi* was killed by *M. charantia* (Mesia et al., 2007; Santos et al., 2012). Similarly, bitter melon extract inhibits proliferation of *Trypanosoma brucei* bloodstream forms in vitro (Amorim et al., 1991; Phillips et al., 2013; Ueno et al., 1996).

**Neuroprotective:** *M. charantia* polysaccharide (MCP) has neuroprotective effects against cerebral ischemia/reperfusion injury through scavenging superoxide ($O_2^-$), nitric oxide (NO) and peroxynitrite ($ONOO^-$), and inhibiting c-Jun N-terminal protein kinase (JNK3) signaling cascades (Duan et al., 2015; Gong et al., 2015). MCP dose-dependently attenuated apoptotic cell death in neural cells under oxygen glucose deprivation (OGD) condition in vitro and reduced infarction volume in ischemic brains in vivo. Bitter melon ameliorated high-fat diets associated changes in blood brain barrier permeability as evident by reduced leakage of Evans blue dye. HFD-induced glial cells activation and

expression of neuroinflammatory markers, such as NF-κB1, IL-16, IL-22 as well as IL-17R, and were normalized in the brains of mice supplemented with bitter melon (Nerurkar et al., 2011). In another study, ischemia-reperfusion-induced neuronal injury was evaluated in terms of cerebral infarct size, generation of free radicals measured as thiobarbaturic acid reactive substances, and neurological functions measured as short term memory and motor activity. The cerebral oxidative stress and damage, and neurological deficits were dose dependently attenuated by pre-treatment with the lyophilized *M. charantia* juice (Malik et al., 2011).

The study was designed to investigate the ameliorative potential of *M. charantia* in tibial and sural nerve transection (TST)-induced neuropathic pain in rats. TST was performed by sectioning tibial and sural nerve portions (2 mm) of the sciatic nerve, and leaving the common peroneal nerve intact. Administration of *M. charantia* significantly attenuated TST-induced behavioural and biochemical changes (Jain et al., 2014).

**Hepatoprotective:** The hepatoprotective activity of hydroalcoholic extract of *M. charantia* leaves against $CCl_4$-induced hepatotoxicity in albino Wistar rats was evaluated (Chaudhari et al., 2009; Sagor et al., 2015). The toxic effect of $CCl_4$ was controlled significantly by restoration of the increased levels of SGOT, SGPT, ALP and total bilirubin. Cucurbitans showed potent cytoprotective activity in tert-butyl hydroperoxide (t-BHP)-induced hepatotoxicity of HepG2 cells (Chang et al., 2010; Chen et al., 2010a, 2010b). Hepatoprotective effect of *M. charantia* against cyclophosphamide-induced hepatotoxicity in rats was evaluated. Liver marker enzymes altered in cyclophosphamide intoxication were significantly normalized in animals administered with momorcharantia extract (Nithya et al., 2012). The animals treated with *Momordica* fruit extract experienced less liver damage due to acetaminophen intoxication indicating that *Momordica* has hepatoprotective property (Zahra et al., 2012). The protective effect of bitter gourd against chronic alcohol-induced liver injury in mice was investigated (Lu et al., 2014). It markedly reduced the steatotic alternation of liver histopathology and altered the enhancement of the antioxidant defence system. *M. charantia* water extract has a hepatoprotective effect against liver injury in restraint-stressed mice (Arafat et al., 2016; Deng et al., 2017; Tennekoon et al., 1994; Teoh et al., 2010).

**Immunotoxicity:** The immunotoxicity of α-Momorcharin were investigated in rats and guinea-pigs. It induced high titer of specific IgG and high positive results of the active systemic anaphylaxis and passive cutaneous anaphylaxis tests in animals (Leung et al., 1987; Meng et al., 2012a, 2012b). Point necrosis was also observed in liver cells, along with abnormal findings in serum chemistry, hematology and bone marrow histopathology tests.

**Protein inhibitor:** A galactose-binding lectin MCL1 was purified from *M. charantia* seeds. The MCL1 showed highest hemagglutinating activity toward human erythrocytes. It inhibited the cell-free synthesis of luciferase in a rabbit reticulocyte lysate system (Tanaka et al., 2009) Besides lectin various ribosome inactivating proteins, trypsin inhibitors, guanylate cyclase inhibitor and α-glucosidase inhibitor, have been isolated from *M. charantia* (Fong et al., 1996; Hamato et al., 1995; Matsuura et al., 2002; Miura & Funatsu, 1995; Mock et al., 1996; Ng et al., 1992a; Parkash et al., 2002; Pu et al., 1996; Puri et al., 2009; Takemoto et al., 1980; Tse et al., 1999; Vesely et al., 1977; Wang & Ng, 1998).

**Antifertility:** β-Momorcharin and α-Momorcharin given intraperitoneally to mice led to an inhibition of implantation. The inhibition of implantation may be a consequence of the deleterious effect on the trophoblast. The termination of the early pregnancy in the mouse may have resulted from an inhibitory effect of the abortifacient protein on the differentiating endometrium. Non-cytotoxic concentrations of these plant proteins can significantly inhibit the mitogenic responses of mouse splenocytes to Concanavalin A, phytohaemagglutinin and lipopolysaccharide in a dose-dependent manner (Adewale et al., 2014; Chan et al., 1992, 1984, 1985, 1986; Law et al., 1983; Leung et al., 1987; Ng et al., 1987a, 1987b; Patil & Patil, 2011; Saksena, 1971; Tam et al., 1984; Yeung et al., 1986). The antifertility effect of *M. charantia* is achieved in a dose-dependent manner. Estrogen level and plasma progesterone of rats were reduced by *M. charantia* (Ng et al., 1988).

**Antispermatogenic:** Extract prepared from *M. charantia* showed antispermatogenic activity. The number of spermatocytes, spermatids and spermatozoa was decreased, and cholesterol level and sudanophilic lipid accumulation increased. MAP30 however did not inhibit the motility or vitality of human sperm cells (Naseem et al., 1998; Patil & Patil, 2011)

**Antiviral:** Cytostatic factors which exhibits antiviral activity have been purified and characterized (Takemoto et al., 1983). A new inhibitor of human immunodeficiency virus (HIV), MAP30, has been isolated and purified from the seeds and fruits of the *M. charantia*. It exhibits dose-dependent inhibition of cell-free HIV-1 infection and replication (Au et al., 2000; Chen et al., 2009; Jiratchariyakul et al., 2001; Lee-Huang et al., 1990, 1995b; Puri et al., 2009; Putnam & Tainer, 2000; Schreiber et al., 1999; Wang & Ng, 2001; Wang et al., 1999, 2008b; Zheng et al., 1999). It is capable of acting against multiple stages of the viral life cycle on acute infection as well as replication in chronically infected cells. Ribosome inactivating proteins are member of the single chain ribosome inactivating protein family which act irreversibly on ribosome by removing adenine residue from eukaryotic ribosomal RNA. Further, MAP30 in combination with low pharmacological doses of dexamethasone and indomethacin may improve the efficacy of anti-HIV therapy (Bourinbaiar & Lee-Huang, 1995). Even limited proteolysis with endopeptidases yields biologically active fragments of MAP30 (Huang et al., 1999). Exposure of human hepatoma HepG2.2.15 cells to MAP30 resulted in inhibition of hepatitis B virus (HBV) DNA replication and HBsAg secretion indicating that MAP30 has inhibiting property (Fan et al., 2009). Lyophilized *M. charantia* extracts prepared from accessions collected in Togo showed high antiviral activity against Sindbis and Herpes simplex type 1 viruses (Beloin et al., 2005; Bourinbaiar & Lee-Huang, 1996). The protein purified from the seed of *M. charantia* inhibited different subtypes of influenza virus like H1N1 and H3N2, but also H5N1 subtype (Pongthanapisith et al., 2013).

α-Momorcharin showed a remarkable antiviral effect and hence could possibly be exploited in crop protection for controlling certain important plant diseases. Tobacco plants pre-treated with α-Momorcharin before inoculation with various viruses showed less-severe symptom and less ROS accumulation (Zhu et al., 2013).

**Gastroprotective/antiulcer:** For the evaluation of the antiulcer activity, ethanol-induced ulcerogenesis model in rats were used. A potent and dose-dependent inhibitory activity was also observed by the administration of ethanol extract of the fruits (Gürbüz et al., 2000). Similarly, the roles of capsaicin-sensitive sensory nerves (CPSN), endogenous nitric oxide, sulphydryls and prostaglandins in the gastroprotection by Momordin Ic on ethanol-induced gastric mucosal lesions were investigated in rats. Momordin Ic potentially inhibited ethanol-induced gastric mucosal lesions (Matsuda et al., 1999). The effect of Momordin Ic was markedly attenuated by the pretreatment with capsaicin, an ablater of CPSN; N(G)-nitro-L-arginine methyl ester, an inhibitor of nitric oxide synthase; N-ethylmaleimide, a blocker of sulphydryls; or indomethacin, an inhibitor of prostaglandins biosynthesis. Fruits of *M. charantia* also showed activity against *Helicobacter pylori* which is responsible for peptic ulcer (Yeşilada et al., 1999).

Antiulcer effect was also evaluated for acetic acid-induced chronic gastric ulcer, pylorus ligation-induced gastric ulcer, ethanol-induced gastric ulcer, stress induced-gastric ulcer, indomethacin-induced gastric ulcer and cysteamine-induced duodenal ulcer model. The methanolic extract of *M. charantia* fruit increases healing of gastric ulcer in different ulcer model (Alam et al., 2009).

**Wound healing:** Powder ointment showed a stastically significant response, in terms of wound-contracting ability, wound closure time, period of epithelization, tensile strength of the wound and regeneration of tissues at wound site which was comparable to reference drug povidone iodine ointment (Pişkin et al., 2014; Prasad et al., 2006; Sharma et al., 2010b; Singer & Clark, 1999). Similarly in another experiment, olive oil macerate of *M. charantia* showed significant wound healing activity both in incision and excision wound models (Ilhan et al., 2015). *M. charantia* ointment has a promising potential for use as an alternative topical medication for diabetic wounds. It accelerates wound healing in diabetic rats, and it is suggested that this occurs by enhancing TGF-β expression (Hussan et al., 2014; Teoh et al., 2009b).

**Antidiarrhoel:** Diarrhoea was induced by oral administration of castor oil in mice and enzymes activities were monitored. The aqueous leaf extract of *M. charantia* increased enzymes activities (maltase, sucrase and lactase) in diarrhoeagenic mice enhancing the absorptive role of these enzymes in the small intestine. This could prevent malnutrition and loss of these enzymes in diarrhoeal conditions (Bakare et al., 2010).

**Antifeedant/larvicidal:** Momordicine II showed significant antifeedant effects on *Pseudaletia separate* and *S. litura* (Yasui et al., 1998). The methanolic extract of *M. charantia* leaves strongly deterred the females *L. trifolii* from ovipositing on kidney bean leaves. Momordicine II and IV further isolated and showed deterred oviposition by *L. trifolii*. Several squash-type serine proteinase inhibitors inhibit the digestive proteinases of the polyphagous insect pest *H. armigera* (Telang et al., 2009). *M. charantia* are toxic to the larval species of mosquito vectors, *Anophels stephensi* and *C. quinquefasciatus* (Batabyal et al., 2009; Maurya et al., 2009). Cucurbitans have inhibitory effects on the feeding and oviposition of *L. sativae* (Ling et al., 2009; Mekuria et al., 2006). In contrast,

concentration of natural fatty acids of young leaves served as attractants for *Epilachna dodecastigma* (Sarkar et al., 2013).

**Toxicological:** Oral administration of aqueous extract of *M. charantia* causes a decrease in haemoglobin concentration which can lead to anaemia (Temitope, 2014). A haemagglutinin and protein (inhibitor) purified from the seeds of *M. charantia* inhibited protein and subsequently DNA synthesis in normal (mitogen-stimulated) and leukaemic human peripheral blood lymphocytes (Licastro et al., 1980).

## Important Secondary Metabolites Found in Cucurbitaceae

In human food conception, this family contributes highest rank among the plant families. Considering its common food diet, phytochemical constituents and pharmacological properties of certain important cucurbits or gourds of Cucurbitaceae family are reviewed in the present chapter. Gourd vegetables contain an array of novel and biologically active phytochemicals. Only limited study had been carried out considering its noticeable importance in the human health. The major class of compounds reported in Cucurbitaceae are cucurbitacins, proteins and enzymes, sterols, triterpenes, phenolics, flavonoids, polysaccharides, etc. The structures of some commonly available secondary metabolites in Cucurbitaceae belonging to different classess are mentioned in the Figures 9.2, 9.3 and 9.4.

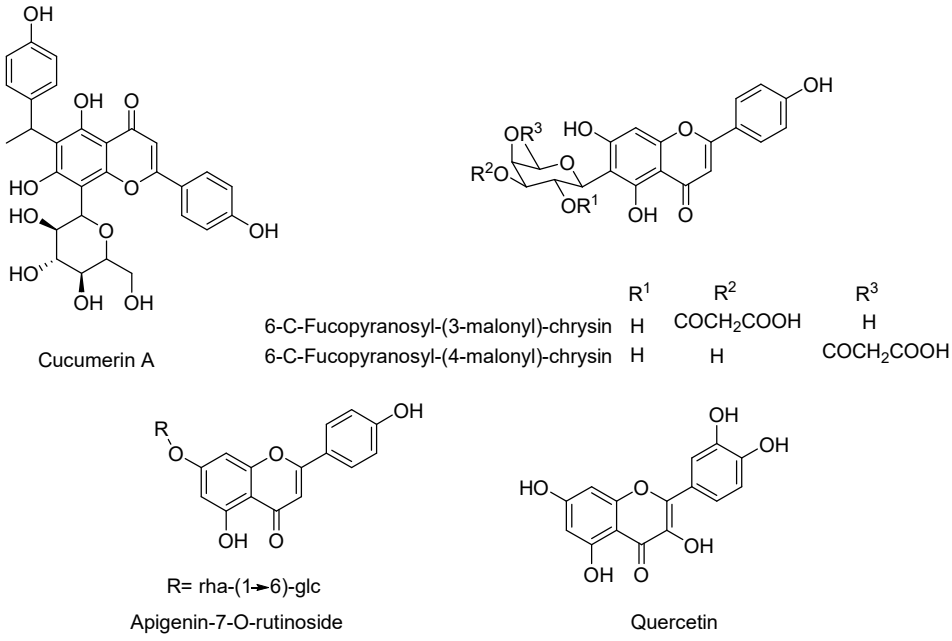



**Figure 9.2.** Selective flavonoids from Cucurbitaceae.

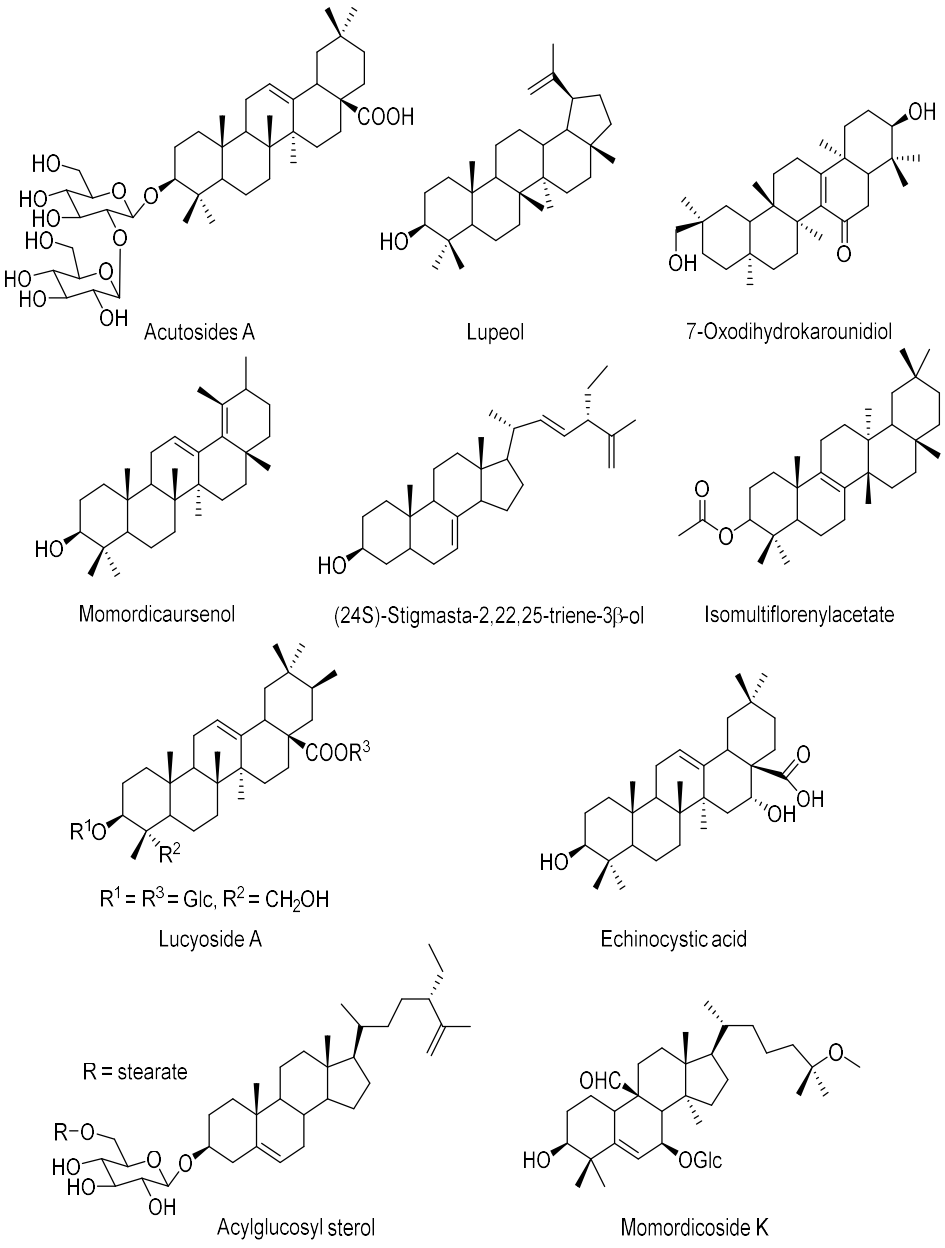



**Figure 9.3.** Selective sterols and triterpenoids from Cucurbitaceae.

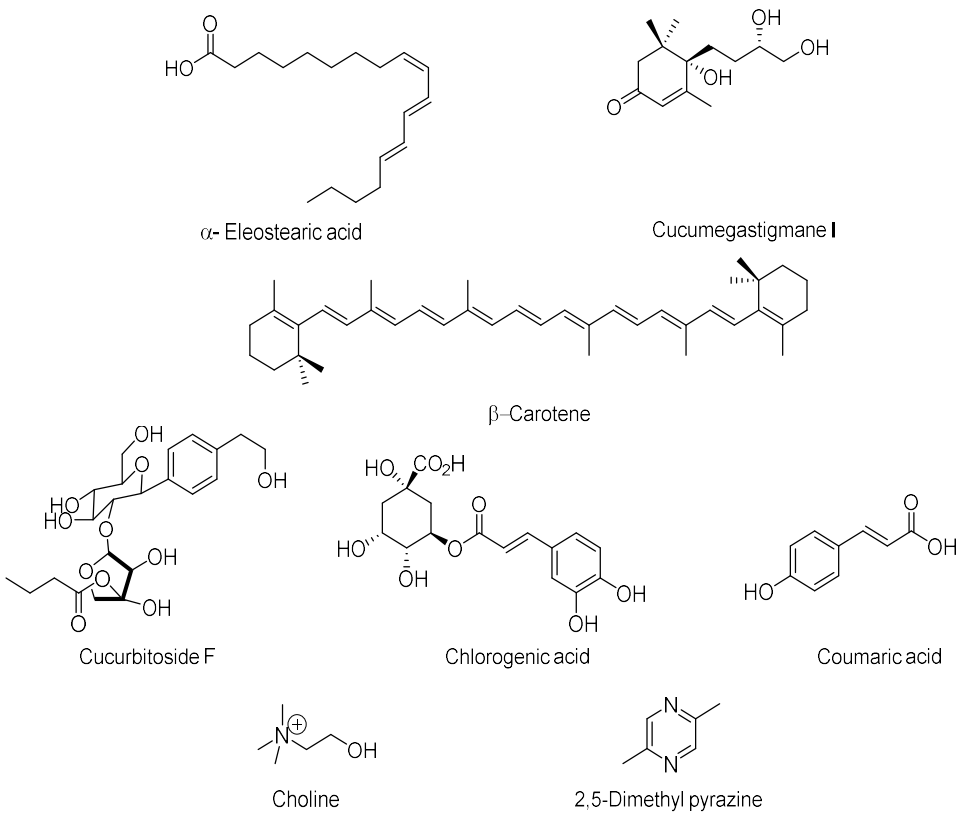
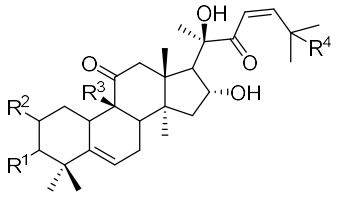



**Figure 9.4.** Different miscellaneous compounds from Cucurbitaceae.

## *Cucurbitacins*

Literature review reveals that cucurbitacins are widely distributed through out the family Cucurbitaceae. For examples, Cucurbitacin B in *Luffa* and *Trichosanthes*, Cucurbitacin E in *Cucurbita*, and Cucurbitacin A in *Cucumis.* It is reported that the bitter flavour of cucurbits or gourd is due to cucurbitacins. Cucurbitacins constitute a group of diverse triterpenoids. They are highly oxygenated tetracyclic triterpenes containing cucurbitane skeleton characterized as 19-(10→9β)-abeo-10α-lanost-5-ene (Figure 9.5). The cucurbitacins differ with respect to oxygen functionalities at various positions and arbitrarily divided into twelve main categories. It is distributed in Cucurbitaceae in free forms as well as in their glycosidic forms. A number of compounds of this group have been investigated for anticancer, anti-inflammatory, antifertility activities, etc. Cucurbitacins are noted for their cytotoxic behaviour and are important from an anticancer drug development perspective.




| | $R^1$ | $R^2$ | $R^3$ | $R^4$ |
|---|---|---|---|---|
| Cucurbitacin A | O | OH | $CH_2OH$ | OCOCH |
| Cucurbitacin B | O | OH | H | OCOCH |
| Cucurbitacin C | OH | H | $CH_2OH$ | OCOCH |

**Figure 9.5.** Structure of cucurbitacins.

## *Proteins and Enzymes*

Enzymes and proteins are unique in nature and possess different biological acitivitites which assist us in protecting from chronic diseases. On the basis of their nature and biological activity, proteins from Cucurbitaceae family can be classified as pathogen related proteins, ribosomal inactivating proteins, protein inhibitors, vicilin like proteins and others (Rajasree et al., 2016). Their amino acid compositions and N-terminal amino acid sequences are differ according to nature of acitivity. The proteins exhibit abortifacient, antitumour, ribosome inactivating, immunomodulatory and anti-human immunodeficiency virus activities. The most significant biological activity of the ribosome inactivating proteins discovered to date is probably the anti-HIV activity. Proteins, α- and β-momorcharins from seeds of *Momordica* and trichosanthin from tubers of *Trichosanthes* are ribosome inactivating proteins. Luffaculin, luffin-a and luffin-b from seeds of *Luffa* are abortificient. Trypsin inhibitors, CPPTI-I and CPPTI-II and serine proteinase inhibitor from *Cucurbita* are protein inhibitors (Ng et al., 1992a).

## Conclusion

The pharmacolgocial review undertaken in this family displayed scientific evidences for traditionally claimed multidisciplinary usage of these plants in curing various types of diseases. Cucumber pulp has been used to clean skin for centuries. The fruit pulps having natural α-hydroxyacid compounds like lactic acid, the anti-hyaluronidase and anti-elastase activities of the lyophilized juice of *C. sativus* have been proved. The diuretic property of leaf powder of cucumber has also scientifically verified. The medicinal properties of *C. pedata* are popularly attributed to anti-inflammatory, hypoglycemic and hypocholesterolemic, and were confirmed by scientific experiments. The compounds isolated from *L. cylindrica* have bronchodilator activity which supports its use in folk medicine for chronic bronchitis. Two immunologically distinct glycoproteins from *L. cylindrica* cause mid term abortion showing its traditionally reported abortifacient property. The active compounds in *C. pepo* seeds are $\Delta^5$-, $\Delta^7$- and $\Delta^8$-sterols. $\Delta^7$-sterols,

which are largely predominant in *C. pepo*, are considered to be the key active constituents of pumpkin seed in the treatment of benign prostatic hyperplasia. From the experiment, *T. dioca* showed gastroprotective effect, and *Patoladi kasaya*, a polyherbal formulation consisting *T. dioca*, has been practiced for improvement of ulcer in Ayurvedic medicine. *B. hispida* as an important ingredient of *Kusmanda lehyam*, and it has been widely used for the treatment of epilepsy and other nervous disorders. Experiments on mouse validate the reported pharmacological properties. The regular intake of *L. siceraria* fruit juice is claimed to relieve cardiovascular disorder and it is proved in laboratory that *L. siceraria* possessed cardioprotective effect against doxorubicin-induced and isoprenalin-induced cardiotoxicity in rats. The leaves of *T. cucumerina* are a potent hair growth promoter which supports the traditional claim. The snake gourd leaves are quite effective in dealing with the treatment of hair and scalp disorders like alopecia, and various formulations have already been marketed. More than over 100 studies using modern techniques have authenticated the use of *M. charantia* in diabetes and its complications. Besides these traditional uses, the extract of *Sechium* was able to reduce the radio labeling in RBC when blood is incubated with stannous chloride and 99mTc in Wistar rat.

Regular consumption of fruits, vegetables, whole grains and other plant foods has been negatively correlated with the risk of the development of chronic diseases. The key is to encourage consumers to increase the total amount servings of fruits and vegetables in all forms available. Increasing evidence suggests that the health benefits of fruits, vegetables, whole grains and other plant foods are attributed to the synergy or interactions of bioactive compounds and other nutrients in whole foods. Each vegetable contains a unique combination of phytonutriceuticals (vitamins, minerals, dietary fiber and phytochemicals), a great diversity of vegetables should be eaten to ensure that individual's diet includes a combination of phytonutriceuticals and to get all the health benefits. The importance of fiber for the normal function of the digestive system has been long appreciated. The dietary fiber content and type of different vegetables may also contribute to the overall health benefit, such as improving bowel transit, lowering cholesterol, helping manage blood glucose concentrations, and by transporting a significant amount of minerals and phytochemicals linked to the fibre matrix through the human gut. Widespread micronutrient deficiency is still prevalent in many developing Asian countries. The most practical way to tackle these deficiencies is to integrate micronutrient-rich foods in existing diets. Vegetables are efficient sources of micronutrients. Different peculiar taste included in our diet might only contribute satiety and hunger. Diversities in gourds might fulfill our appetite providing diverse taste and nutritional satitation. In view of evidence reported in the literature regarding the medicinal properties of gourds, the importance of gourds in a well balanced diet, and therefore, should be strongly advocated.

**Abbreviations:** ABTS = 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid); ACE = angiotensin-converting enzyme; ALP = alkaline phosphatase; ALT = alanine transaminase; AMPK = AMP-activated protein kinase; AST = aspartate transaminase; bFGF = basic fibroblast growth factor; CHP = cumene hydroperoxide; CNS = central nervous system; CPD = cyclobutane pyrimidine dimer; DFTQC = Department of Food Technology and Quality Control; DNA = deoxyribonucleic acid; DPPH = 1,1-diphenyl-2-picrylhydrazyl; EAC = Ehrlich's ascites carcinoma; ECG = electrocardiogram;

ESI-MS = electrospray ionization mass spectrometry; FRAP = ferric-reducing antioxidant power; GC-MS = gas chromatography-mass spectrometry; GoN = Government of Nepal; HBV = hepatitis B virus; HDL = high density lipoprotein; HeLa = human cervical carcinoma; HIV = human immunodeficiency virus; HL = leukemia cell; HMG-CoA = 3-hydroxy-3-methylglutaryl coenzyme A; HPLC = high performance liquid chromatography; HPTLC = high performance thin layer chromatography; IFN-γ = interferon-gamma; IGT = impaired glucose tolerance; IL = interleukin; LC-MS = liquid chromatography-mass spectrometry; LDH = lactate dehydrogenase; LDL = low density lipoprotein; MDA = malondialdehyde; MoAD = Ministry of Agricultural Development; MTT = 3-(4,5-dimethylthiazole-2-yl)-2,5-diphenyltetrazolium bromide; NIDDM = non-insulin dependent diabetes mellitus; NK = natural killer; NSAID = non-steroidal anti-inflammatory drug; OGTT = oral glucose tolerance test; P-gp = P glycoprotein; PPAR = peroxisome proliferator-activated receptor; PTP = protein-tyrosine phosphatase; RBC = red blood cell; ROS = reactive oxygen species; SGOT = serum glutamic oxaloacetic transaminase; SGPT = serum glutamate pyruvate transaminase; SPME = solid-phase microextraction; STZ = streptozotocin; TEAC = trolox equivalent antioxidant capacity; TGF-β = transforming growth factor-beta; TNF-α = tumour necrosis factor-alpha; VLDL = very low density lipoprotein; WBC = white blood cell.

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# Author's Biography



Dr. Sajan Lal Shyaula is a Senior Scientific Officer at Nepal Academy of Science and Technology (NAST). He obtained his Ph.D. degree from HEJ Research Institute of Chemistry, University of Karachi, Pakistan, in 2010. He carried out his post-doctoral studies at Shanghai Institute of Materia Medica, Chinese Academy of Science, Shanghai, under CAS-TWAS postdoctoral fellowship. He has published more than 24 research articles in reputed international and national peer-reviewed journals, and has written book chapters in renowned international publications. Dr. Shyaula has isolated hundreds of varieties of bioactive compounds from different plant species found in Himalaya region of Nepal. The research projects were mostly focused in identification of bioactive constituents from medicinal plants and scientific verification of the traditional uses.



Prof. Dr. Mangala Devi Manandhar is an Academician of Nepal Academy of Science and Technology (NAST). She has completed her Ph.D. from Central Drug Research Institute (CDRI), Lucknow and submitted to the Kanpur University, Kanpur, India (1976). She was Head of Department, Central of Department of Chemistry, Tribhuvan University, Kathmandu, Nepal from 1992–2002. She was involved in teaching and research since 1970. She has published more than 50 research articles in reputed international journals. She was member of Executive Board, Tribhuvan University (2007–2010); senate member, Tribhuvan University (1996–2001); president, Nepal Chemical Society (1996–1998); and member, Third World Organisation for Women in Science (TWOWS), Triesty, Italy. She was awarded with Shree Panch Birendra Bigyan Tatha Prabidhi Pragyan Puraskar, 2057/58 and Rastriya Pratibha Puruskar, 2055.

# Chapter 10

## Bioactive Phytochemicals from Brassicaceae Family

**Meena Rajbhandari**
*Research Center for Applied Science and Technology (RECAST)*
*Tribhuvan University, Kirtipur, Kathmandu, Nepal*
Email: karmacharyameena@gmail.com

*From ancient time,* brassicaceae *vegetables are one of the most consumed vegetables worldwide.* Brassicaceae *vegetables have cultural and religious values in Nepal, and Nepalese consume fresh, dried or fermented brassicaceae vegetables depending on their availability. Cauliflower, cabbage and raddish occupied about 35% of total production of vegetables in Nepal. Although actual data are not available, production and consumption of fresh leafy vegetables are high in Nepalese culture. A diet rich in brassicaceae vegetables has long been considered healthy. Consumption of these vegetables reduced the risk of chronic diseases, such as cancer, inflammation, neurodegenerative and cardiovascular diseases, due to the presence of various phytochemicals, such as carotenoids, phenolics, phytoalexins, vitamins and glucosinolates. Many reports on phytochemical investigations as well as profiling of phytochemicals by HPLC-MS in brassicaceae vegetables grown in the USA, Europe and Asian countries are available. However, such scientific investigations and profiling are lacking in the context of vegetables grown in Nepal. As it is well known that the quality and quantity of secondary metabolites depends on the plant variety, parts, developmental stage, agronomic management and climatic conditions, it is necessary to assess the quality of Nepalese of crucifer vegetables which provide valuable information for developing new cultivars with an appropriate level of bioactive phytochemicals.*

**Keywords:** Brassicaceae vegetables; glucosinolates; health benefit; phenolic, phytoalexins.

## Introduction

It is well known that vegetables have profound health benefits. In the last couple of decades, consumer's perception about food has considerably changed as it was evident that food and food components significantly influence human health and well-being. More and more consumers now believe that food contribute to their health through prevention of nutrition-related diseases and improvement of physical and mental well-being, instead of satisfying their hunger. Epidemiological evidence supports that consumption of fruits and vegetables is associated with a reduction in the incidence of

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cancer at multiple sites (Block et al., 1992). Among the vegetables belonging to several families, brassicaceae vegetables and their seeds have been used in traditional Chinese and Ayurvedic medicine (Ram et al., 2009; Sham et al., 2013). They have been a dietary staple around the world for thousands of years. Extracts from these vegetables were thought to have medicinal and curative properties, and both Pythagoras and Hippocrates understood the medicinal properties of mustard. Hippocrates widely recommended mustard as a natural treatment for scorpion stings in their statement 'Let food be thy medicine and medicine be thy food' (Fenwick & Heaney, 1983). Radishes, which probably originated in China, were cultivated extensively by the Egyptians in the time of the Pharaohs and were highly esteemed by the ancient Greeks (Hendrick, 1972). During the middle ages, brassicaceae vegetables achieved widespread popularity and became common across Europe. By the 16$^{th}$ century, vegetables like cabbage were considered to cure many ailments. Cabbage has widespread use in the traditional medicine, in alleviation of symptoms associated with gastrointestinal disorders, such as gastritis, peptic and duodenal ulcers, and irritable bowel syndrome, as well as in the treatment of minor cuts, wounds and mastitis. In fact, many Germans and Flemish even began consuming cabbage before and after meals to promote a better health. In the following years, brassicaceae vegetables were used to treat many disorders from swollen spleens to heart pain and venomous snake bites. Mustard seed was said to cure toothaches while horseradish root was mixed with white wine and bitter apple to treat jaundice (Link, 2018). The initial chemical observations were made at the beginning of the 17$^{th}$ century to understand the sharp and pungent aroma and bitter taste of mustard seeds (Challenger, 1959). Today, these nutritious vegetables have spread throughout the world and are the major ingredients in many types of cuisine.

In Latin, the word '*Cruciferae'* means cross-bearing, the plants in the Cruciferae family have flowers with four equal-sized petals in the shape of a 'cross'. The Cruciferae or Brassicaceae family are among the oldest cultivated plants known (Snowdon, 2007), and represented by 341 genera and 3977 species of economically important and dominant food crops worldwide (Franzke et al., 2011). They are also known as the vegetables of mustards or cabbage family, and one of the most dominant food crops that consumed all over the world due to their easy availability at the local markets, cheap and consumers' preference. The genus *Brassica* is the most important within the Brassicaceae family. The genus is categorized into oilseed, forage, condiment and vegetable crops by using their buds, inflorescences, leaves, roots, seeds and stems. Oilseed crucifers constitute the third largest source of edible vegetable (Kimber & McGregor, 1995). They are cultivated worldwide and constitute an extremely valuable group of plants. Enormous types of vegetables, such as broccoli (*Brassicaoleracea* var. *botrytis*), cauliflower (*Brassica oleracea* var. *italica*), kale (*Brassica oleracea* var. *acephala*), radish (*Raphanussativus*) and a variety of cabbages (*Brassica oleracea*), are consumed annually (Kimber & McGregor, 1995). Brown- (*Brassica juncea*) and white-mustard (*Sinapis alba*) seedsas well as wasabi (*Wasabiae japonica*) are well-known condiments (Hemingway, 1995; Chadwick et al., 1993). The different *B. oleracea*are not distinguishable from one another taxonomically, but only by horticultural category of cultivar groups. At least 40 types of brassicaceae vegetables are consumed worldwide. These vegetables have different colours, shapes and sizes. Additionally, these seasonal vegetables may be stored for long

periods of time and hence could be available throughout the year. Because of their large and frequent consumption, they may become a significant source of nutrients and bioactive compounds in the daily diet. They have several nutritional benefits. They are good sources of a variety of nutrients and phytochemicals that synergistically contribute to health promotion. The major nutritional constituents of brassicaceae vegetables are carbohydrates, proteins, vitamins and minerals including copper, iron, selenium, calcium, manganese and zinc (Manchali et al.,2012). Some common brassicaceae vegetables are mentioned in Table 10.1.

**Table 10.1.** Some common brassicaceae vegetables consumed in Nepal

| Common name | Local name | Scientific name |
|---|---|---|
| Cabbage | Banda | *Brassica oleracea* var. *capitata* |
| Cauliflower | Cauli | *Brassica oleracea* var. *italica* |
| Broccoli | Broccoli | *Brassica oleracea* var. *botrytis* |
| Brussels sprout | - | *Brassica oleracea* var. *gemmifera* |
| Kohlrabi | Gyathkobi | *Brassica oleracea* Gongylodes group |
| Turnip | Salgam | *Brassica rapa* subsp. *rapa* |
| Chinese or Napa cabbage | - | *Brassica rapa* subsp. *pekinensis* |
| Mustard green | Rayo | *Brassicajuncea* |
| Black mustard | Tori | *Brassica nigra* |
| Yellow mustard | Sarso | *Brassica hirta* |
| Rapeseed | - | *Brassica napus* subsp. *napus* |
| Bok choi | Chinese cabbage | *Brassica rapa* subsp. *chinensis* |
| White mustard | - | *Sinapis alba* |
| White raddish, Daikon | Mula | *Raphanussativus* var. *longipinnatus* |
| Cherry raddish | Dale mula | *Raphanusraphanistrum* subsp. *sativus* |

## Bioactive Phytochemicals of Brassicaceae Vegetables

Brassicaceae vegetables contains well-known antioxidants, such as vitamin C, vitamin E, vitamin K, carotenoids, and antioxidant enzymes, such as catalase, superoxide dismutase, peroxidase, folate, and fibers (Singh et al., 2010). Besides, brassicaceae vegetables are also rich in bioactive, non-nutrient phytochemicals. The beneficial effects of brassica vegetables on human health have been somewhat linked to these phytochemicals that may help to lower inflammation and reduce the risk of developing cancer that include sulphur containing glucosinolates, anthocyanins, flavonoids, terpenes, S-methylcysteine sulphoxide, coumarins and other minor compounds (Björkman et al., 2011; Ferreres et al., 2009; Liu, 2004). In the 20$^{th}$ century, epidemiological studies were conducted with the aim to find out the cancer-protecting properties of brassicaceae vegetables (Verhoeven et al., 1996). A meta-analysis carried out over 18 years in Europe revealed the reduction in the risk of

several common cancers, such as colorectal, breast, kidney and upper digestive tract cancers, by the weekly consumption of these vegetables (Bosetti et al., 2012). As these vegetables are a source of vast array of phytochemicals, the mechanism by which these vegetables counteract cancer is still not solved (Björkman et al., 2011).

## Phenolics and Health Benefits

The consumption of vegetables of *Brassica* species is increasing because of their nutritional value and good source of natural antioxidants due to the presence of high levels of carotenoids, tocopherols, ascorbic acid and phenolic compounds (Podsedek, 2007). Among phytochemicals possessing antioxidant capacity, phenolic compounds are the most important groups. They are the best studied and extensively reviewed metabolites. They have positive effect in the management of obesity, type 2 diabetes, metabolic syndrome, neurodegenerative diseases, atherosclerosis and cancer (Bahramsoltani et al., 2019; Chiva-Blanch & Badimon, 2017; Farhat et al., 2017; Guasch-Ferré et al., 2017; Hossen et al., 2017; Russo et al., 2017). It was reported that polyphenols, in synergy with other compounds, significantly contribute to the biological activity of brassica plants (Šamec et al., 2011, 2017). The most widespread and diverse groups of polyphenols in *Brassica* species are flavonoids (mainly flavonols), hydroxycinnamic acids and anthocyanins. Flavonoids and the hydroxycinnamic acids are the most prevailing and heterogeneous group of polyphenols in *Brassica* species (Cartea et al., 2011).

Quercetin, kaempferol, isoquercitrin and isorhamnetin are the main flavonols present in brassica crops. They are most commonly found as O-glycosides. Conjugation occurs most frequently at the 3-position of the C-ring, but substitutions can also occur at the 5, 7, 4′, 3′ and 5′ positions (Aron & Kennedy, 2008; Crozier et al., 2007; Hollman & Arts, 2000). The main flavonol glycosides of *B. oleracea* varieties are non-acylated and acylatedkaempferol glycosides. They are generally acylated with hydroxycinnamic acids, such as ferulic, sinapic, *para*-coumaric and caffeic acids. The main monoacylated flavonol glycosides are kaempferol-3-O-sinapoyl-sophoroside-7-O-glycoside and kaempferol-3-O-feruloyl-sophoroside-7-O-glycoside, and non-acylated glycosides are kaempferol-3-O-glucoside and kaempferol-3-O-sophoroside-7-O-glycoside (Price et al., 1998; Vallejo et al., 2004). Hydroxycinnamic acids derivatives are abundant in brassica vegetables. The content of hydroxycinnamic acid derivatives in *B. oleracea* (broccoli, cabbage and cauliflower) are generally higher than those of *B. rapa*. The most common hydroxycinnamic acids are *para*-coumaric, sinapic, isosinapic, caffeic and ferulic acids. Cabbage contained ferulic and sinapic acid derivatives conjugated with gentiobios, such as 1,2-disinapoylgentiobiose and 1-sinapoyl-2-ferulicgentiobiose. Feruloylquinic and caffeoylquinic acid derivatives are common in some varieties of raddish (Li et al., 2018).

Anthocyanins, such as pelargonidin, cyanidin, delphinidin, peonidin, petunidin and malvidin, are present in fruits and flowers, and they are responsible for red, blue and purple colourations. In addition, they are also found in leaf, stem, seed and root tissues. Nevertheless, in certain fruits and vegetables, anthocyanins exist in only smaller amounts and they cannot bringa proper colour. They are involved in the protection of plants against excessive light and also have an important role in attracting pollinating insects (Agati & Tattini, 2010; Mageney et al., 2017; Scalzo et al., 2008). The red pigmentation

of red cabbage and purple cauliflower is caused by anthocyanins. The major anthocyanins identified in red cabbage or broccoli sprouts are cyanidin-3-O-(sinapoyl) (feruloyl) diglucoside-5-O-glucoside and cyanidin-3-O-(sinapoyl) (sinapoyl) diglucoside-5-O-glucoside. The quantity varies among the species and within the species (Moreno et al., 2010; Prior, 2005). Structures of some phenolics are given in Figure 10.1.

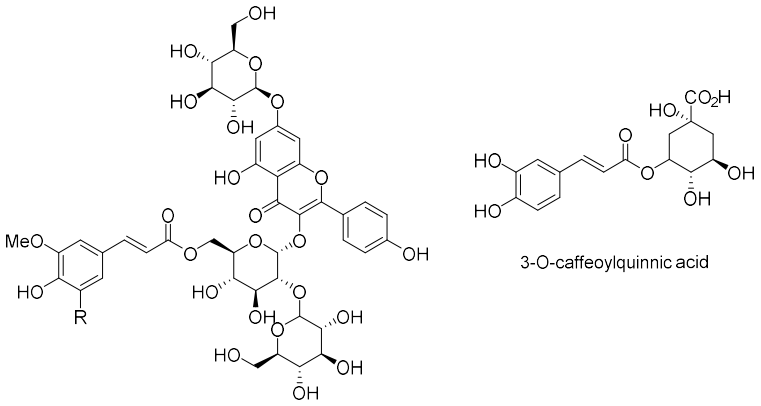



**Figure 10.1.** Structures of some phenolics isolated from crucifers.

Phytochemicals from brassica vegetables may act on different and complementary levels. They prevent oxidative stress, induce detoxification enzymes, stimulate immune system, decrease the risk of cancers, inhibit malignant transformation and carcinogenic mutations as well as reduce proliferation of cancer cells (Boivin et al., 2009; Forman et al., 2006; Herr & Büchler, 2010; Kestwal et al., 2011). Reactive oxygen species (ROS) in the body can cause lipid and protein oxidation, DNA damage, base modification and modulation of gene expression. They play an important role in etiopathology of many diseases, including atherosclerosis, vasospasm, cancers, stroke, heart attack and liver injury. Imbalance between ROS and antioxidants causes oxidative stress. Oxidative stress may be caused by antioxidant deficiency in the diets or increased production of free radicals by stress, smoking and environmental contaminations (Lee et al., 2004).

## Glucosinolates and Health Benefits

Consumption of vegetables of *Brassica* species has been strongly associated with the reduced risk of chronic diseases, such as cardiovascular, cancer, diabetes, Alzheimer's, cataracts and age-related functional decline (Cohen et al., 2000; Knekt et al., 2002; Zhang & Hamauzu, 2004). Additionally, human atherosclerosis and age-related brain and heart degeneration are mostly related with DNA changes (Flora et al., 1997; Fimognari et al., 2012; Izzotti et al., 1999). The formation of cancer is a prolonged and complex process consisting of initiation, promotion and progression (Ferrarini et al., 2012). Brassicaceae vegetables consumption appears to lower the risk for some kinds of cancers, like renal cancers, prostate and possibly colorectal due to the presence of the glucosinolates.

The evidence is however not as strong for lung, breast and oral cancers (Janosik et al., 2018).

Glucosinolates are a group of natural products mainly found in brassicaceae vegetables. These compounds are responsible for the pungent aroma and bitter flavour that distinguish brassicaceae vegetables from other vegetables (Higdon et al., 2007). They are very stable, sulphur containing and water-soluble secondary metabolites. The structure of the glucosinolates consists of a β-D-glucose moiety linked to a sulphatedthiohydroximate. Presence of a glucose moiety and ionic forms makes glucosinolates hydrophilic and non-volatile. Glucosinolates are precursors of isothiocyanates and are typically present at much higher levels than their cognate isothiocyanates in fresh plants. Glucosinolates are divided into a number of chemical classes on the basis of their structural similarities. Around 200 different aliphatic, aromatic and indolic glucosinolates are known today, but their presence is genetically predetermined andtheir content varies among different brassicaceae vegetables. Each type of brassicaceae shows a characteristic glucosinolates profile that includes more than ten different glucosinolates in each species/varieties, although only 3-4 are predominate (Fahey et al., 2001). The most common glucosinolates are those containing either straight or branched carbon chains. Many of these compounds also contain double bonds, hydroxyl or carbonyl groups, or sulphur linkages in various oxidation states, such as methyl-, thioalkyl-, methylsulphinylalkyl- or methylsulphonylalkyl-groups. It is reported that sinigrin is the major component in mustards, such as B. juncea, Brassicacarinata and Brassicanigra, glucosinalbinis predominant in S. alba, and progoitrin in *B. napus*and *B. oleracea* (Kumar & Andy, 2012). Aliphatic glucosinolates are mostly present in *Brassica* genus, indole glucosinolates are present in traces while indolylglucosinolates are major glucosinolates in the vegetative parts of *Brassica* species but lacking in seed (Bergmann, 1970; Josefsson, 1970). Sinalbin has been reported to occur only in trace amounts in the seeds of *B.napus*, glucoraphanin in *B. oleracea* var. *botrytis*, glucoraphasatin in *R. sativus* (Kjær, 1960; Razis & Noor, 2013). The quantity and quality of glucosinolates in brassica plants depend on plant variety, parts, age, developmental stage, agronomic and climatic conditions (Borowski et al., 2008; Kushad et al., 1999; Vallejo et al., 2003). Glucosinolate content in plants is about 1% of dry weight in some tissues of the brassica vegetables, although the content is highly variable and can approach to 10% in the seeds of some plants (Kushad et al., 1999; Rosa & Rodrigues, 1999). Structures of some typical glucosinolates are illustrated in Figure 10.2.

The relatively nonreactive glucosinolates are converted to isothiocyanates upon wounding of the plant, mastication of fresh plants or by tissue damage during cultivation, harvesting, shipping or handling (see Figure 10.2). This tissue damage releases myrosinase. Glucosinolates and myrosinase are stored in separate plant compartments and release only after cell rupture. The breakdown products of glucosinolate are toxic to herbivorous and pathogens, and cause deterrent effect. They are toxic to plants themselves and they cause the characteristic sharp taste of brassicaceae vegetables (Bones & Rossiter, 2006; Halkier & Gershenzon, 2006; Keck & Finley, 2004).

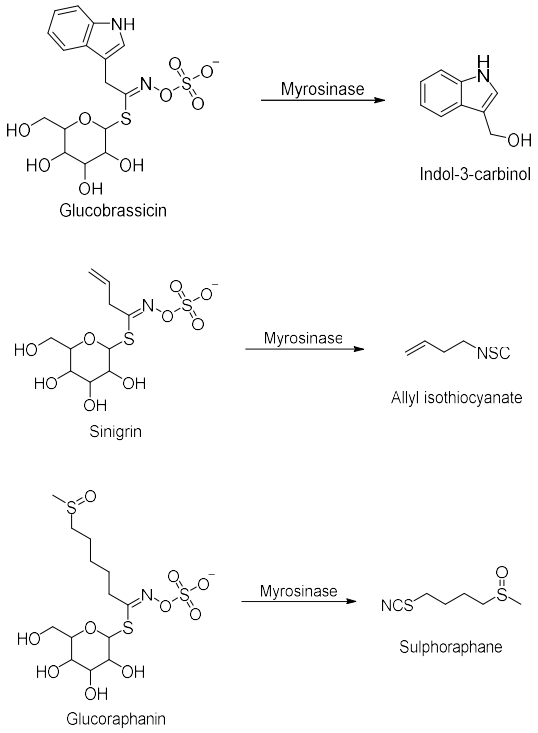



**Figure 10.2.**Structures of some glucosinolates.

After hydrolytic cleavage of the glucosyl moiety, the sulphate moiety is released non-enzymatically to form thiohydroxamate-O-sulphonate from both aliphatic and aromatic glucosinolates. This unstable intermediate then rearranges to form isothiocyanates or other breakdown products, such as epithionitriles, thiocyanates, nitriles and oxazolidinethiones, in a manner that depends upon the glucosinolate substrate as well as the reaction conditions, such as pH. Epithionitriles and oxazoldinethiones are formed from glucosinolates with a hydroxyl group at the 2-position of the side chain. Low pH tends to favour production of allylcyanide; however, under neutral and alkaline pH conditions, allylisothiocyanate is formed as predominant breakdown product of sinigrin (Rouzaud et al., 2004; Uda et al., 1986) (see Figure 10.3). Process of cooking vegetables destroys much of the naturally available myrosinase; however, glucosinolates can still be converted into isothiocyanates inside the body but much less efficiently than when myrosinase is available. The conversion can occur in the colon where native gut bacteria hydrolyze the glucosinolates (Getahun & Chung, 1999; Johnson, 2002). Hydrolysis of progoitrin and epiprogoitrin gives rise to hydroxyalkenylisothiocyanates. These compounds cyclize to oxazolidine-2-thiones which have goitrogenic effects in mammals. Radish contains goitrogenic constitutents. The mechanism of action of most goitrogens is to diminish the supply of iodide to the thyroid or interfere with thyroxine production, thus

causing the thyroid enlargement (Greer, 1950; Hanson et al., 1974; Webster & Chesney, 1930).

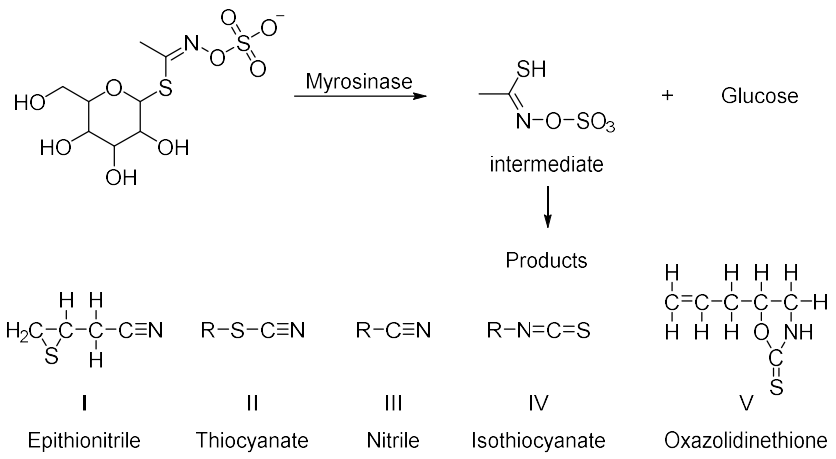



**Figure 10.3.**Hydrolysis of glucosinolate with the formation unstable intermediate.

The cancer chemoprotective activity of crucifers is due to the presence of isothiocyanates. Hydrolysis of glucobrassicin gives indole-3-carbinol. Similarly, hydrolysis of glucoraphanin gives sulphoraphane (see Figure 10.3). These compounds have potentiality to reduce the risk of various types of cancers, diabetes, atherosclerosis, respiratory diseases, neurodegenerative disorders, ocular disorders and cardiovascular diseases (Elbarbry & Elrody, 2011; Fujioka et al., 2016). A strong correlation was observed between the increased consumption of brassicaceae vegetables and the reduction of the incidence of many types of cancer (Talalay & Zhang, 1996). Intake of brassicaceae vegetables about two servings per day may result in as much as a 50% reduction in the relative risk for cancer at certain sites (Wattenberg et al., 1986). Certain glucosinolates, such as benzyl-, *para*-hydroxybenzyl- and 2-hydroxybut-3-enyl-glucosinolates, have themselves been reported to induce mammalian Phase 2 enzymes of detoxication (Fahey & Talalay, 1999; Wattenberg et al., 1986). The enzyme myrosinase, that activated in damaged plant tissue and also present in the microflora of the human digestive tract, converts these glucosinolates to a number of compounds including thiocyanates, nitriles and isothiocyanates, which have potential antiproliferative, apoptosis-promoting, redox regulatory and Phase 1 enzyme inhibiting roles in addition to Phase 2 enzymes detoxication (Nakamura et al., 2000; Zhang & Talalay, 1994, 1998). Sulphoraphane has been shown to elevate levels of mammalian Phase 2 enzymes by antioxidant response element (ARE)-mediated transcriptional activation (Talalay et al., 1995). Studies show that sulphoraphane reduced the incidence, delayed the appearance of and reduced the size of tumours in a rat mammary tumour model (Fahey et al., 1997). It also serves as an indirect antioxidant (Fahey & Talalay, 1999), exerts selective cytostatic and cytotoxic

effects on human colon cancer cells *in vitro* (Gamet-Payrastre et al., 1998), inhibits cytochrome P450, and induces cell cycle arrest and apoptosis in human colon cancer cells *in vitro* (Gamet-Payrastre et al., 2000; Mahéo et al., 1997; Morel et al., 1997). The antibacterial activities of glucosinolates and isothiocyanates, and their antifungal activity have been recognized for many decades. The activity of isothiocyanates against numerous human pathogens indicated the medicinal properties of brassicaceae vegetables (Hartwell, 1982; Hashem & Saleh, 1999; Lin et al., 2000).

## Phytoalexins and Health Benefits

Cruciferes synthesizephytoalexins as an arsenal of chemical defenses in response to pathogen invasion and other types of stress. They have unique structures, significant ecological role and applications. They are toxic to the plants. They may have synergistic, additive or antagonistic activities. The first reported phytoalexins from Brassicaceae are brassinin, 1-methoxybrassinin and cyclobrassinin (Bailey & Mansfield, 1982; Takasugi et al., 1986).They have potential chemopreventive activity. Several indolephytoalexins like brassinin, spirobrassinin, brassilexin, camalexin, 1-methoxy spirobrassinin, 1-methoxy spirobrassinol and methoxyspirobrassinol methyl ethershave displayed significant antiproliferative activity against various cancer cells. This activity was associated with the modulation of transcription factors regulating cell cycle, differentiation and apoptosis (Pilátová et al., 2005). It is shown that 1-methoxybrassinin displayed the most potent antiproliferative activity, which was attributed to cell cycle arrest and apoptosis induction. The phytoalexins cyclobrassinin, spirobrassinin and brassinin exhibited cancer chemopreventive activity in models of mammary and skin carcinogenesis. Till today, 39 phytoalexins have been reported. Most of these phytoalexins contain sulphur, except methyl 1-methoxyindole-3-carboxylate, indolyl-3-acetonitrile, isalexin, caulilexins B and C, and arvelexin (Pedras et al., 2007b). Rutalexin, 1-methoxyspirobrassinin, 1-methoxybrassitin, 1-methoxybrassinin and spirobrassini were isolated from kohlrabi. Brassicanal A, brassicanal C, brassinin, cyclobrassinin, dioxibrassinin, 1-methoxybrassenin A, 1-methoxybrassenin B, 4-methoxybrassinin, 1-methoxybrassitin and spirobrassinin were isolated from white cabbage. Caulilexins A-C, isalexin, 1-methoxybrassinin, 1-methoxybrassitin and spirobrassinin were isolated from cauliflower florets. Caulilexin A is the first example of an indolyl disulphide phytoalexin. Rapalexins A and B, isolated from *B. rapa*, are the most recently reported phytoalexins. These compounds are the first examples of naturally occurring aromatic isothiocyanates (Monde et al., 1990, 1991a, 1991b; Pedras et al., 2004, 2006, 2007a). The structures of some typical phytoalexins are shown in Figure 10.4.

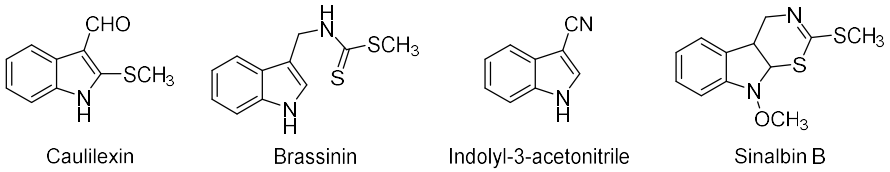



**Figure 10.4.** Structures of some phytoalexine isolated from crucifers.

Although the colour of carotenoids is masked by chlorophyll, brassicaceae vegetables are good sources of β-carotene and lutein, which, together with zeaxanthin, are considered to play a role in ocular health due to the strong antioxidant activity (Manikandan et al., 2016). Both β- and α-carotenes are precursors to vitamin A, which is important for healthy skin, bone, gastrointestinal and respiratory systems (Manikandan et al., 2016). Tocopherols are prevalent in brassicaceous vegetables (Granado et al., 2006; Ibrahim & Juvik, 2009). Of these, α-tocopherol is generally the predominant compound (Goffman & Möllers, 2000). An intake of additional bioactive compounds from the Brassicaceae, such as carotenoids and tocopherols, has been implicated in a reduced risk of certain cancers and degenerative diseases, immune dysfunction and aged-related macular degeneration (Nagao, 2009). Lignans, particularly lariciresinol and pinoresinol, are prevalent in the crucifers (Heinonen et al., 2001; Milder et al., 2005).

## Conclusion

Brassicaceae vegetables, especially of *Brassica* genus, are rich source of bioactive phytochemicals. Among them, phenolics, glucosinolates and phytoalexins have been extensively investigated and vast information are available regarding their role in minimizing the risk of oxidative stress, cancer and several other diseases. The availability of analytical HPLC-DAD-MS methods and libraries facilitated the survey of phytochemicals from crucifers and the isolation of new structures.

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**Abbreviations:**ARE = antioxidant response element;DNA = deoxyribonucleic acid; HPLC-DAD-MS = high performance liquid chromatography coupled with diode array detection and electrospray ionization tandem mass spectrometry; HPLC-MS = high performance liquid chromatography-mass spectrometry; ROS = reactive oxygen species.

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# Author's Biography



Dr. Meena Rajbhandari is Professor of Chemistry at Research Center for Applied Science and Technology (RECAST), Tribhuvan University. She received her M. Sc. degree from Tribhuvan University and Ph. D. from University of Greifswald, Germany under DAAD scholarship. She received TWAS award in 2003 from NAST. She was the former member of the research committee, Dean's office, IOST. She is serving as the member of RECAST management board. Her area of specialization is natural product chemistry. She has published more than two dozens of research articles in international and national journals.

# Chapter 11

## Scientific Validation of Some Nepalese Fruit and Root Vegetables for Improving Diabetes Mellitus

**Deegendra Khadka**
*Nepal Academy of Science and Technology (NAST)*
*Faculty of Science, Khumaltar, Lalitpur, Nepal*
*Email: deegendrakhadka@gmail.com; deegendra.khadka@nast.gov.np

*Diabetes mellitus (DM) is listed in top four priorities non-contagious diseases targeted for action by world health organization. DM is a fatal chronic disease that evolves either inadequate amount of insulin secretion by the pancrease or malfunction of insulin receptor in a cell to detect insulin molecules as a ligand. Over 415 million of the world population is suffering from diabetes and 4% of Nepal's population is diabetic patients. Treatment of diabetes by synthetic drugs always triggers severe side effects. While searching an alternative of the chemical drugs, vegetables would be a lucrative option in improving diabetes. Nepal, being highly diversified in geographic and climatic conditions, is a house of a variety of vegetables. Easily available fruity and rooty vegetables throughout the country with their contributions to manage diabetes are incorporated in this chapter. Scientific data related to antidiabetic characters are extracted from the renowned database sources like Spinger, Scopus, Wiley, PubMed, Science Direct, etc. The significant data are retrieved after studying more than 700 articles published in several journals. This chapter consolidates fruity and rooty vegetables having glycemic index below 50.*

**Keywords:** Diabetes; fruity and rooty vegetable; glycemic index; in vitro; in vivo; Nepal.

## Introduction

Diabetes mellitus (DM) is a group of metabolic disorders noticed by elevated blood glucose level (BGL) and obstacles in carbohydrate, protein and fat metabolism process leading to curb insulin secretion and insulin action or both. The symdrome stands in the 6$^{th}$ position for the cause of death worldwide (Aligita et al., 2019). The global diabetes prevalence in 2019 is estimated to be 9.3% (463 million people), rising to 10.2% (578 million) by 2030 and

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10.9% (700 million) by 2045. The prevalence is higher in urban (10.8%) than rural (7.2%) areas, and in high-income (10.4%) than low-income countries (4.0%). One in two (50.1%) people living with diabetes does not know that they have diabetes (Saeedi et al., 2019). According to the International Diabetes Federation, there were 657,200 cases of diabetes in Nepal in 2017 which is about 4% of the total adult population (16,592,000) (Gyawali et al., 2015). Alas, there is still deficient for the remedies of diabetes but can live longer if BGL is able to keep in the normal range. Diabetes is classified mainly into three types:

### *1. Type 1 Diabetes Mellitus*

Type 1 diabetes mellitus (T1DM), also famous for the name juvenile diabetes or insulin-dependent diabetes, is a chronic condition in which the β-cells of the pancreas produce insufficient or no insulin. Insulin is indispensable for entering glucose molecules inside the cells to produce energy. Insulin lacking is the main problem of this sort of diabetes and gets promoted to deposit glucose molecules solely in blood cells. Less than 10% of the total diabetic population is the victim of T1DM. Injecting external insulin at definite time interval is the best way of maintaing BGL. Insulin injection is needed for the lifetime period. The key inquisitions concerning the strength of current therapies, causes of disease develops, how the disorder prevented and cured and epidemiology of this diabetes are still ambiguous (Atkinson et al., 2014).

### *2. Type 2 Diabetes Mellitus*

Type 2 diabetes mellitus (T2DM) is formerly known as adult-onset diabetes or insulin indepent diabetes which is diagonsed by high blood sugar and insulin resistance. Sufficient insulin can produce by the β-cells but working capacity is questionable due to insensitivity of the insulin receptors. As a result, insulin signaling pathway is blocked. Incomplete insulin signaling pathway consequently resists to flow glucose molecules to other cells from blood cells. Consequently, glucose concentration would be high only in blood cells and a person gets diabetes called T2DM. More than 90% diabetic patients are belonged to this category (Khadka, 2020). Thereby, most of the research in the field of diabetes focuses on T2DM. T2DM is associated with obesity, family history, prior history of gestational diabetes, sedentary lifestyle, cardiovascular diseases, hypertension and race/ethnicity (Regmi et al., 2019). Oral medications like synthetic drugs can maintain BGL.

### *3. Gestational Diabetes Mellitus*

Gestational diabetes mellitus (GDM) is defined as any degree of glucose intolerance with onset or first recognition during pregnancy (Szmuilowicz et al., 2019). Approximately 7% of all pregnancies are complicated by GDM, resulting in more than 200,000 cases annually. The prevalence may range from 1 to 14% of all pregnancies, depending on the population studied and the diagnostic tests employed (Szmuilowicz et al., 2019).

### *4. Specific Types of Diabetes*

It is due to other causes, e.g., monogenic diabetes syndromes (such as neonatal diabetes and maturity-onset diabetes of the young (MODY)), diseases of the exocrine pancreas (such as cystic fibrosis and pancreatitis), and drug or chemical-induced diabetes (such as with glucocorticoid use, in the treatment of HIV/AIDS, or after organ transplantation) etc (Firdous et al., 2018).

Diabetic patients need a healthy diet, proper exercise and medication to avoid risk of long-term complications like retinopathy, kidney failure, neuropathy and cardiovascular problems etc. Healthy diets rich in fiber especially vegetables can play a pivotal role to reduce the risk and easy management of T2DM (Sami et al., 2015). Currently, a pretty little is explored regarding the effect of vegetables consumption on dibetes management. Though, this chapter has been written gathering research findings that explains indispensable role of vegetables to assist in regulating BGL. A few manifestations are published defending diabetes risks after consuming vegetables. A meta-analysis revealed a strong connection between chronic diseases and vegetable consumption. Higher the vegetables consumption, lower the risk of chronic diseases, including diabetes (Boeing et al., 2012). Vegetables are sources of nutrients, carbohydrates, starches, lipids, proteins, minerals (mainly K, Ca, Mg, P and Fe), vitamin D, and fibers such as lignin and chitin. Good sources of Mg are the darker green vegetables, such as lettuce, spinach, green onions and nettles, and dried legumes in which Mg is an essential constituent of chlorophyll.

This review article encompasses only those vegetables whose fruit and shoot parts are edible after cooking and their effects in diabetes management are published in a peer-reviewed journal. The vegetables, even if their fruity and rooty parts are edible in our communities, are not included when their antidiabetic activity is not reported.

## Glycemic Index

The glycemic index (GI) is just a number designated to particular foods to calculate the rate of converting carbhohydrate into glucose. The time lag between food eating and converting into blood level determines GI of a particular food. Food that slowly heightening BGL has low GI and food that quickly raising glucose possesses high GI value. The glycemic index of glucose is arbitrarily set at 100. The ratings of other foods are calculated by ranking them in comparison to glucose. Foods with a high GI raise blood glucose proportionally higher than foods with a lower GI. Foods that rise blood sugar quickly have a higher number, whereas foods that take longer to affect BGL have a lower number (Arvidsson-Lenner et al., 2004). It is recommended that the vegetables of higher GI are vulnerable to health and people should avoid these vegetables (Pi-Sunyer, 2002). Mathematically, GI is expressed as: BGL after ingestion of product containing 50 g carbohydrate/BGL after ingestion of 50 g glucose × 100 (Anderson et al., 2002). Some of the vegetables reporting GI are tabulated below in Table 11.1. Thereby, diabetic patients can consume vegetables comfortably after knowing the GI. Vegetables having GI below 50 are considered more beneficial to the diabetic persons. Lesser GI than 50 is more advantageous. Above 50 GI value is not recommendated for the patients.

**Table 11.1.** Glycemic index of some of the vegetables

| S.N. | Vegetable name | GI |
|---|---|---|
| 1 | *Agaricus competris* (गोब्रे च्याउ) | 12 |
| 2 | *Abelmoschus esculentus* (भिन्डी) | 20 |
| 3 | *Agaricus bisporus* (डल्ले च्याउ) | 10 |
| 4 | *Brassica oleracea* (Capitata Group) (बन्दाकोभी) | 10 |
| 5 | *Brassica oleracea* var. *Italic* (ब्रोकोली) | 15 |
| 6 | *Brassica oleracea* var. *Botrytis* (फूलकोभी) | 15 |
| 7 | *Colocasia esculenta* (पिडाँलु) | 54 |
| 8 | *Glycine max* (भट्मास) | 20 |
| 9 | *Lagenaria siceraria* (लौका) | 15 |
| 10 | *Pleurotus florida* (पाते च्याउ) | 13 |
| 11 | *Vigna unguiculata* ssp. *Unguiculata* (लामो बोडी) | 46 |

## Vegetables with Ethnomedical Importance

Drug discovery from natural products used in ethnomedicine insights a crucial knowledge for the current therapeutic systems development. Natural products mainly plants, animals and minerals have been applied in the treatment of many diseases from the ancient time. Nowadays, traditional medicinal plants including vegetables are being a fascinating domain to explore pharmacognostical, phytochemical and pharmacological activities. Lots of pre-clinical and clinical analyses of natural medicine have been accomplished. The analysis has unfolded diverse biological consequences of a spectrum of plant derived active compounds. Desigining and synthesizing drug molecule in today's date is entirely based on ethanomedical interventions. Majority of the pharmaceutical companies emphasize their research strategies focusing on natural product for the sake of developing potential and novel drug molecules. A bulk of research findings related to medicinal plants are being published abundantly whereas, vegetable-based research is still finger counting in numbers. Vegetable with their multiple ailments healing actions are tabulated below in Table 11.2:

**Table 11.2.** Selected antidiabetic vegetables and their uses in several aliments

| S.N | Botanical name (Family) | नेपाली नाम | Disease(s) treated/Medicinal value | Image |
|---|---|---|---|---|
| 1 | *Abelmoschus esculentus* (L.) (Malvaceae) | भिन्डी | Antidiabetic, antispasmodic, treating phlegm, antidandruff (Manandhar, 2002; DeFilipps et al., 2004; Ruffo et al., 2002) |  |
| 2 | *Agaricus bisporus* (J. E. Lange) Imbach (Agaricaceae) | डल्ले च्याउ | Reduce risk of breast cancer, antibacterial, antifungal (Winer et al., 2002; Hong et al., 2004) |  |

| | | | | |
|---|---|---|---|---|
| 3 | *Agariucs compestris* (Agaricaceae) | गोब्रे च्याउ | Antioxidant (Racchi et al., 2002) |  |
| 4 | *Asparagus racemosus* Willd. (Asparagaceae) | कुरिलो | Antidiuretic, appetizier, antiseptic, antidysentery, treating reproductive and hormonal issues in women, gastric ulcers, indigestion (Manandhar, 2002; Goyal et al., 2003) |  |
| 5 | *Brassica oleracea* var. *gongylodes* L. (Brassicaceae) | ग्यान्टे मूला | Treating for earache (Manandhar, 2002) |  |
| 6 | *Brassica oleracea* var. *italic* Plenck (Brassicaceae) | ब्रोकोली | Cardio protective, antioxidant, anti-inflammatory (Vasanthi et al., 2009; Sun et al., 2007) |  |
| 7 | *Brassica oleracea* (L.) Metzg (Brassicaceae) | बन्दाकोभी | Anti-inflammatory, antioxidant, antidiabetic, analgesic, antiulcer (Rokayya et al., 2013; Pallavi et al., 2019) |  |
| 8 | *Brassica oleracea* var. *botrytis* (L.) Metzg (Brassicaceae) | फुलकोभी | Anticancer, antioxidant, antimicrobial (Ahmed & Ali, 2013; Sanz-Puig et al., 2015) |  |
| 9 | *Capsicum annum* (Solanaceae) | डल्ले खोर्सानी | Wound, male virility, toothache, cough, asthma, sore throat, stomachache and antibacterial (Farkas & Mohácsi-Farkas, 2014) |  |
| 10 | *Colocasia esculenta* (L.) Schott (Araceae) | पिंडाँलु | Antibacterial, antidiabetic, anti-inflammatory, antifungal, antidepressant, sedative and smooth muscle relaxant (Pawar et al., 2018; Kalariya et al., 2015) |  |
| 11 | *Cucurbita maxima* Duchesne (Cucurbitaceae) | फर्सी | Antiobesity, antidiabetic, hepatoprotective, antioxidant (Eagles, 1990; Ethiraj & Balasundaram, 2016) |  |

| | | | | |
|---|---|---|---|---|
| 12 | *Glycine max* (L.) (Fabaceae) | भट्मास | Seed - cooking oil and manufacturing soap and varnish (Manandhar, 2002), leaves – snakebite, stem ashes – used as antifungal, seed pods – to treat corneal and smallpox ulcers (Kanchana et al., 2016) |  |
| 13 | *Lagenaria siceraria* (Molina) Standl. (Cucurbitaceae) | लौका | Emetic, purgative, fruit juice - heal stomachie, acidity, indigestion, ulcers, Fruits – treatment of jaundice, diabetes, ulcer, piles, hypertension (Manandhar, 2002; Prajapati et al., 2010) |  |
| 14 | *Luffa cylindrical* (L.) (Cucurbitaceae) | घिरौला | Anti-inflammatory, antifungal, antiallergy, antiasthma (Muthumani et al., 2010; Partap et al., 2012) |  |
| 15 | *Momordica balsamina* (L.) (Cucurbitaceae) | बरेला | Fruit pulp - anti-HIV, antiviral, anti-inflammatory, antidiarrhoeal, antiseptic, antimicrobial (Hassan & Umar, 2006) |  |
| 16 | *Momordica charatina* L. (Cucurbitaceae) | करेला | Antidiabetic, anti-inflammatory, chronic ulcers, skin diease, cough, cold, anemia, bronchitis, gout, dysentery, gonorrhoea, cancer (Manandhar, 2002; Grover & Yadav, 2004) |  |
| 17 | *Moringa oleifera* Lam (Moringaceae) | सज्जिवन | Cardiac and circulatory stimulants, antitumour, antipyretic, antiepileptic, antiulcer, antihypertensive, cholesterol lowering, antidiabetic (Anwar et al., 2007; Jaiswal et al., 2009) |  |
| 18 | *Pleurotus florida* (Pleurotaceae) | पाते च्याऊ | Antidiabetic, anti-HIV, antineoplastic, antimicrobial, antioxidant, anticancer, antihypertensive, antiobesity, antiaging (Cohen et al., 2002; Venturella et al., 2016) |  |
| 19 | *Phaseolus vulgaris* L (Fabaceae) | राजमा | Analgesic, antiobesity, antibacterial anticancer, antidiabetic, antifertility, anti-inflammatory, antioxidant (Ocho-Anin et al., 2010a; Ng et al., 2011) |  |

| | | | | |
|---|---|---|---|---|
| 20 | *Raphanus sativus* L. (Brassicaceae) | मूला | Antifungal, antihypertensive, antitussive, anticancer, antimicrobial, antidiabetic, diuretic, antifertility (Sham et al., 2013; Borș et al., 2015) |  |
| 21 | *Sechium edule* (Jacq.) Sw. (Cucurbitaceae) | स्कुश | Antidiabetes, antiobesity, reduce burning during urination, dissolve kidney stones, anti-inflammatory, hypertension, reduces the risk of coronary heart diseases (Yang et al., 2015; Ibarra-Alvarado et al., 2010) |  |
| 22 | *Solanum melongena* L. (Solanaceae) | बैगुन | Analgesic, antipyretic, antioxidant, antiasthmatic (Das & Barua, 2013) |  |
| 23 | *Solanum betaceum* (Cav.) (Solanaceae) | रुख भेंडा | Antioxidatant, antinociceptive anticancer antiobesity, anti-inflammatory (Mutalib et al., 2017; Umamageswari & Maniyar, 2015) |  |
| 24 | *Trichosanthes cucumerina* Linn (Cucurbitaceae) | चिचिन्डो | Stomachic, refrigerant, purgative, laxative, antibacterial, antidandruff, antidiabetic (Devi, 2017; Arawwawala et al., 2009) |  |
| 25 | *Trichosanthes dioica* Roxb. (Cucurbitaceae) | पर्वल | Jaundice, edema, alopecia treatment, antipyretic, diuretic, cardiotonic, laxative, antihyperglycemic, antitumour, anti-inflammatory, antidiarrheal (Kumar et al., 2012; Khandaker et al., 2018) |  |
| 26 | *Vigna unguiculate* (L) Walp. (Fabaceae) | लामो बोडी | Anthelmintic, antibacterial, antioxidant, antidiabetic, anticholesterol (Ibrahim et al., 2017; Weththasinghe et al., 2014) |  |
| 27 | *Vicia faba* L. (Fabaceae) | बकुल्ला | Antidiabetic, anticancer, antifungal (Sathya & Rajeswari, 2018) |  |

## Vegetable as an Alternative Source of Antidiabetic Agents

Vegetables cultivated in Nepal are highly diverse because of the country's geographical status. Common fruity and rooty vegetables grown around the nation are incorporated in this article. People use vegetable either fresh or processed and well known to be one of the main sources of phytochemicals in a human diet. Phytochemicals like phenolics as flavonoids have an important effects as antimicrobial, anti-inflammatory, antioxidant, antidiabetic, antiviral, etc. diminishing risks of several human diseases (Nisar et al., 2018). Antioxidants, such as flavonoids, exhibit significant antidiabetic effect by inhibiting the activity of certain enzymes such as aldose reductase (Alim et al., 2017). Moreover, because of the significant roles of oxidation reactions in advanced glycated end products (AGE) formation, the antioxidant posseses hypoglycemic effect through anti-AGE mechanism (Nowotny et al., 2015). The food with high antioxidant content often recommended to the diabetic patients.

## *Abelmoschus esculentus* (Lady finger)

*A. esculentus* (Okra) is a well-known vegetable, has been reported to possess hypoglycaemic activity. To show the effectiveness of *A. esculentus*, the in vivo experiment was carried out in which diabetes was induced by intra-peritoneal (i.p.) administration of a single dose (120 mg/kg body weight) of alloxan to 72 young Wister albino rats weighing between 100-200 g (Yaradua et al., 2018). Seventy-two hours after the alloxan administration, the animals were fasted overnight and diabetes was confirmed by measuring fasting BGL. The effect of administration of different parts of okra fruit on normal rats showing BGL 5.13±0.18 mmol/L, diabetic rats 14.50±1.21 mmol/L, metformin control 4.72±0.35 mmol/L and extract 300 mg/kg bw 5.32±0.40 mmol/L. From the α-glucosidase inhibition activity, it was known the acarbose's $IC_{50}$ was 44.374 µg/mL, while okra fruit extract exhibited 1533.742 µg/mL. And, the $IC_{50}$ value of acarbose to α-amylase enzyme was 46.821 µg/mL, while okra fruit extract showed 1228.469 µg/mL. Okra fruit was experimented on alloxan induced (50 mg/kg) male Swiss-webster mice, 2-3 months old, weighing 20–30 g. After 14 days of the experiement, BGL shown by negative control 94±8 mmol/L, positive control 388±68 mmol/L, glibenclamide 0.65 mg/kg bw 116±22 mmol/L and the ethanolic fruit extract 50 mg/kg bw 101±6 mg/dL were observed (Aligita et al., 2019). Another experiment on male albino wistar strain rats of 50–60 days aged was done by dissolving drug glibenglimide (5 mg/kg) and *A. esculentus* (150 mg/kg) in water and supplied orally (p.o.). The mice were diabetic with alloxan monohydrate in normal saline in a dose of 150 mg/kg injecting intraperitoneally after 16 hours fasting. Thus the result showed that the BGL of plant extract was 110.8±0.14 mg/dL, normal and diabetic rats contained 74.3±0.52 and 212.5±1.3 mg/dL, respectively, while standard drug glibenclamide treated rats revealed 85.4±3.9 mg/dL (Agnes & Kanimozhi, 2016). Conclusively, *A. esculentus* fruit extract with a dose of 50 mg/kg bw had the antidiabetic activity with the mechanism of action by increasing insulin secretion, increasing insulin sensitivity and inhibiting carbohydrate absorption in the intestine but couldn't inhibit α-glucosidase and α-amylase enzymes significantly.

## *Agaricus bisporus* (White button mushroom)

Hypoglycemic activity of *A. bisporus* is proven by carrying out an experiment. Mushroom powder 200 mg/kg bw was fed to streptozotocin (STZ)-induced (50 mg/kg bw) diabetic male Sprague-Dawley rats for 3 weeks. The powder exhibited significantly decreased plasma glucose and triglyceride (TG) concentrations by 24.7 and 39.1% respectively in the ratio of normal rats (Jeong et al., 2010). Serum glucose levels was decreased by 29.68% and insulin levels was increased to 78.5% when dehydrated fruiting body extracts 400 mg/kg p.o. was fed to STZ-induced diabetic rats (Yamac et al., 2010).

## *Agaricus campetris* (Gilled mushroom)

*A. competris* is documented as one the conventional interventions to cope with diabetes. In vivo experiment was done by feeding aqueous extract (62·5 g/kg bw) on STZ diabetic mice for 21 days. The BGL was lowered by 2.5% than the normal mice (Gray & Flatt, 1998). Ethanolic extract at 500 μg/mL concentration inhibited α-amylase by 91% and revealed no any cytotoxicity effect after 3 hr (Maktoof et al., 2019). For in vitro experiment, 50 g/L of mushroom aqueous extract was used to know the effects on glucose diffusion in gastrointestinal tract and found striking result showing remarkably down glucose diffusion compared to control with $p < 0.001$ (Gallagher et al., 2003). Lowering glucose level is attributed by both promoting insulin releasing cells and acting extracts self as insulin.

## *Asparagus racemosus* (Satawari)

Daily oral administration of ethanolic extract (1·25 g/kg bw) of *A. racemosus* to Long-Evans male (180–220 g bw) diabetic rats for 28 days decreased serum glucose, increased pancreatic insulin and plasma insulin. Diabetes was induced by a single intraperitoneal injection of STZ (65 mg/kg bw, freshly dissolved in 0·5 M citrate buffer, pH 4·5). After 28 days, BGL was found 8·90±1.0 mmol/L on control and 6·50±0·8 on extract feeding groups. Insulin was measured 0·442±0·1 ng/mL on control and 0·579±0·1 ng/mL on extract feeding mice. Pancreatic insulin 0·79±0·2 nmol/g on control and 1·07±0·42 nmol/g on extract treated mice was measured (Hannan et al., 2012). *A. racemosus* powder at the dose 500 mg/kg bw was provided daily to alloxan-induced 30 male albino diabetic rats, weighing 170–200 g for 30 days. After 30 days, fasting blood serum was measured showing 68.8±4.979 mg/dL of control, 222.8±24.40 mg/dL of alloxan treated diabetic rat and 73.142±5.217 mg/dL of extract treated groups (Wesam et al., 2018). Ethanolic extract of *A. racemosus* root was tested on albino Wister diabetic rats. The animals were induced diabetes by single intraperitoneal injection of alloxan (150 mg/kg). Extract (200 and 400 mg/kg) and glibenclamide (5 mg/kg) orally administered daily for 14 days. After 14 days, the plasma glucose level showed 90.8±6.0 mg/dL of control group providing normal saline (2 mL/kg), 262.3±17.7 mg/dL of diabetic control, 86.7±4.4 mg/dL of diabetic mice supplied *A. racemosus* extract (400 mg/kg bw), 112.0±4.2 mg/dL of diabetic mice supplied *A. racemosus* extract (200 mg/kg bw) and 82.3±6.2 mg/dL of glibenclamide (5 mg/kg) feeding mice (Dheeba et al., 2012).

## *Brassica oleracea* var. *gongylodes* (Kohlrabi)

While performing in vitro assay of the methanolic extract of the red and green varieties of *B. oleracea* var. *gongylodes* (BOvG) against protein tyrosine phosphate (PTP) 1B enzyme showed $IC_{50}$ value of 207±3.48 g/mL for red BOvG and 287±3.22 g/mL for green BOvG (Jung et al., 2014). To show the effectiveness of BovG extract at a dose 800 mg/kg bw, Wister rats weighing 160±15 g were made diabetic by intraperitoneal injection of freshly prepared STZ in citrate buffer (0.1 M, pH 4.5) at a dose of 47 mg/kg bw. The experiment was run for 28 days. The fasting blood sugar (FBS) of control group over the course of 4 weeks was 99–113 mg/dL and diabetic groups showed steep increase in FBS (420 mg/dL). Treatment with BOvG extract reduced the FBS in the first week to 98.5 mg/dL (by 64%) and was maintained as such for the entire experimental period. BOvG group showed no significant difference ($p < 0.05$) compared to control from week 1$^{st}$ to the end of week 4$^{th}$. Similarly, glibenclamide group (1 mg/kg bw) also showed reduction in FBS to 180 mg/dL (by 42%) at the end of the 4$^{th}$ week. BOvG extract showed more potency for antihyperglycemic activity than glibenclamide (Sharma et al., 2015).

## *Brassica oleracea* var. *italic* (Brocooli)

Broccoli exerts beneficial health effects in several diseases including diabetes; however, the mechanism has not been elucidated yet. An experiment on 15 mice inducing diabetes with nicotinamide 70 mg/kg bw and STZ 150 mg/kg bw is recently reported (Suresh et al., 2017). The test material, i.e. broccoli extract, at doses 75, 150 and 300 mg/kg bw are given for a 14 days period. This result shows that glibenclamide (4.5 mg/kg bw) reduces BGL by 13.6±6.9% and broccoli extract (300 mg/kg bw) by 38.8±6% while negative control group by 13.6±6.9%. To investigate the effects of broccoli sprouts powder (BSP) containing high concentration of sulphoraphane on insulin receptor (IR) in type 2 diabetic patients, 81 patients were randomly assigned to receive 10 g/day BSP, and 5 g/day BSP and placebo for 4 weeks. Consumption of 10 g/day BSP resulted in a significant decrease in serum insulin concentration from 5.20 to 4.35 mU/I and fasting glucose level decreased from 9.38 to 7.48 mmol/L. Therefore, broccoli sprouts may improve IR in type 2 diabetic patients (Bahadoran et al., 2012). Extract prepared by 500 g of broccoli fresh or processed florets in the mixture of ethanol and water in 7:3 ratio was tested on alloxan treated (5% w/v in normal saline at a dose of 140 mg/kg bw) male albino rats weighing about 180–200 g. The rats with serum glucose level >300 mg/dL were considered to be diabetic. The serum glucose level was calculated 97.34±0.27 mg/dL on basal diet feeding control group, 405.43±1.08 mg/dL on diabetic group, 105.00±0.61 mg/dL on sulforaphane 0.3 mg/kg/day bw feeding group, 140.54±0.78 mg/dL on ethanol extract without process at concentration of 0.175 g/kg/day bw feeding group equal to 0.1 mg/kg/day bw sulforaphane, and 110.54±0.73 on ethanol extract without process at concentration of 0.525 g/kg/day bw feeding groups equal to 0.3 mg/kg/day bw sulforaphane (Magied et al., 2016).

## *Brassica oleracea* var. *capitata* (Cabbage)

Aqueous extract of 50 mg/kg cabbage was fed to male albino rats weighing 110–120 g for 6 weeks. The BGL shown by control was 44.00±9.42 mg/dL and the extract was 44.75±4.349 mg/dL (Adeoye et al., 2019). The male Wister rats of weight 200±50 g was

transformed into type 2 diabetes by injecting STZ (60 mg/kg bw). After 3 days of STZ injection, diabetic rats showed 358.56±6.78 mg/dL glucose level, diabetic rats feeding aqueous extract of white cabbage showed 86.89±6.78 mg/dL and antidiabetic drug treated rats demonstrated 89.00±2.99 mg/dL (Gaafar et al., 2014). Diabetes was induced in male Wistar rats (130–180 g) using STZ (60 mg/kg bw). Throughout the experimental period (60 days), diabetic rats exhibited many symptoms including loss of body weight, hyperglycemia, polyuria, polydipsia, renal enlargement and renal dysfunction. Significant increase in malondialdehyde, a lipid peroxidation marker, was observed in diabetic kidney. Daily oral ingestion (1 g/kg bw) of *B. oleracea* extract for 60 days reversed the adverse effect of diabetes in rats. *B. oleracea* extract lowered BGL and restored renal function and body weight loss.

## *Brassica oleracea* var. *botrytis* (Cauliflower)

Tested extract prepared by 500 g of cauliflower fresh or processed florets in the mixture of ethanol and water in the ratio of 7:3, and was tested on alloxan treated at a dose of 140 mg/kg bw male albino rats weighing about 180–200 g (Magied et al., 2016). The rats with serum glucose level >300 mg/dL were considered to be diabetic. The study was carried out for 14 days. The serum glucose level was calculated 97.34±0.27 mg/dL on basal diet feeding control group, 405.43±1.08 mg/dL on diabetic group, 105.00±0.61 mg/dL on sulforaphane 0.3 mg/kg/day bw feeding group and 200.15±0.58 mg/dL on ethanol extract at 4.05 g/kg/day bw feeding group.

## *Capsicum annum* (Capsicum)

Forty albino mice were utilized and randomly allocated on four groups consisting of a positive control (i.e. insulin glargine), a negative control and two treatment groups receiving different doses of *C. frutescens* seed extract at 2.5 mg/kg bw (i.e. low dose) and 7.5 mg/kg bw (i.e. high dose) (Sandhya & Trupti, 2017). Diabetes was induced by administration of a single dose of alloxan-monohydrate 5% intraperitoneally (300 mg/kg bw). Twenty-four mice were included. The extracts were administered intraperitoneally and changes in BGL were monitored over an 8 hr period using a glucometer. Results obtained showed that *C. frutescens* seed extracts exhibited hypoglycemic activity. However, only the low-dose extract showed a significant effect in lowering BGL up to 44% from the baseline which was comparable to the insulin glargine ($p < 0.05$, $n = 6$).

## *Colocasia esculenta* (Cocoyam)

Ethanol extract of *C. esculenta* (EECE) leaves was subjected to phytochemical investigation and evaluated antidiabetic activity on BGL and on the body weight in alloxan induced diabetic rats (Kumawat et al., 2010). EECE (100, 200 and 400 mg/kg) and metformin (450 mg/kg) were administered orally in alloxan (120 mg/kg, i.p.) induced diabetic rats. In acute oral toxicity (AOT) study, upon administration of EECE, no mortality upto 5000 mg/kg was observed. The onset of reduction of blood glucose was observed at 4 hr (96 mg/dL), peak at 6 hr (120 mg/dL) but antihyperglycemic effect declined at 24 hr. In a sub-acute study, maximum reduction in blood glucose was observed (174.34 mg/dL) at the dose of 400 mg/kg on 14$^{th}$ day. After 24 hr, control

showed BGL 299.16±12.44 mg/dL, metformin (450 mg/kg. p.o.) 237.33±12.9 mg/dL and EECE (400 mg/kg) 245.83±13.92 mg/dL. These results suggest that EECE (400 mg/kg) showed anti-hyperglycemic activity in alloxan induced diabetic rats.

Various doses of *C. esculenta* corms were given orally to normal and albino Wistar rats having weight 150–200 g. Diabetes was induced to overnight fasted rats by an intraperitonial injection of STZ 50 mg/kg bw in 0.1 M citrate buffer (pH = 4.5). The most effective dose of 200 mg/kg was given to severely diabetic rats for 28 days to assess the antihyperglycemic. The results reveal the maximum decrease of 34% in the BGL of normal rats at 6 hr during fasting blood glucose (FBG) studies and 43.1% at 3 hr during glucose tolerance test (GTT). Whereas, in case of mild diabetic rats, the maximum reduction observed in BGL during GTT was only 9.6%. In case of severely diabetic rats, a noteworthy reduction of 41.6, 31.1, 34.8 and 46.2% was observed in FBG, Post Prandial Glucose, serum Total Cholesterol and Triglycerides levels respectively (Yadav et al., 2019). Forty male albino rats of the Wistar strain (146.76–228.74 g) were induced diabetes with STZ (65 mg/kg bw) injecting intraperitoneally at fasting state. Administration of the test feeds for 21 days resulted in 58.75% and 38.13% decreases in hyperglycemia showing fasting BGL (mg/dL) of control 93.67±8.5 mg/dL, diabetic control rats administered 70 mg/kg bw STZ 153.88±30.09 mg/dL and diabetic rats administered unripe plant incorporated feed 29.92±52.80 mg/dL (Eleazu et al., 2013).

Aqueous shoot extract of *C. esculenta* inflorescence was experimented in STZ (120 mg/kg bw) induced albino diabetic rats for 14 days. The oral acute ($LD_{50}$) toxicity study showed that the aqueous shoot inflorescence extract did not cause mortality to any experimental animals even at the highest dose of 5000 mg/kg. The animals that received different aqueous shoot extract of *C. esculenta* showed significant ($p < 0.05$) reduction of blood glucose. After 28 days, normal groups showed 75 mg/dL BGL, diabetic control 315 mg/dL, standard drug treated glycinorm had 130 mg/dL and the extract at 200 mg/dL was 132 mg/dL (Li et al., 2019).

## *Cucurbita maxima* (Pumpkin)

Investigation on hypoglycemic effect and potential mechanism of pumpkin polysaccharides and puerarin was performed on T2DM mice (Chen et al., 2019). The research was carried out by feeding high-fat diet and injecting intraperitoneally with STZ to induce T2DM male Kunming mice, 12–14 weeks old and weighing 13–15 g. After one week of mouse housing, the mice in the control group were fed with a normal standard diet while another group, called model group, was fed high fat diet (78.8 g/100 g commercial standard pellet diet, 10 g/100 g lard, 10 g/100 g custard powder, 1 g/100 g cholesterol and 0.2 g/100 g sodium cholate). After 4 weeks, the model group was injected intraperitoneally with 35 mg/kg STZ daily for 3 consecutive days. After 8 weeks, the serum glucose level was measured showing diabetic mice 17.85±1.53 mM, mice feeding pumpkin polysaccharide (400 mg/kg/day bw) and puerarin (200 mg/kg/day bw) 6.35±0.53 mM, and control group showed 3.03±0.27 mM (Chen et al., 2019). Feeding 5 g lyophilized powder of *C. maxima* to two ICU admitted patients, every 12 hours for 3 days, showed average BGL 178.4±36.1 mg/dL ($p < 0.001$). But before the experiment, the glucose level was reported to be 214.9±55.7 mg/dL. Insulin dose and BGL were measured

every 1–4 hr during experimental period. The average insulin dose during 3 days before intervention was 48.05±36.5 IU and during the 3 days of *C. maxima* administration was decreased to 39.5±27.8 IU (p = 0.06). It seems that *C. maxima* may decrease high BGL instantly and effective in diabetic critically ill patients (Mahmoodpoor et al., 2018).

Extract in petroleum ether, ethyl acetate and alcohol were tested on Wister albino rats weighing 150–170 g (Sharma et al., 2013). The different extracts were suspended in distilled water and administered orally thorugh gastric tube at dose of 200 mg/kg bw for 21 days. Rats were made diabetic by single administration of streptozotocin (50 mg/kg) dissolved in 0.1 M citrate buffer, pH 4.5, intraperitoneally, to overnight fasted rats. After the trial period, there was marked reduction in BGL from 289.7±3.375 to 264.1±1.815 mg/dL of petroleum ether extract, 287.5±3.402 to 230.8±2.712 mg/dL of ethyl acetate extract and 285.3±3.753 to 189.9±1.896 mg/dL of alcohol extract in 21 days. In standard group, initial blood glucose was 270.6±1.783 mg/dL and the post test was 141.6±1.113 mg/dL, which showed that the standard drug produced maximum hypoglycemic effect. Seed aqueous extract (200 mg/kg bw) testing on STZ-induced mild diabetic rats demonstrated BGL reduced by 29.02% at 6 hr during FBG and 23.23% at 3 hr during GTT studies (Kushawaha et al., 2017). In case of severely diabetic rats, BGL was decreased by 39.33% and GTT in the same time interval was 26.15%. Positive control rats treated with 2.5 mg/kg of glipizide showed a fall of 42.9% in FBG levels after 28 days. Post pranial glucose (PPG) level demonstrated a fall of 33.20% in severely diabetic rats as compared to the positive control showing a fall of 44.2% at the end of the 28 days. In vitro assays against α-amylase and α-glucosidase were done taking the aqueous extract of *C. maxima* and found the inhibitory activity of 46.03±1.37% with $IC_{50}$ value of 7.00±0.29 mg/mL at 1 mg/mL (Kushawaha et al., 2016). Standard drug acarbose showed 98.14±1.74% at a concentration of 1 mg/mL for α-amylase and inhbititory effect 35.11±1.045% with $IC_{50}$ value of 8.11±0.36 mg/mL at 1 mg/mL, while acarbose demonstrated 95.52±1.90% at a concentration of 10 mg/mL for α-glucosidae. The above findings concluded that *C. maxima* showed effective hypoglycemic and antidiabetic effects, and hence this extract could be explored further for developing as a novel antidiabetic agent

## *Glycine max* (Soybean)

The aqueous extract of *G. max* seed (GM-AQE) was prepared and evaluated for antihyperglycemic activity (Badole & Bodhankar, 2009). GM-AQE (100, 200 and 400 mg/kg, p.o.) and glibenclamide (10 mg/kg, p.o.) were administered in alloxan-induced (80 mg/kg, i.v.) diabetic mice. Swiss albino mice (25–30 g) of both sexes were induced by a single intravenous injection of aqueous alloxan monohydrate (80 mg/kg, i.v.) solution. In oral glucose tolerance test (OGTT), increased glucose tolerance was observed in GM-AQE (100 and 200 mg/kg) treated non-diabetic as well as diabetic mice. After 24 hr, serum glucose levels exhibited by distilled water (10 mL/kg) feeding mice, glyburide (10 mg/kg) delivered mice and aqueous extract (400 mg/kg) treated mice were 540.35±15.68, 21.71±34.27 and 374.00±19.24 mg/dL, respectively (Badole & Bodhankar, 2009). Twenty-four STZ (50 mg/kg bw) induced albino diabetic rats (Sprague Drawley strain) with a body weight ranging from 88 to 120 g were fed germinated *G. max* and the biochemical analysis revealed that germinated *G. max* was more effective to improve

blood glucose demonstrating diabetic control group 298.03±14.97 mg/dL, diabetic rats feeding non-germinated *G. max* 246.19±11.15 mg/dL and diabetic feeding gerimated (sprouted) *G. max* 222.83±5.90 mg/dL (Mahmoud et al., 2016).

Consuming of either soaked or germinated soyabean seed demonstrated a highly effective blood sugar regulator as confirmed by testing in 35 volunteers of age 37–50 years with T2DM patients (Pathak, 2005). After 6 hr of luch, the blood sugar was measured at the range of 76–477 mg/dL. All the patients were administered 250 mL of soaked soybean solution (SSS) orally, and after 2 hr, BGL showed in between 63–409 mg/dL. So the BGL was reduced remarkably after SSS treatment. Antidiabetic potential of soybean extracts (chloroform and alcohol) has been evaluated in alloxan-induced diabetic rabbits at a dose of 150 mg/kg bw (Khushk et al., 2010). The extracts (50 mL/rabbit/day) were given orally to 12 healthy male rabbits for 24 days. The study revealed that the chloroform and alcoholic extracts have reduced the glucose level by 42.53 and 49.78%, respectively.

## *Lagenaria siceraria* (Bottle gourd)

An experiment was carried out to confirm the antidiabetic nature of *L. siceraria* by testing on female albino mice, weighing 110–118 g, inducing diabetes with alloxan monohydrate at 100 mg/kg bw dose (Bhattacharya & Das, 2012). After 8 days, the obtained data indicated that the glucose level in the animals that were subjected with alloxan was 210 mg/dL comparing with normal 70 mg/dL, the BGL in diabetic group when subjected with the extract decreased to 89 from 106.5 mg/dL. The activity of globulin protein, extracted from *L. siceraria*, was examined on 3 months old male Wister albino rat with 285–310 g body weight. The protein in 10 mg/mL concentration was fed at 50 mg/kg bw. Thirty min after globulin administration, a glucose solution (18 g in 45 mL) was administered orally in a single dose of 2 g/kg bw. After 150 min of induction of hypoglycaemia, the control showed 84% decrease in BGL and extract treated group had 137.8% decrese in BGL (Teugwa et al., 2013). Healthy Wistar albino rats, weighing 160±20 g, were induced diabetes by administration of STZ (50 mg/kg). The rats showing BGL >200 mg/dL were considered to be diabetic. Methanolic extact of the plant at doses of 200 and 400 mg/kg, p.o., were fed for 14 days. Glibenclamide (500 μg/kg) was used as a reference drug. After 15 days, fasting blood glucose was measured showing normal control 15±0.57 mg/dL, diabetic control 296.67±2.46 mg/dL, plant (200 mg/dL) 85.83±3.73 mg/dL, plant (400 mg/dL) 80.83±1.74 mg/dL and glibenclamide (0.5 mg/kg) 93.00±2.16 mg/dL (Saha et al., 2011).

## *Luffa cylindrica* (Sponge gourd)

The methanolic fruit extract was tested in alloxan-induced hyperglycemic male Swiss rats (27–30 g) at two dose levels 200 and 400 mg/kg bw p.o. with no prior history of drug treatment. Diabetes was induced in male Wistar albino rats (150–180 g) by a single i.p. injection of 160 mg/kg bw of alloxan monohydrate in 0.9% w/v saline solution. After 15 days, BGL was measured to 5.12±3.12 mg/dL for normal control, 296.5±1.73 alloxan glucose, 73.50±1.70 glibenclamide, and methanolic extract (200 mg/kg) 77.4±2.61 (Hazra et al., 2011). STZ (65 mg/kg, i.p.) along with nicotinamide (120 mg/kg, i.p.) was used to

induce non-insulin dependent DM in rats. The effect of different extracts (100, 200 and 400 mg/kg, p.o.) in the management of diabetes and related complications was determined. The methanolic extract at a dose of 100 mg/kg was found to be active ($p < 0.05$) but the activity was increased significantly ($p < 0.01$) at a dose of 200 and 400 mg/kg showing serum insulin 15.21±0.53 µU/mL of normal group, 05.03±0.30 µU/mL of STZ control, 13.12±0.90 µU/mL of STZ with glibenclamide and 10.14±0.41 µU/mL of STZ with 400 mg/kg aqueous extract (Pimple et al., 2011).

The alcoholic and aqueous extracts were studied for antidiabetic activity on alloxan (80 mg/kg bw) induced Sprague dawley rats (150–200 g) (Chaurasia et al., 2011). Diabetic rats were administered extract 100 mg/kg bw orally for 15 days. After 15 days, diabetic control showed BGL 270.83±20.01 mg/dL, diabetic rats feeding glibenclamide 139.83±21.45, diabetic rat and alcholic extract 161.33±16.57, and diabetic with aqueous extract 136.83±20.60 mg/dL. Methanolic extract was examined on Swiss albino mice male, weighing 12–15 g. At a lower extract dose of 50 mg/kg bw, the extract reduced BGL by 13.1%, but the results were not statistically significant. A standard antihyperglycemic drug, glibenclamide, when administered to glucose-loaded mice at a dose of 10 mg/kg bw reduced BGL by 41.3% and at a higher dose of 40 mg/kg bw by just 41.8 % (Juma et al., 2013).

## *Momordica balsamina* (Balsam apple)

STZ-induced diabetic rats were housed for the experiement. After 21 days of regular feeding of the aqueous extract (500 mg/kg) of *M. balsamina* showed a significant ($p < 0.05$) reduction in fasting serum glucose level by 60.04% as compared to 0 day of the experiment. The standard drug metformin (500 mg/kg) treated diabetic rats had shown consistently decreasing serum glucose level by 52.27% at the last day ($21^{th}$ day) of the experiment (Bhardwaj et al., 2010).

## *Momordica charatina* (Bitter gourd)

The ethanolic extract was used in in vitro experiment against α-amylase and α-glucosidase to calculate half inhibitoryconcentration. The results were pretty shocking due to having high hypoglycemic property. *M. charantia* extract displayed $IC_{50}$ value of 56.86±1.12 µg/mL against α-amylase and $IC_{50}$ value of 88.19±0.74 µg/mL against α-glucosidase in the comparison of acarbose having $IC_{50}$ values of 93.07±1.49 µg/mL and 77.25±1.20 µg/mL, respectively (Güder, 2016). The extract acted as competitive inhibitor for α-amylase and α-glucosidase by oppressing 66 and 69% respectively with $IC_{50}$ of 0.26 mg/mL for α-amylase and 0.29 mg/mL for α-glucosidase (Poovitha & Parani, 2016). Furthermore, STZ-induced diabetic rats were used for supporting the evidence. Oral administration of juice to diabetic rats at a dose of 10 mL/kg/day for 14 days showed that the juice caused a significant reduction of serum glucose (135.99±6.27 mg/mL) and a remarkable increase of serum insulin by 3.41±0.08 mg/mL (Mahmoud et al., 2017). Therefore, *M. charantia* would be one of the best natural treatments for diabetes (Güder, 2016; Poovitha & Parani, 2016).

## *Moringa oleifera* (Drumstick)

Numerous articles published in the indexed journals describing hypoglycemic action of *M. oleifera* tender leaves but only few findings are reported about antihyperglycemia effect of the fruit (drumstick). In Nepalese communities, drumsticks are consumed massively as a vegetable rather than the tender leaves. The results revealed that leaf extract demonstrated significantly beneficial to the diabetic patients instead of its drumstick. Aqueous extract of leaf inhibited α-amaylase and α-glycosidase by 56.96 and 62.1% in a dose dependent manner (Khan et al., 2017). Antidiabetic activity of the aqueous extract of leaves has been studied on female Wistar rats of body weight 200–250 g. The rats were transformed to diabetes by a single injection of STZ at a dose 45 mg/kg bw intraperitoneally. STZ-induced diabetic rats were treated with 100 mg/kg of the aqueous extract showing 53.2% fall in fasting glucose level compared to the control group after 4 hr of oral administration, whereas the fall of 40.1, 45.6, and 41.7% was observed after 3, 6 and 8 hr, respectively (Khan et al., 2017). In another 28 days experiments, Wistar albino rats having body weight of 150–250 g were induced diabetes by injecting STZ (55 mg/kg bw) in a peritoneal region (Naidu et al., 2017). Standard groups treated with glibenclamide (0.5 mg/kg bw) showed mean BGL 349.8 mg/dL on first day, and after 28 days, the glucose level was reduced to 169.8 mg/dL. In the extract (150 mg/kg bw) treated group, the BGL on first day was 348.8 mg/dL that decreased to 206.3 mg/dL on $28^{th}$ day. Feeding of leaf powder in 500 mg/kg ratio to the alloxan-induced diabetic Sprague-dawley rats for two months showed an eye opening results in the reduction of BGL from 300 mg/dL to 100 mg/dL (Villarruel-López et al., 2018). Alloxan-induced diabetic Wistar rats were fed aqueous leaf extract (250 mg/kg) for 18 days (El-Desouki et al., 2015). On $19^{th}$ day, BGL was decreased from 400 mg/dL to 200 mg/dL ($p < 0.05$). The methanolic leaf extract (200 mg/kg/day bw) was supplied to the STZ-induced diabetic Wistar rats for 21 days period. The BGL in diabetic rats, after 21 days, was suppressed from 229±9.05 to 86±4.2 mg/dL ($p < 0.05$) (Sánchez-Muñoz et al., 2018).

Randomly choosen 30 post-menopausal women at the age range 45–55 years were enrolled in a study (Kushwaha et al., 2014). Leaf powder (7 g/day) was provided consistently till 3 months. The result showed that the reduction from a baseline of 125.6±9.15 to 106.7±7.23 mg/dL ($p < 0.01$) in fasting BGL. Altogether 27 volunteers, including 17 diabetic patients (9 females and 8 males) and 10 healthy people (6 females and 4 males), were recruited in the experiment. Equal amount (20 g) of leaf powder was supplied to each volunteer. BGL was measured after 150 min of powder consumption. In healthy subjects, post-prandial blood glucose peaked at 60 min (after 20 g powder and control meal consumption) was 121±5 and 135±7 mg/dL, respectively. There is no significant difference in either case in the end of the experiment. In diabetic subjects, the post-prandial glucose levels, after consumption of 20 g powder and control meal, at 60 and 150 min, were 315±15 and 340±18 mg/dL, and 15±22 and 49±18 mg/dL, respectively (Leone et al., 2018).

## *Pleurotus florida* (Oyster mushroom)

*P. florida* is commonly called as *Pattechiyau* in Nepali. The mushroom is easily available in the local market with affordable expenses. Mushroom extracted in methanol solvent

demonstrated an eye catching consequences when the extract inhibited α-amylase and α-glucosidase at 1 mg/mL by 94.93±1.75 and 84.90±0.42% respectively in a dose dependent manner (Prabu & Kumuthakalavalli, 2017). Alloxan-induced diabetic mice were feasted 50 mg/kg bw of crude polysaccharide extracted from mushrooms. After 4 hrs, BGL was decreased to 406 from 450 mg/dL, but in case of solenly metformin feeding mice, it was reduced 275 from 410 mg/dL. While combining both crude polysaccharide and metformin in 2:3 ratio, the result was obtained reducing BGL from 433 to 82 mg/dL (Sultana et al., 2014). Polysaccharide extract showed harmless to the dose 5,000 mg/kg bw based on acute toxicity studies.

## *Phaseolus vulgaris* (Common beans)

In vivo experiment on male Wister rats was performed by feeding the seed extract in the ratio of 100 g/kg bw (Ocho-Anin et al., 2010b). Surprising result was obtained while the extract efficiency was compared with standard drug glibenclamide (0.20 g/kg bw) feeding in hyperglycemic rats. BGL of extract feeding rats was 68 gm/dL and drug feeding rats showed 69 mg/dL, while diabetic rats had 120 mg/dL. Extract was prepared from 132 g of dried plant material per litre of water and given in a dose of 4 mL/kg led to a decrease in the area under the glucose tolerance curve by 18.5%, whereas with tolbutamide only a 14.3% reduction was achieved. A decoction of *P. vulgaris* pods (132 g/L) when administered orally to rabbits in a dose of 4 mL/kg showed decreases in BGL significantly different from control and comparable to tolbutamide (Helmstädter, 2010). Another experiment was performed by taking 200 mg/kg bw of dried pods *P. vulgaris* on 50 STZ induced male albino wistar rats (170 to 200 g) for 45 days. After 5 hrs of glucose tolerance test, the BGL was observed showing control water feeding 117.1±5.5 mg/dL, tolbutamide 95.0±3.4 mg/dL and *P. vulgaris* treated mice 89.1±3.4 mg/dL (Pari & Venkateswaran, 2003a). Aqueous extract of *P. vulgaris* pods fruit wall 200 mg/kg was tested on STZ (45 mg/kg bw) induced diabetic rats. On the 28$^{th}$ day diabetic rats showed glucose utilization in muscle cells was 80% higher, compared with water-treated diabetic rat (Halenova et al., 2019).

Aqueous extract of *P. vulgaris* was experimented on STZ induced diabetic wistar rat having weight 175–185 g for 6 weeks. BGL was monitored after 120 minutes of normal (82.40±5.22 mg/dL), diabetic rat (325.91±4.41 mg/dL), diabetic and extract combined (97.89±5.72 mg/dL) and dibetic with glibenclamide was (116.70±6.76 mg/dL) (Atchibri et al., 2017). Results evidenced that the peptide fractions with the lowest molecular weight (<3 kDa) have the highest inhibitory activities, and a 16.9–89.1% inhibition of α-amylase and 34.4–89.2% inhibition of α-glucosidase. Naturally occurring fraction showed percentage inhibition against α-amylase (31.8±2.1) and α-glucosidase (89.2±0.1) while acarbose had 32.8±0.4 and 76.0±0.1 percentage inhibition with α-amylase and α-glucosidase, respectively (Valencia-Mejía et al., 2019). Distilled water extract (400 mg/kg bw) was introduced orally to alloxan (150 mg/kg) induced-diabetic albino rats for 14 days. On the 15$^{th}$ day, glucose level was observed showing diabetic rat (6.8±0.3 mmol/L), diabetic and extract (6.0±0.36 *P. vulgaris*), normal (6.4±0.10 mmol/L) and normal with extract feeding rat (5.3±0.20 mmol/L) (Luka et al., 2013).

Aqueous extract was fed to STZ (45 mg/kg bw) induced white non-linear diabetic rats of body weight 100–120 g for 28 days. On 29$^{th}$ day, blood glucose was calculated in mmol/L of control having 5.0, control rat feeding extract showed 6.0, diabetic rat measured 29.0 and diabetic feeding extract calculated 11.0 (Kyznetsova et al., 2015). Normal mice were transformed to diabetic by injecting intraperitoneally in a volume of 1 ml/kg. Forty-eight hours afterstreptozotocin (600 µg/kg bw) administration, rats with blood glucose of 200–300 mg/dLreceiving glibenclamide (600 µg/kg bw) in aqueous solution were fed pod extract daily for 6 weeks. After 45 days, effect of *P. vulgaris* pod extract (PPEt) on blood glucose and plasmainsulin levels on normal rats (79.12±5.4 mg/dL, 14.41±0.70 µU/mL), diabetic control (278.40±22.00 mg/dL, 4.13±0.26 µU/mL), diabetic mice feeding pod extract (91.20±4.65 mg/dL, 7.78±0.40 µU/mL) and diabetic mice feeding glibenclamide (98.20±6.50 mg/dL, 7.50±0.34 µU/mL) (Pari & Venkateswaran, 2003b).

## *Raphanus sativus* (Radish)

Overnight fasted 100 male albino Wistar rats of body weight 150–200 g were induced diabetes by a single intraperitonial injection of freshly prepared STZ (50 mg/kg bw) in 0.1 M citrate buffer. BGL was first checked after 90 min of treatment, considered as 0 hr value, and then 2 g/kg glucose were given orally to all the groups. After 6 hr, BGL measured for control 96.7±3.7 mg/dL and extract (300 mg/kg) 65.5±3.8 mg/dL. The dose of 300 mg/kg bw was identified as the most effective dose which lowers BGL by 33.4% ($p < 0.001$) at 6 hr during FBG studies in normal rats. However, GTT revealed the maximum reduction of 15.9% ($p < 0.001$) in BGL at 3 hr in normal rats with the same dose, whereas the reduction observed was by 23.8 and 28.3% ($p < 0.001$) in sub- and mild-diabetic rats, respectively, at the same interval of time (Shukla et al., 2011).

## *Sechium edule* (Choyota)

Oral administration of *S. edule* ethanol extract (200 mg/kg, p.o. and 100 mg/kg, p.o.) prevented body weight loss and significantly ($p < 0.01$) decrease BGL on 0, 7, 14 and 21 day. On 22$^{th}$day, the BGL was measured showing 94.3±2.95 mg/dL of normal control, 259.5±2.53 mg/dL of diabetic control, 112±2.77 mg/dL of glinbenclamide (5 mg/kg) and 133.33±2.39 mg/dL of *S. edule* extract (200 mg/kg) (Maity et al., 2013). The fresh water extract of *S. edule* showed 80.77% inhibition and decocted water extract showed 80.40% against α-amylase (Muaña & Billacura, 2018).

## *Solanum melongena* (Egg plant)

It is always doubtful in the Nepalse society that egg plant contains health advantages. But after searching literatures related to the biological activities, some amazing information were found. A research team published an intriguing findings linked to the egg plants possessing antidiabetic property. Rats with STZ (60 mg/kg) became intraperitoneally diabetic. Experimental rats were fed hydroalcoholic acid extract in 5 mg/kg bw ratio to 200–250 g mature diabetic male Wistar rates for 14 days. Lowering in BGL showed similar to the healthy rats. Normal rat showed 100 mg/dL BGL while diabetic rat showed just above to the normal rats (nearly 105 mg/dL) ($p < 0.001$) (Gholizadeh et al., 2016). In

vitro assay taking 500 µL of the aqueous plant extract for α-amylase and 500 µL for α-glucosidase enzyme, and thus calculated percentage inhibition showed 50% for rat intestinal glucosidase and 40% for α-amylase (rat intestinal glucosidase) (Kwon et al., 2008). *S. melongena* (500 µL of 1 mg/mL) inhibited α-amylase and α-glucosidase enzymes exhibiting $IC_{50}$ 40.11±0.15 and 63.24±0.30 µg/mL, respectively (Nwanna, 2013).

## *Solanum betaceum* (Tamarillo)

The crude extract of the fruits of *S. betaceum* was analysed for α-amylase inhibition activity. The study showed that the fruits contain various classes of secondary metabolites like flavonoids, tannins, saponins, etc. The fruit possessed a moderate antidiabetic activity in terms of α-amylase inhibition. The inhibition percentage of *S. betaceum* was 60.50% while standard ascarbose showed 62% at 80 µg/mL (Bharathi et al., 2019). Extract in 70% ethanol containing 3% citric acid (ratio 1:4) was used for the experiement. The results showed that the three crude extracts: the tamarillo anthocyanin crude extract, the tamarillo carotenoid crude extract and combination of tamarillo anthocyanin and carotenoid crude extract could inhibit α-glucosidase activity in 30.59, 42.14 and 48.08%, respectively, and for acarbose drug was 73.763% (Puspawati et al., 2018). Ethanol extract at doses of 200 mg/kg bw and 600 mg/kg bw were supplied to male white Wistar strains, aged 3–4 months, with a body weight of 150–200 g. Alloxan (150 mg/kg) was given intraperitoneally to make mice diabetic. After 17 days, BGL was measured exhibiting 72.0±1 mg/dL for negative control (carbocyt methyl cellulose 0.5%), 150±2.34 mg/dL for positive control (glibenklarmid 0.09 mg), 100±1.41 mg/dL for the extract (400 mg/kg bw) and 90±1.14 mg/dL for the extract (600 mg/kg bw) (Yuliani, 2018).

## *Trichosanthes cucumerina* (Snake gourd)

Hot water extract of the aerial parts of *T. cucumerina* was evaluated for the antidiabetic potentiality in normoglycemic rats. The extract exhibited a dose dependent reduction in FBS levels (by 35% at 4 hr post-treatment with dose of 750 mg/kg) and a significant ($p < 0.05$) improvement of glucose tolerance (Arawwawala et al., 2009). In STZ-induced diabetic rats, no immediate hypoglycemic effect was observed. However, with continuous administration, there was a gradual reduction in FBS (by 56.8% on day 14 and by 64.4% on day 28). In normoglycemic rats, on day 14 and day 28, the percentage reduction in FBS levels were 41 and 44%, respectively (Arawwawala et al., 2009). Ethanolic extract dose at a 750 mg/kg was treated to healthy adult male and female Wister rats weighing 200–225 g. After 6 hr, the fasting BGL (60.5±2.6 mg/dL) in normoglycemic rats was significantly ($p < 0.05$) reduced and the effect was comparable to that of the reference drug, tolbutamide at 6 hr (62.4±1.8 mg/dL) (Alam, 2016). Upon administration of the aqueous extract and glibenclamide to the healthy Wistar rats, there was a significant ($p < 0.05$) reduction in the fasting BGL in STZ-induced type-2 diabetic rats by 39% and by 46%, respectively. After 28 days, diabetic control had 286.0±1.5 mg/dL BGL and 6.20±0.48 IU/mL insulin concentration, diabetic with 75 mg/kg of aqueous extract had 104.6±4.6 mg/dL BGL and insulin concentration 14.10±0.99 IU/mL (Arawwawala et al., 2012).

## *Trichosanthes dioica* (Pointed gourd)

Diabetes was induced in 100 albino Wistar rats weighing 150–200 g by a single intraperitoneal injection of STZ (50 mg/kg bw). After 3 days of STZ induction, rats were considered hyperglycemia, whose FBG is more than 150 mg/dL. In GTT, aqueous extract of *T. dioica* (500 mg/kg bw) showed BGL after 3 hr 68.2±3.9 mg/dL and while extract pre-treatment blood glucose was 76.7±3.7 mg/dL. Control group had glucose level 76.7±3.7 mg/dL before extract treatment and after post-treatment at 3 hr 98.7±3.9. Diabetic rats showed fasting BGL 76.8±4.1 mg/dL pre-extract treatment and 51.5±3.7 mg/dL after post-extract treatment, while control group had 75.9±3.6 mg/dL, and after 6 hr of extract treatment was 75.1±3.9 mg/dL. So, the extract diminished BGL by 32.9% ($p < 0.001$) at 6 hr during FBG experiment in normal rats. GTT indicated the maximum reduction of 30.9% ($p < 0.001$) in BGL at 5 hr in normal rats with the same dose, whereas the reduction observed was by 40.3% and 88.6% ($p < 0.001$) in sub- and mild-diabetic rats, respectively, at 3 hr of glucose administration only (Rai et al., 2008). Ninty six male albino rats (200–250 g body weight) get hyperglycemic with the injection of STZ (45 mg/kg, i.p.). OGTT revealed that aqueous extract 1600 mg/kg feeding to glucose loaded hyperglycemic rats showing glucose level 90.75±6.62 mg/dL at 0 min and 92.75±2.42 mg/dL at 120 min, normal rat showing glucose level 62.00±2.51 mg/dL at 0 min and 62.00±1.08 mg/dL at 120 min, and diabetic rats with 251.66±3.81 mg/dL blood glucose at first day and 172.33±2.91 mg/dL after 15 days. In the case of control groups, extract showed BGL 72.25±6.52 mg/dL at 0 min and 105.75±5.39 mg/dL at 120 min for glucose loaded hyperglycemic rats, 65.50±2.02 mg/dL at 0 min and 80.00±4.56 mg/dL at 120 min for normal rats, and 259.33±3.99 mg/dL at first day and 286.50±1.91 mg/dL after 15 days for diabetic rats. In glucose loaded rats, normal rats and hyperglycemic rats, the aqueous extract at the dose 1600 mg/kg p.o. deduced blood glucose remarkably when compared to the control (Adiga et al., 2010).

Diabetes was induced by intraperitoneal injection of STZ at a dose of 55 mg/kg bw to the healthy Wistar rats of body weight 150–200 g. Administration of ethanolic extract of *T. diocia* (800 mg/kg, p.o.) stems for 14 days demonstrated BGL 89±1.5 mg/dL at 14 days, while in the beginning, it was 281±1.2 mg/dL. Diabetic control showed BGL 300±2.8 mg/dL at 14 days but 269±2.5 mg/dL in the starting. Normal saline injecting mice demonstrated BGL pre-treatment 90.2±2.4 mg/dL and after 14 days (post-treatment) it was 92±2.5 mg/dL. Diabetic mice introducing metformin (500 mg/kg) had BGL 270±1.5 mg/dL and after 14 days the BGL remained 300±2.8 mg/dL (Poonam et al., 2017). Experiments were performed on 6–8 weeks old healthy albino Wistar rats of body weight 150–200 g. Diabetes was induced by a single intraperitoneal injection of STZ at a standard dose of 55 mg/kg bw to the overnight fasted mice. Aqueous extract at 1000 mg/kg dose was fed to the diabetic mice for 28 days. BGL was calculated before and after the extract treatment. Mice showed BGL pre-treatment 298.2±7.5 mg/dL, 274.3±4.6 mg/dL at 7 days and 212.3±5.2 mg/dL at 28 days, but control groups had 82.2±3.5 mg/dL pre-treatment, 85.6±2.8 mg/dL at 7 days and 85.2±3.9 mg/dL at 28 days (Rai et al., 2013).

## *Vigna unguiculata* (Cowpea)

Administration of methanol extract led to dose-dependent and significant reductions in BGL in glucose-loaded Swiss albino mice weighing between 15–19 g. At doses of 50, 100, 200 and 400 mg/kg bw, the extract reduced BGL by 24.8, 32.2, 42.0, and 51.7%, respectively compared to control animals. In comparison, the standard antihyperglycemic drug, glibenclamide, when administered at a dose of 10 mg/kg bw reduced BGL by 55.2% (Tazin et al., 2014).

## *Vicia faba* (Faba bean)

The compounds vicine and aglycone divicine were isolated and treated separately to STZ-induced diabetic rats at a dose 50 mg/kg/day bw for 30 days. The results showed that vicine and divicine lessened the blood glucose by 24.9% ($p < 0.01$) and 51.28% ($p < 0.01$), respectively. Vicine remarkably increased insulin level and haemoglobin by 35.45% and 19.20% ($p < 0.05$) and divicine significantly heightened the level of insulin and haemoglobin by 62.36% ($p < 0.01$) and 28.86% ($p < 0.01$) compared to untreated diabetic rats (El-Maksoud et al., 2013). Seed extracted in acetone demonstrated a significant effect on glucose uptake rate (77.28±2.42%) in yeast cells at 25 mM glucose concentration. Minimum glucose uptake rate was found to be 52.36±2.06% using chloroform seed extract (Choudhary & Mishra, 2018). In silico docking analysis was accomplished taking bioactive compounds identified from the bean pod against peroxisome proliferator-activated receptor gamma (PPARγ). The results indicated that gene expression of PPARγ was inhibited by bioactive compounds. Butein has a high binding energy (−8.6 kcal/mol) with an atomic contact energy of −214.10 kcal/mol, followed by apigenin and quercetin against PPARγ. Hence, the results concluded that inhibition of PPARγ by the bioactive compounds may provide insights into developing future therapeutic molecules for DM (Prabhu & Rajeswari, 2018).

## Conclusion

The present review has presented comprehensive details of antidiabetic plants used in the treatment of DM. Some of these plant derived medicines, however, offer potential for cost effective management of diabetes through dietary interventions, nutrient supplementation and combination therapies with synthetic drugs in the short term, and as the sole medication from natural sources over the long term. The presence of bioactive chemicals is mainly responsible for this antidiabetic action. However, many other active agents obtained from plants have not been well characterized. Specifying bioactive compounds present in vegetables is still lacking. More investigations must be carried out to evaluate the mechanism of action of medicinal plants with antidiabetic effect.

This chapter has disclosed comprehensive details of Nepalese fruit and root vegetables used in the treatment of DM based on scientific data. Antidiabetic vegetables aid in effective cost management of diabetes through diet, nutrient supplement and unified therapies along with synthetic drugs.

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**Abbreviations:** BGL = blood glucose level; bw = body weight; DM = diabetes mellitus; FBG = fasting blood glucose; GDM = gestational diabetes mellitus; GI = glycemic index; GTT = glucose tolerance test; PPG = post pranial glucose; STZ = streptozotocin; T1DM = type 1 diabetes mellitus; T2DM = type 2 diabetes mellitus.

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# Author's Biography



Dr. Deegendra Khadka received Master's Degree in Chemistry from Tribhuvan University, Kathmandu, Nepal in 2005 specilization in organic chemistry and natural product, and PhD from Inha University, Incheon, South Korea on molecular biology in 2012 majoring in enzyme chemistry. His research field is mainly focussed on designing and synthesizing phosphatase inhibitors involved in insulin signaling pathway. Dr. Khadka has published research findings in several international journals. Currently, he is working in the capacity of Senior Scientific Officer at Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal.

# Chapter 12

## Fruits and Vegetables - Drug Interaction

**Deepak Basyal**
*Department of Pharmacy, Maharajgunj Medical Campus, Institute of Medicine*
*Tribhuvan University, Maharajgunj Kathmandu, Nepal*
Email: deepakbasyal@iom.edu.np

*Protein, carbohydrate, fat and other nutraceuticals present in food are used by human body to sustain growth, perform vital metabolic processes, furnish energy and maintain life. Secondary metabolites found in small quantities in plants are considered to possess medicinal values, and have a role in defense against pests, pathogens and ailments. These secondary metabolites play a pivotal role in the design and development of drugs. The effect of a drug may vary on a person because it can interact with another drugs or phytoconstituents consumed. Therefore, taking drug together with food may have interactions, and eventually the drug effect can be increased or decreased or may produce a new effect neither produces on its own. These interactions may occur either due to misuse of the drugs or due to lack of knowledge about the active ingredients present in the food. Some interactions may produce synergistic effects and are advantageous to the patients under drug treatment, while some interactions resulted in adverse effects. This chapter focuses on some common drug interactions with fruits and vegetables, and their clinical impact on drug therapy.*

**Keywords:** Adverse drug reaction; cytochrome P450; drug interaction management; food; patient safety; phamacology.

## Introduction

Fruits and vegetables are considered as the cornerstone of healthy dietary recommendations (Smethers & Rolls, 2018). Epidemiologic evidence suggests that, the regular consumption of fruits and vegetables reduces risk of some major chronic non-communicable diseases due to the presence of bioactive natural products (Riboli & Norat, 2003). The interaction of natural products and drugs is a common obscure problem encountered in clinical practice (Joshi & Medhi, 2008). When a food affects medications in the body, this is called drug-food interaction (Mouly et al., 2017). Natural products may modulate metabolizing enzymes (cytochrome P450) and transport proteins of different drugs. This modifies absorption, distribution, metabolism and excretion

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properties of the drug with increased or decreased drug plasma concentrations leading to the presence of adverse events or treatment failure. This can cause the medication to be less or more potent than intended or result in unexpected side effects (Lin et al., 2003). Failure to identify and properly manage drug-nutrient interactions can lead to serious consequences (Kang et al., 2020). The effect of a drug on a person may be different than expected because the drug interacts with another drug the person is taking (drug-drug interaction); food, beverages and dietary supplements the person is consuming (drug-nutrient/food interaction); or another disease the person has (drug-disease interaction) (Buhra et al., 2011). Therefore, it is advisable for patients to follow the instructions of healthcare professionals for obtaining optimal benefits with least food-drug interactions.

Food is one of the most important components of a healthy lifestyle (Bigliardi & Galati, 2013). Traditional Nepali diet reflects our rich culture and tradition (Alonso, 2015). Nutritional richness is another attribute of our traditional diet that deserves to be recognized, appreciated and promoted. According to Nepalese tradition, food and eating are all divine, and delivers a variety of taste, wholesome nourishment and confers protection from diseases. Nepalese cuisine comprises a variety of cuisines based upon ethnicity, soil and climate relating to Nepal's cultural diversity and geography (Harmayani et al., 2019). Diets, high in fruits and vegetables, are widely recommended for their health-promoting properties (Liu, 2013). Fruits such as apple, banana, mango, peach, orange, grapes, watermelon, pears, strawberry, avocado, etc. and vegetables such as potato, tomato, garlic, onion, spinach, cucumber, cabbage, broccoli, carrot, radish, cauliflower, gourd, etc. are commonly consumed in Nepalese culture. Fruits and vegetables include a diverse group of plant foods considered in dietary guidance because of their high concentrations of dietary fiber, vitamins, minerals and bioactive phytochemicals (Septembre-Malaterre et al. 2018). Beyond providing basic nutrition, sufficient intake of fruits and vegetables has been associated with a reduced risk of chronic diseases like asthma, cancers, stroke, diabetes, hypertension, myocardial infarction, neurodegeneration, etc (Medina-Remón et al., 2018; Aguilera et al., 2016; Adefegha, 2018). Therefore, enhancing strategies to promote fruit and vegetable intake are essential for health promotion among population. The World Health Organisation (WHO), and Food and Agriculture Organization of the United Nation (FAO) reports recommend an intake of five to eight portions (400-600 g) daily of fruits and vegetables to reduce risk of cardiovascular diseases, cancers, poor cognitive performance, and other diet-related diseases, as well as for the prevention of micronutrient deficiencies (Rodriguez-Casado, 2016). Despite of all the beneficial effects of intake of different fruits and vegetables, special care should be taken while they are consumed along with allopathic drugs. The phytochemicals may interact with the pharmacological action of administered drug resulting in therapeutic failure or serious adverse effects (Efferth & Koch, 2011).

## Drug Interaction

Drug interactions (DIs) are potential and widely under-recognised source of medication errors which possess significant harm to patients by decreasing efficacy of drugs or causing various adverse events. DI occurs when two or more drugs are co-administered. The pharmacological action of one drug is altered by the co-administration of another drug(s) (Benet, 1971; Brahmankar et al., 2009). When number of co-administered drugs

(usually more than four) is increased, the risk of DI increases substantially (Huang & Lesko, 2004; Izzo et al., 2005; Won et al., 2012). Fruits and vegetables are considered as important part of healthy diet. They are the reservoir of different classes of bioactive secondary metabolites, which prevent from numerous health disorders and ailments. These secondary metabolites have potentiality to interact with different drugs when taken concurrently. They may inhibit or stimulate drug-metabolizing enzymes or alter the plasma drug concentration leading to therapeutic failure (Rodríguez-Fragoso et al., 2011). Knowledge of drug interactions when co-administered with fruits and vegetables is necessary for effective treatment of disease and to decrease economic burdens due to therapeutic failure. Commonly used fruits and vegetables in Nepal like mango, guava, grapes, citrus fruits, apple, papaya, pomegranate, onion, garlic, spinach, tomato, potato, etc. have significant interactions with several drugs used. The important question of today is – Which food should I avoid during my medications? This review focuses on the general overview of some significant drug interactions with fruits and vegetables, and their clinical implications.

## *Drugs More Likely to be Involved in Drugs Interaction*

The topic of DI has received a great deal of recent attention from the regulatory, scientific and health care communities worldwide. The following classes of drugs are particularly responsible for DI (Benet, 1971; Bressler, 2006; Vazquez, 2018; Brahmankar et al., 2009).

1. *With narrow therapeutic index (Low safety margin)*: These include the drugs in which a small change in drug plasma concentration leads to therapeutic failure or toxic effects. Examples: aminoglycosides, lithium and digitalis.
2. *Metabolized by zero order kinetics or saturation kinetics*: These include the drugs whose elimination rate from the body is independent of the plasma concentration. Examples: theophylline and phenytoin.
3. *With high plasma protein binding capacity*: Plasma protein binding plays a key role in drug therapy. Human serum albumin is one of the most widely studied proteins in plasma. High plasma protein binding will extend the half-life of the drug in the body, as only the free or unbound drug is metabolized by enzymes. Examples of high plasma protein bound drugs include NSAIDs, sulfonylureas and warfarin.
4. *Affecting vital physiology of the body*: Drugs which are responsible to alter the physiological actions of the body are more prone to undergo drug interaction with other drugs. Examples include antihypertensive drugs, anticoagulants, CNS acting drugs and anti-diabetic drugs.

## *Classification of Drug Interaction*

Most of the classifications revolve around the effect of a drug's action on the normal pathway of another drug. DI can be broadly classified into three classes viz. physicochemical, pharmacokinetic and pharmacodynamic interactions. Physicochemical interaction occurs because of an incompatibility between chemical structures. Pharmacokinetic interaction occurs due to alteration of absorption, distribution, metabolism or elimination of another drug (Figure 12.1). Pharmacodynamic interaction

can be direct, due to interaction on the same receptor system; or an indirect, when they act on different receptor system.

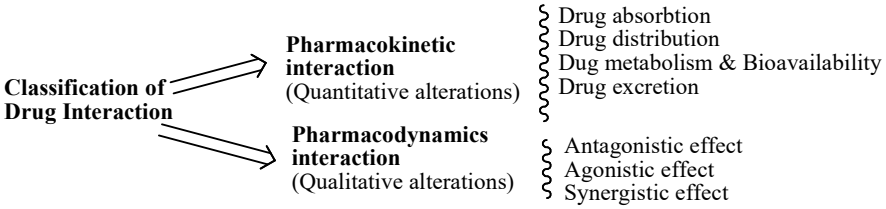



**Figure 12.1.**Pharmacokinetic and pharmacodynamic interactions.

Based on severity level, DI can also be classified into: major, moderate, and minor levels (Benet, 1971; Polasek et al., 2011; Brahmankar et al., 2009).

(a) *Major*: Highly clinically significant. The risk of the interaction outweighs the benefit.

(b) *Moderate*: Moderately clinically significant. Use it only under special circumstances.

(c) *Minor*: Minimally clinically significant. Minimize risk, assess risk and consider an alternative drug.

These classifications are only a guideline. The relevance of a particular DI to a specific individual is difficult to determine.

### *Types of Drug Interaction*

DI can be pharmacokinetic or pharmacodynamic in nature (Mandlekar et al., 2006; Yadav & Yadav, 2019; Nand & Khar, 2007). If plasma concentration of one drug is altered by another – it is a pharmacokinetic drug interaction, and if biological action of one drug is altered by another – it is a pharmacodynamic drug interaction. Pharmacokinetic drug interaction occurs when one drug or food alters, the rate or extent of any one of following four basic processes viz. absorption, distribution, metabolism or excretion, of a second drug. A pharmacodynamic interaction is caused by the concurrent administration of two drugs that have an opposite (antagonistic) effect or similar (synergistic) effect on a particular drug target site. In this type of interaction, there is a change in drug action without altering the plasma concentration (Fukuda et al., 2000; Ötles & Senturk, 2014; Rodríguez-Fragoso et al., 2011).

## Factors Affecting Drug Interaction

Factors affecting in DI can be broadly categorized into two (Benet, 1971; Polasek et al., 2011; Blume et al., 2006; Bressler, 2006; Yadav & Yadav, 2019; Yu et al., 2018; Ötles & Senturk, 2014; Brahmankar et al., 2009; Nand & Khar, 2007):

***1. Drug-related Factors Affecting DI***

- Narrow therapeutic range: The narrower the safety ranges of a drug; more it is prone to DI.

- Drug formulation (presence of interacting excipients): Selection of excipients, which do not interact with active chemical, is important when preparing drug formulation.
- Drug stereochemical and physiochemical properties: Stereochemical and physiochemical considerations are important while formulating drugs.
- Drug potency: More the potency of drug; more it is prone to DI.
- Low bioavailability: Drug with low bioavailability has more clinically significant DI.
- Drug concentration in blood and tissue / Degree of protein binding of interacting drugs: A higher concentration of drug in blood and tissue is more prone to DI.
- Route of administration: Oral route is considered most common route undergoing DI.
- Drug dosage: A higher dose yields a more significant interaction.
- Duration of therapy (acute *versus* chronic administration): Chronic administration of drug has high chances to undergo DI.

***2. Patient-related Factors Affecting DI***

- Inherent inter- and intra-individual variability in pharmacokinetics and pharmacological responses.
- Quantity and activity of specific drug-metabolizing enzymes (genetic polymorphism).
- Age: Adults in their 50s and older are more vulnerable to serious drug side effects and interactions. Patients with age above 70 years are at higher risk of having DI.
- Polypharmacy and multiple drug therapy, particularly with enzyme inhibitors or inducers.
- Gender: Physiological differences between man and women also affect the drug pharmacokinetics and pharmacodynamics.
- Drinking alcohol (acute or chronic users): Alcohol intake can alter the pharmacokinetics of several medications and increase the risk of adverse drug events.
- Diet: Some foods or diets can interact with drug metabolizing enzymes and interfere with the drug metabolism resulting in increase or decrease of plasma drug concentration.
- Underlying disease states and their severity (acute, chronic and/or unstable).
- Tobacco chewing and smoking: It interacts with medications by influencing the absorption, distribution, metabolism and excretion of other drugs, and potentially causes an altered pharmacological response.
- Malfunction and disease of organs of drug elimination (e.g. liver, kidney, etc.)

## Food–Drug Interaction

Other than drug-drug interactions, drugs may interact with food, fruits, vegetables, nutrients (e.g. vitamins and minerals), alternative medicines (herbal products, homeopathic remedies) and cytokines or environmental chemical agents (e.g. cigarette

smoke) (Amadi, 2017; Farkas & Greenblatt, 2008; Liu, 2003; Rodríguez-Fragoso et al., 2011). Like drug–drug interactions, food–drug interactions can also result in two main clinical outcomes: decrease in bioavailability of a drug, which predisposes to treatment failure; or increase in bioavailability, which increases the risk of adverse events and may even precipitate toxicities. Such interactions can either lead to loss of therapeutic efficacy of drug or result in drug toxicities. It can produce negative effects in safety and efficacy of drug therapy, as well in the nutritional status of the patient (Blume et al., 2006; Farkas & Greenblatt, 2008; Genser, 2008). The predictability of DIs can be divided into five documentation levels: established (well documented), probable, suspected, possible, or unlikely. The data may be from in vitro studies, animal studies, anecdotal case reports, or randomized controlled trials in the target population or healthy volunteers (Benet, 1971; Joshua et al., 2007; Polasek et al., 2011; Yadav & Yadav, 2019; Brahmankar et al., 2009; Lambert et al., 2007; Nand & Khar, 2007). Although, significance of interactions between drugs is widely studied, little attention has been given to interactions between drugs and fruits/vegetables. In vitro models and animal models have shown that many of these agents influence drug metabolizing enzymes and drug transporters. It is possible that other fruits and vegetables could have the same potential for fruits and drug interactions, and this should be taken into account. A more consistent approach for evaluation of fruit/vegetable–drug interactions in human beings is therefore needed (Bailey, 2010; Chen et al., 2018; Farkas & Greenblatt, 2008; Izzo et al., 2005; Rodríguez-Fragoso et al., 2011; Won et al., 2012; Yu et al., 2018).

## Cytochrome P450 Enzyme System

Cytochrome P450 (CYP450) consists of a superfamily of heme containing proteins or enzymes (Figure 12.2), which are responsible for the metabolism of a broad range of endogenous compounds (such as, steroidal hormones, lipids and bile acids), as well as exogenous compounds (xenobiotics) including drugs, environmental pollutants, carcinogens and dietary products (Danielson, 2002; Huttunen et al., 2008). CYP450 was first reported in the microsomes of animal liver in 1962 (Omura, 1999). Most of the drugs in use today are metabolized in part by a small set of human CYP450 isozymes (Donato & Castell, 2003).

CYP450s are highly promiscuous enzymes capable of oxidizing many different substrates and their reactions display high stereo- and regioselectivities (Skarydova, 2010). Six enzymes (isozymes) of this family (CYP-1A2, 2C9, 2C19, 2D6, 2E1 and 3A4/5) are responsible for 90% of oxidation processes, among which, CYP3A4 is the most abundant P450 in human liver accounting 30% of the total P450 protein content, but is also expressed in the prostate, breast, gut, colon, small intestine and brain (Tang et al., 2011). The major drug-metabolizing CYP450 is CYP3A4, which contributes to the metabolism or biotransformation of approximately half of the drugs that are in use today followed by the CYP2D6, CYP1A2, and CYP2C9 isoforms, each of which can metabolize about 10% of existing pharmaceutical compounds (McGinnity et al., 2000; Zhou et al., 2009). In recent studies, evidence has accumulated to indicate potent interactions between CYP3A4 and edible phytochemicals. These compounds, some of which are abundant in our diet, belong to the large and diverse family of polyphenolics, including flavonoids, phenolic acids, phenolic alcohols, stilbenoids and lignans

(Nekvindová & Anzenbacher, 2007; Polasek et al., 2011; Remmer et al., 1966; Kim et al., 2006; Won et al., 2012; Yu et al., 2018; Mandlekar et al., 2006; Basheer & Kerem, 2015). The enzyme kinetics, substrates and inhibitors of CYP450s have received a lot of attention in biochemical and pharmacological researches (Roy & Roy, 2009). The sizes and shapes of CYP450s are determined by X-ray crystallography and solution or solid-state NMR studies (Basudhar et al., 2015). Many X-ray structures of different CYP isoforms have been resolved and deposited in the PDB database (Web, 1).




**Figure 12.2.**Protein structure of CYP450.

With the explosion of molecular biology in the 1980s, it became clear that P450 genes existed in virtually all species – from prokaryotes to rodents and humans (Nebert et al., 2013). CYP450s have been identified in bacteria, yeast, fungi, worms, plants, insects, fishes and mammals (Johnson & Stout, 2013). Eukaryotic P450 system proteins generally reside in membranes, primarily the endoplasmic reticulum (microsomal type) or the mitochondrial membrane (mitochondrial type). Microsomal type CYP450s are attached to endoplasmic reticulum and are critical for body's defenses against xenobiotics (foreign chemicals) by mediating their metabolism. Mitochondrial type CYP450s are attached to mitochondria and responsible for metabolisms of endogenous substrates, and have negligible activity towards xenobiotic compounds. Plants and fungi have many microsomal P450s, but no mitochondrial P450 has so far been reported (Brignac-Huber et al., 2016; Omura, 2010; Williams et al., 2000).

The alignment of deduced amino acid sequences in CYP450 led to the first proposal of a gene superfamily nomenclature system based on evolutionary divergence (Nelson et al., 1993). The members of this family are represented as: CYP followed by Arabic numeral (family), capital letter (sub-family) and Arabic numeral (gene). For example, in the enzyme CYP3A4, "3" stands for the gene family, "A" for the sub-family, and "4" defines the gene that encodes a specific polypeptide (Nekvindová & Anzenbacher, 2007; Remmer et al., 1966; Kim et al., 2006). Family and sub-family designations reflect >35% and >70% amino acid sequence identity, respectively. 57 human CYP genes from 18 families and 3753 mammalian CYP genes from 18 families have been described, which encode for CYP450s (Johnson & Stout, 2013). CYPs are associated with many drug–drug interactions and their activity can be influenced by interactions with food, genetic polymorphisms, and many other factors (Zanger et al., 2013; Yoshida et al., 2013).

## Drug Efflux and Influx Transporters

Drug efflux transporters (e.g. P-glycoprotein, P-gp) and influx transporters (e.g. organic anion transporting polypeptide, OATP) located in human intestine (enterocytes) are present in several fruit juices. OATP is responsible for influx of anionic drugs such as 3-hydroxy-3-methylglutaryl coenzyme A (HMG CoA) reductase inhibitors, angiotensin receptor blockers (ARBs), several β-blockers and fexofenadine (Bailey, 2010; Mallhi et al., 2015; Tamai & Tsuji, 2000).

Fruits can inhibit CYP1A1, CYP1A2, CYP1A4, CYP3A1, CYP3A4, CYP2C6, CYP2C9, CYP2E1 and drug transporters (P-glycoprotein, OATP). On the other hand, CYP1A1, CYP1A2, CYP2A2, CYP3A1, CYP1B1, CYP2B1, CYP2B2, CYP2C1, CYP2C6 and CYP2E1 can be inhibited by some vegetables. Antihypertensives, antidiabetics, statins, analgesics and antipsychotics are the most common drugs interacting with fruits and vegetables. The inhibition of their metabolism by fruits and vegetables can cause serious toxic effects, e.g. hypertension, poor glycemic control, rhabdomyolosis and drug overdose-related toxic effects. Overall, active components of fruits and vegetables can interact with many drugs leading to adverse effects (Bressler, 2006; Foti et al., 2010; Hisaka et al., 2010; Lynch & Price, 2007; Nekvindová & Anzenbacher, 2007).

Some of the common fruit/vegetable–drug interactions and their potential implications are highlighted in Table 12.1.

**Table 12.1.**Common fruit/vegetable–drug interactions and their potential implications.

| S.N. | Drugs | Fruits/Vegetables | Interaction |
|---|---|---|---|
| 1 | Warfarin, aspirin | Green leafy vegetable containing vitamin K | Interferes with the effectiveness and safety of warfarin therapy (Nutescu et al., 2006; Guengerich, 2007; Vazquez, 2018) |
| | | Cooked onions, potato | Increase warfarin activity (Booth & Centurelli, 1999) |
| | | Green leafy vegetable | Thromboembolic complications may develop (Greenblatt & von Moltke, 2005) |
| | | Cranberry juice | Elevated International Normalized Ratio(INR) without bleeding in elderly patient (Rindone & Murphy, 2006; Uesawa&Mohri, 2006 |
| 2 | Diuretics | Liquorice | Hypokalemia and sodium retention (Izzo et al., 2005) |
| 3 | Digoxin | Liquorice | Hypokalemia and sodium retention (Izzo et al., 2005) |
| 4 | Anticoagulants | Green tea | Large intake may inhibit hypoprothrombinemic response of drugs (Nutescu et al., 2011; Vazquez, 2008) |
| 5 | Theophylline | Green tea | Increase intake may enhance drug side effect (nervousness, insomnia) (Izzo et al., 2005; Lambert et al., 2007) |

| | | | |
|---|---|---|---|
| 6 | Quinidine | Citrus fruits | Excessive intake may increase blood levels of drugs (alkalization of urine) (Huang & Lesko, 2004; Freiburghaus et al., 1995) |
| 7 | Carbamazepine | Pomegranate juice | Inhibit metabolizing enzyme, increase blood levels of drug (Hidaka et al., 2005; Lambert et al., 2007) |
| 8 | Midazolam, diclofenac, phenytoin, chlorzoxazone | Mango juice | Inhibit drug metabolizing enzymes and drug transporters (Mallhi et al., 2015) |
| 9 | Statins, calcium channel blockers, sildenafil, tricyclic antidepressants, estrogen-containing oral-contraceptives, benzodiazepine, carbamazepine, amiodarone, tacrolimus | Grape fruit juice | Inhibit the cytochrome P450 3A4 (CYP3A4) enzyme and increase blood levels of drug (Sultan et al., 2016; Hulisz & Jakob, 2007; Uesawa & Mohri, 2006; Farkas & Greenblatt, 2008; Peng et al., 2003; Fukuda et al., 2000; Genser, 2008) |
| 10 | Digoxin, fexofenadine, indinavir, vincristine, colchicine, topotecan, paclitaxel | Guava juice | Inhibitory effect on P-glycoprotein mediated efflux in Caco-2 cells (Rodríguez-Fragoso et al., 2011; Chen et al., 2018) |
| 11 | Midazolam | Raspberry and mulberry juice | Inhibition of CYP3A activity, increase blood levels of drug (Kim et al., 2006; Chen et al., 2018) |
| 12 | Fexofenadine, rosuvastatin | Apple juice | Reduction in the oral bioavailability (Liu, 2003; Bailey, 2010; Kamath et al., 2005; Chen et al., 2018) |
| 13 | Antidiabetic drugs | Papaya juice | Significant decrease in plasma sugar levels (Boullata, 2005; Aluefua et al., 2017) |
| 14 | Propranolol | Protein-rich foods | Increase blood levels of drug (Liedholm & Melander, 1990) |
| 15 | Carbidopa, levodopa, theophylline | Protein-rich foods | Decrease concentration in blood and decrease therapeutic efficacy (Debnath et al., 2017) |
| 16 | Diclofenac, tolbutamide, warfarin | Pineapple juice | Inhibits CYP2C9, increase blood levels of drug (Hidaka et al., 2008) |
| 17 | Midazolam, diclofenac | Litchi juice | Inhibits CYP2C9, increase blood levels of drug (Mallhi et al., 2015) |
| 18 | *N*-methylnitrosourea, dimethylnitrosamine, dimethylhydrazine | Tomato | Inhibit CYP1A1, increase blood levels of drug (Wargovich, 2006) |
| 19 | Theophylline, xanthine oxidase, salicylates, hypoglycemic drugs | Red pepper | Inhibit CYP1A1, increase blood levels of drug (Mallhi et al., 2015, Hu et al., 2005) |
| 20 | Heterocyclic aromatic amines | Spinach | Inhibit CYP1A2, increase blood levels of drug (Marley & Blackwell, 1971) |

## Some Common Vegetable–drug Interaction from Our Kitchen

The concurrent use of multiple drugs along with different fruits/vegetables increases the chances of drug–fruit/vegetable interactions (Bressler, 2006). Failure to identify and properly manage drug–fruit/vegetable interactions can lead to serious consequences (Genser, 2008). Patient populations like elderly patients, patients with cancer and/or malnutrition, acquired immunodeficiency syndrome, gastrointestinal tract dysfunctions, those receiving enteral nutrition and transplant recipients have increased risks of suffering from adverse events associated with drug–fruit/vegetable interactions. Elderly patients are particularly at high risk because this population takes more than 30% of all the prescription drugs (Farkas & Greenblatt, 2008; Foti et al., 2010; Izzo et al., 2005; Joshua et al., 2007; Kamath et al., 2005; Lambert et al., 2007).

Limited studies have been conducted on fruits and vegetables to elucidate their potential in inhibition of drug metabolizing enzymes and transporters. Tropical fruits are most commonly used in tropical and sub-tropical countries, and screening of these fruits can avoid drug related complications among patients (Farkas & Greenblatt, 2008; Mallhi et al., 2015; Rodríguez-Fragoso et al., 2011). More studies are still required to find out the safety and risk profile of concomitant use of tropical fruits/vegetables with drugs. It will aid health care professionals during patient counseling. Since it is difficult to create public awareness about the fact that despite offering curative and nutritional benefits, fruits/ vegetables can also confer health risk, and therefore, avoidance of concomitant use of fruits/vegetables and drugs where required, can be an effective strategy for preventing such interactions (Ötles & Senturk, 2014; Vazquez, 2018; Yadav & Yadav, 2019; Yu et al., 2018; Nand & Khar, 2007). To generate public awareness, vegetable-drug interactions of some commonly consumed vegetables are briefly described beneath.

### *1. Drug Interaction with Garlic*

Garlic (*Allium sativum*) has acquired a reputation in different traditions as a prophylactic as well as therapeutic medicinal plant (Shakya & Shakya, 2017). Garlic has played important dietary and medicinal roles throughout the history (Rivlin 2001). The preparations of garlic have been widely recognized as agents for prevention and treatment of cardiovascular and other metabolic diseases such as atherosclerosis, arrhythmia, hyperlipidemia, thrombosis, hypertension and diabetes (Peltz, 2002; Banerjee & Maulik, 2002). The antiplatelet activity of garlic is well documented. Garlic may enhance the pharmacological effect of anticoagulants (e.g. warfarin) and reduce the efficacy of anti-AIDS drugs (e.g. saquinavir) by inhibiting the metabolism of CYP450s (CYP2C9 and CYP3A4 substrates) (Borrelli et al., 2007). Thus, there is a possibility that concurrent use of both garlic and anticoagulant may potentiate the antiplatelet activity and may cause prolongation of bleeding time, hence increasing the risk of hemorrhage. Garlic may also cause treatment failure, if combined with anti-HIV drugs.

### *2. Drug Interaction with Tomato*

Lycopene, a major ingredient in tomato (*Lycopersicon esculentum*), shows promising anticancer effect, including antioxidant activity, inhibition of cell cycle progression, apoptosis induction, increased gap-junctional cell communication, inhibition of insulin-

like growth factor I signal transduction, and inhibition of androgen activation and signalling (Milani et al., 2017; Sharoni et al., 2012). Tomato juice extract contains potent mechanism-based inhibitor(s) of CYP3A4 (Kim et al., 2006; Sunaga et al., 2012). Therefore, all the drugs that are metabolized by CYP3A4 should not be taken concurrently with tomato.

### *3. Drug Interaction with Potato*

Cholinesterases such as acetylcholinesterase (AChE) and butyrylcholinesterase (BuChE) hydrolyze and inactivate several anesthetic drugs, including cocaine, heroin, esmolol, local ester anesthetics, and neuromuscular blocking drugs (Bentué-Ferrer et al., 2003; McGehee et al., 2000). Natural glycoalkaloid toxins, produced by plants of the family Solanaceae which includes potatoes (*Solanum tuberosum*), inhibit both AChE and BuChE (Friedman, 2006; Krasowski et al., 1997).

### *4. Drug Interaction with Onion*

Onion (*Allium cepa*) is one of the food materials in our daily diet, and has been used as a medicinal and dietary supplement for the treatment of hypertension and hyperlipidemia (Teshika et al., 2019). Onion scales contain large amounts of flavonoids (mainly quercetin), and are responsible for antihypertensive, hypolipidemic, antithrombotic, antioxidant, antibacterial and anticancer effects (Asif & Khodadadi, 2013; Corzo-Martínez et al., 2007; Upadhyay, 2016). Study shows that quercetin inhibits P-gp-mediated efflux of antiviral drug (ritonavir) and human CYP3A4 activity (Patel et al., 2004).

### *5. Drug Interaction with Ginger*

Ginger (*Zingiber officinale* ), commonly used spice and herbal supplement, possesses several pharmacological activities such as antioxidant, anti-inflammatory, antiplatelets, hepatoprotective, antitumor and antiviral (Abdel-Azeem et al., 2013; Ashraf et al., 2017). The main pharmacological component of ginger is pungent flavored compound, gingerol. Ginger extract has inhibited activities of CYP2C9 and CYP3A4 in recombinant human CYP isozyme system, and CYP2C19 activity in human liver microsomes (Li et al., 2013; Cho & Yoon, 2015; Abou-Diwan & Ritchie, 2011).

### *6. Drug Interaction with Turmeric*

The rhizome of turmeric (*Curcuma longa*) contains curcumin, which has anti-inflammatory, antioxidant, hypolipidemic and anticancer activities, attributed to its inhibitory effect on several cell signal transduction pathways (Hamidpour et al., 2015; Krup et al., 2013; Wickenberg et al., 2010; Kumar et al., 2011). Curcumin inhibits the activity of CYP1A1, CYP1A2 and CYP2B1 in rat liver microsomes making it susceptible for inhibition of human cytochrome enzymes (Deng et al., 2018; Oesch et al., 2007).

### *7. Drug Interaction with Cauliflower*

Cauliflower (*Brassica oleracea* var. *botrytis*) and broccoli (*Brassica oleracea* var. *italica*) are cruciferous vegetables containing high levels of aliphatics glucosinolate and glucoraphanin (Manchali et al., 2012). Studies show that cruciferous vegetables, including

broccoli, cauliflower, daikon radish sprouts and cabbage, can increase cytochrome P450 (CYP1A2) activity by increasing the clearance and decreasing the effect of drugs metabolized by CYP1A2 (e.g. clazapine, imipramine, propranolol, etc.) (Eagles et al., 2020; Lampe et al., 2000).

### *8. Drug Interaction with Bitter Gourd/Bitter Melon*

Bitter gourd (*Momordica charantia*) contains momordicin, which acts like insulin to decrease blood sugar level. Bitter gourd has synergistic effects with antidiabetic medications causing low blood sugar level (hypoglycemia). Special care should also be taken by the patients taking both antihypertensive and antihyperlipidimic mediciations, as it has synergistic effects with those medications (Basch et al., 2003; Malagi et al., 2014).

### *9. Drug Interaction with Cabbage*

Cabbage (*Brassica oleracea* var. *capitata*) may fluctuate the level of blood sugar and thyroid hormones in human body, so special care should be taken while taking antidiabetic and thyroid medications. It also contains blood thinners such as warfarin which may result in bleeding disorder when taken along with anticoagulants (Girennavar et al., 2004).

### *10. Drug Interaction with Okra/Lady's Finger*

Okra (*Abelmoschus esculentus*) contains vitamins, potassium, calcium, carbohydrates, dietary fiber, and unsaturated fatty acids such as linolenic and oleic acids. Antidiabetic and antihyperlipidemic actions have been documented in this plant. So special care should be taken by the patients taking antidiabetic drugs, since okra has synergistic effects causing low blood sugar level (hypoglycemia) (Roy et al., 2014; Durazzo et al., 2019).

### *11. Drug Interaction with Bottle Gourd*

Consumption of bottle gourd (*Lagenaria siceraria*) is advocated by traditional healers for controlling diabetes mellitus, hypertension, liver diseases, weight loss and other associated benefits. Several flavonol glycosides such as rutin, quercetin and anthocyanins present in the fruit and seed extracts have been found to possess significant antidiabetic activity. Due to this, it may synergistically interact with antidiabetic medications causing low blood sugar level (hypoglycemia) (Sharma et al., 2012).

## Conclusion

Vegetables and fruits that are otherwise considered beneficial to our health can have serious consequences in medical care due to modulation of CYP450 enzymes and P-gp, which are recognized as representative drug metabolizing enzymes and drug transporter, respectively. Interference of plant-based foods with drug performance and pharmacological activity may potentially contribute to an increased risk of side effects or treatment failure. Many food and/or beverages have recently been found to influence drug metabolism and transport, sometimes resulting in clinically important drug interactions. These food–drug interactions are a critical aspect of pharmacotherapy, with potential impacts on the pharmacokinetics and pharmacodynamics of drugs.

Although the importance of drug–food interactions has long been known, a systematic approach to identify, predict and prevent potential interactions between food and drugs has not yet been established. Our knowledge regarding the potential risk of fruit/vegetable–drug interactions is still limited. Therefore, efforts to elucidate potential risk of fruit/vegetable–drug interactions by understanding the mechanisms, magnitude, and potential consequences of any given drug interaction should be intensified in order to prevent undesired and harmful clinical consequences. Healthcare providers, such as physicians, pharmacists, nurses and dietitians have to be aware of importance of fruit/vegetable–drug interactions in order to optimize the therapeutic efficacy of the prescribed and over-the-counter drugs.

**Abbreviations:**CNS = central nervous system; CYP450 = cytochrome P450 enzyme; FAO = Food and Agriculture Organization of the United Nation; NSAID = nonsteroidal anti-inflammatory drug; P-gp = P-glycoprotein; WHO =World Health Organisation.

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# Author's Biography



Mr. Deepak Basyal is currently working as a Lecturer at Department of Pharmacy, Maharajgung Medical Campus, Institute of Medicine, Tribhuvan University (TU). Mr.Basyal passed his B. Pharm. in 2009 from TU. He completed his M. Pharm. (Pharmacognosy) in 2012 from Jaipur National University, India. He has attended several seminars, capacity building trainings and workshops as a resource person regarding structural characterization of natural products, natural products drug discovery, standardization and development of herbal products, etc. He has supervised more than thirty B. Pharm. dissertations and published several reviews and original research papers regarding extraction and biological evaluation of Nepalese medicinal plants.

# Chapter 13

## Trends in Pesticide Use in Different Agricultural Commodities and Residues in Nepal

**Sunil Aryal*, Naresh Dangi and Resona Simkhada**
*National Entomology Research Center, Nepal Agricultural Research Council*
*Khumaltar, Lalitpur, Nepal*
* Email: sunilaryal2005@gmail.com

*Chemical pesticides are major ways for the protection of the crops in field and storage employed by farmers in Nepal. Though, a low pesticide consumption is substantiated in terms of unit area per year, large proportions of which are still used in vegetable crops. It is obvious that chemical pesticides are harmful to human and environment. Major vulnerable sectors are those involved directly in pesticide cycle specifically producers, users and agriculture product consumers. So the use pattern and the residue work on the insecticides have been reviewed in Nepal, to furnish the current status and situation on pesticide issue. It is known from various sources that highest amount of pesticide has been used in the vegetables, followed by cereals in Nepal. The amount of pesticide in agricultural produce, when it reaches to the consumers' table for their viable consumption, is key question to be addressed. Therefore, this paper aims to review using pattern of the pesticides and their residue levels in different commodities in Nepal. The work on pesticide residue has been done since 1981 and the work has been reported in scattered manner. Some of the results show that the amount of pesticide residue was higher than the codex MRLs (maximum residue limits) and ADI (acceptable daily intake) even after twenty-fifth day of insecticide spray. Recent study also shows that almost all the samples analyzed contained pesticide in varying amounts, among which some proportion of different vegetables exceed European Union (EU) MRL level and have potential threat to the human health. So the analyses of pesticide residues in markatbale agricultural commodities are essential through various means. In the meantime, there is also need to widen the area of the awareness raising program for the safe and proper use of chemical pesticides among farmers as well as its effect on the consumers.*

**Keywords:** Acceptable level; environment pollution; human health; pesticides; residue; vegetables.

## Introduction

The era of use of synthetic chemicals began with the formulation of dichlorodiphenyl-trichloroethane (DDT) by Paul Muller (Anonymous, 1965). Before that, the insecticide

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available were either expensive natural products or synthetics ineffective against insects, and both effective and inexpensive were arsenic compounds (Flint & Bosch, 1981). Though the invention was to control the vector mosquitoes causing malaria, it was widely used in agricultural and other household pest since 1945 (Shaw, 1946). In succeeding years, millions of pounds of DDT had been used in agriculture and the problem of residue was investigated and application on forage crops were discouraged (Decker, 1946). After its negative impact and environmental hazard focused by Carson (1962), the world has changed the way of thinking of the pest management that put the world in different direction (Lear, 1998). It was banned for agricultural use in the US in 1972 for the first time (Whitney, 2012). After this various other formulations like organophosphate, organochlorine, synthetic pyrethroids, IGR and other novel insecticides came into existence to be used in Agriculture.

Ministry of Health (MoH), Government of Nepal (GoN) introduced DDT for the first time in Nepal in the year 1952 to use against malarial vector mosquitoes, *Anopheles* spp., (Diptera: Culicidae: Anophilinae) (Kandel & Mainali, 1993). Department of Agriculture (DoA) initiated farmers to use chemical pesticides in crop against insect pests since the importation of DDT in 1956 in Nepal. Later for the plant protection improvement in the country, different classes of chemicals belonging to organophosphates (in 1960s), carbamates (in 1970s) and synthetic pyrethroids (in 1980s) started being imported by different agencies without paying attention toward their ill effects in human health and environment (Aryal & Bista, 2002). Though the yield has been increased since the use of technologies like seed, fertilizers and pesticides, the ill effect of pesticide was also evident due to their improper use. Chemical pesticides are major ways for the protection of the crops since they have been introduced in Nepal, and are the major pest management techniques employed by the farmers in field and storage. Annual consumption of the chemical pesticides is low in Nepal compared to other countries, and large amount of which are used in a specific commodity, particularly vegetables. The government of Nepal has formulated various laws and acts to regulate the pesticide import and use. New Pesticide management Act 2076 covers more pesticide related issues and has stringent rule for offender. Since Nepal is the signatory country of various conventions and has obligation to meet the code of conduct for the proper use while production, and also safeguard the consumers restricting the residue level below MRL specified.

Pesticides use with the doses and frequency higher than recommendation, even with the cocktail spray, were evident (Giri et al., 2004, 2014; Maharjan et al., 2004). Such improper pesticide treatment practice in crop is a regular practice in the crop husbandry, thus expected the crop products poisoned to a level alarming to the human health. Which also pose more risk to the farmers than consumers who are actively involved using pesticides in the fields. On this ground, it is imperative to know the amount of pesticide residues on the instantly consumable marketable commodities like vegetables and fruits. The harmful effect of the chemical insecticide to human and environment is well known in all the three major sectors of pesticide chain, such as pesticide producer, user (farmers) and consumers, where farmers have much greater risk than consumers (Koirala et al., 2009; Martin-Reina et al., 2017; Thapa, 2003; Damalas & Koutroubas, 2016). Besides environmental and human health hazards, Manandhar (2016) categorized the pesticide problem in eight distinct areas such as pesticide misuse, insecticide residues, insect

resistance to insecticides, secondary pest outbreak, incidental loss of life due to pesticide contamination, cases of insecticide poisoning, lack of continuity of data base in pertinent areas, and weak regulatory and poor monitoring systems. Therefore, he has emphasized that pesticide use pattern and residue analysis should be the research priority of the organizations. In the meantime, there is also need to widen the area of the awareness raising program for the safe and proper use of chemical pesticides among farmers as well as its effect on the consumers.

Since its harmful effect is evident through different literatures and cases, the awareness must be imparted to the respective stakeholder. So the use pattern and the residue work on the insecticide have been reviewed in Nepal to furnish the current status and situation on pesticide issue. It is know from various sources that the highest amount of pesticide has been used in the vegetables, followed by cereals in Nepal. Pesticide level in agricultural produce should be monitored before it reached to the consumers' table to know whether they are viable for consumption or not, and this should be the key issue to be addressed in pesticide residue work. The work on pesticide residue has been done since 1981 and the work has been reported in scattered manner. The toxic analysis was done through various methods in vegetables, soil and waters, food articles and other commodities. Some of the results showed that the amount of pesticide residue was higher than the codex MRL and ADL even after twenty-fifth day of insecticide spray (Paneru et al., 2012). Recent study also showed that almost all the samples analyzed contained pesticide in varying amount, among which some proportion of different vegetables exceed EU MRL level and have potential threat to the human health (Bhandari et al., 2019). So the analyses of pesticide residues in marketable agricultural commodities are essential through various means. Not only the residue with GC-MS or LC-MS analyses, but also by the rapid method like Rapid bioassay of pesticide residue (RBPR) analysis, which has been introduced in Nepal by the Entomology Division in 2012 and now being the official method of screening vegetables for rapid residue analysis (Entomology Division, 2013).

Pesticides have been in use since their introduction to the country and the consumption has also been increased from 142 to 396 g active ingredients/hectare (a.i./ha) and vegetables get the most of them (Sharma et al., 2013; Sharma, 2015). As pesticide being used for crops, its regulation and monitoring should be also in place according to act and regulation imposed by GoN. Since the reality of the environmental hazard due to excessive use of pesticide and the prospect of pesticide free export potential of some of the commodities in Nepalese context, Nepal Government has also envisaged priorities to promote health and environment friendly export potential crop productions. Therefore, it is also necessary to monitor toxic residues on the commodities prior to compete in the international market, following World Trade Organization (WTO) regulation. Various researchers from different organizations performed pesticide use surveys and residue analysis independently at different times. Thus, this paper review and discusses the pesticides' consumption, their use pattern and residue analysis published by various organizations and researchers through different media.

Trend analysis of the pesticides is done using data obtained from Plant Quaratine and Pesticide Management Centre, Ministry of Agriculture and Livestock Development; and Food and Agriculture Organization of the United Nations (PQPMC, 2018; FAOSTAT, 2020). The review has been done consulting different available research papers published

in journals, papers in national and international seminars, workshops, proceedings, annual reports, and students' dissertation works as well.

## Trend in Pesticide Import and Consumption

Pesticides registered in Nepal up to December 15, 2018 are 3035 with trade names and 70 with common names. Among them, insecticides (1635) are much more than other pesticides. Acraricides are 28, fungicides 746, bactericides 17, herbicides 436, rodenticides 38, molluscicides 2, biopesticides 113, nematicide 1 and herbal products 19 (PQPMC, 2018). Total pesticides consumption (formulated inside the country + imported) was 1636.41 tons in 2012 which raised to 2271.73 tons in 2017/18. Total amount of imported pesticides is much higher than that of the pesticides formulated inside the country (Figure 13.1).

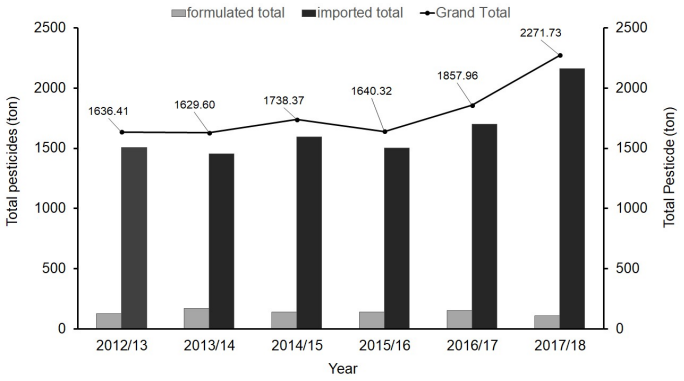



**Figure 13.1.** Imported and formulated pesticides used during 2012/13 to 2017/18 in Nepal. (Bars with left vertical axis represents the data on total pesticide formulated and total pesticide imported. Line with right vertical axis represents the total pesticides combining both formulated and imported).

As amount of imported pesticides was much higher, we did trend analysis of pesticide consumption which was mainly focused on total imported pesticides. Insecticides import occupied around 74% during 2012/13, which decreased up to 67% during 2017/18 (Table 13.1, Figure 13.2A). Fungicide (Figure 13.2B) was the second most pesticide imported, followed by herbicide (Figure 13.2C), rodenticide (Figure 13.2D), biopesticide (Figure 13.2E) and bactericide (Figure 13.2F). Bactericides were least imported. Biopesticides occupied only 0.5% (11.87 tons) of the total pesticides imported during 2017/18, which was decreased from 1.2% (20.45 tons) during 2016/17 (Table 13.1, Figure 13.2E.). The total amount of pesticides imported during 2017/18 was 2,160 tones, which cost about 771 million NRs. The total import of pesticide was increased to 30% during 2017/18 from that of 2012/13 which was 1,505 tons (Figure 13.2G). During 2017/18, the import amount of molluscicides and herbal pesticides was also included in the list (PQPMC, 2018). When the import amount calculated in terms of total pesticides, insecticide held rank first, but when calculated in terms of active ingredients, fungicide ranked first (Kalauni & Joshi, 2019).

**Table 13.1.** Proportion of import of different pesticides from 2012/13 to 2017/18

| | Pesticide import % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Insecticide** | **Fungicide** | **Bactericide** | **Herbicide** | **Rodenticide** | **Biopesticide** | **Molluscicide** | **Herbal** |
| 2012/13 | 73.829 | 12.510 | 0.004 | 12.145 | 0.824 | 0.689 | NA | NA |
| 2013/14 | 71.557 | 15.368 | 0.021 | 11.624 | 0.998 | 0.431 | NA | NA |
| 2014/15 | 63.849 | 18.577 | 0.004 | 15.917 | 1.197 | 0.456 | NA | NA |
| 2015/16 | 61.065 | 20.198 | 0.009 | 16.535 | 1.631 | 0.561 | NA | NA |
| 2016/17 | 61.905 | 24.839 | 0.004 | 10.559 | 1.491 | 1.202 | NA | NA |
| 2017/18 | 67.383 | 16.223 | 0.017 | 14.484 | 1.109 | 0.549 | 0.275 | 0.073 |

NA = Not available

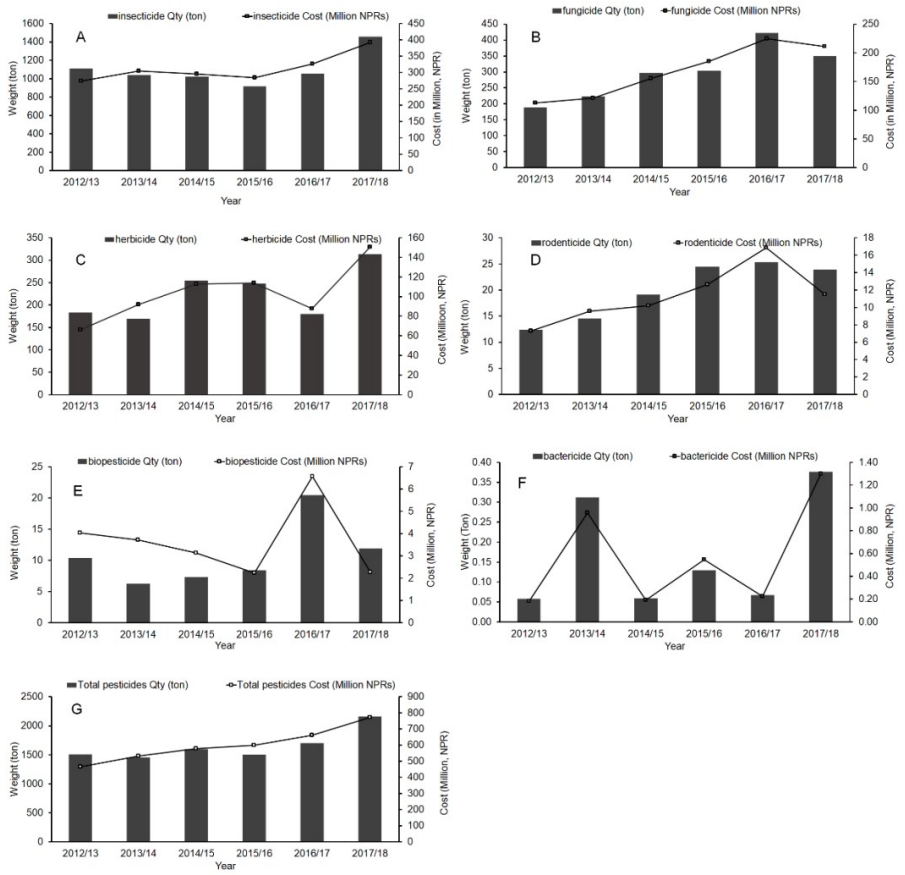



**Figure 13.2.** Pesticides import (tons) and cost in million NRs in Nepal during 2012/13 to 2017/18. (Bars represent the quantity of pesticides with the values in left vertical axis, whilelines represent the cost involved in import of pesticides in right vertical axis). (A-Insecticide, B-Fungicide, C-Herbicide, D-Rodenticide, E-Biopesticide, F-Bactericide, andG-Total Pesticide).

Import of four major pesticides from 2012 to 2018 showed the linear increment on the import of total formulated pesticides. Regression analysis showed there was positive linear increase of import of insecticides ($F_{1, 5} = 1.16$, $p = 0.341$, $R^2 = 0.225$)

and herbicides ($F_{1, 5} = 2.73$, $p = 0.341$, $R^2 = 0.405$), which were not significant, while quantities of import of fungicides ($F_{1, 5} = 15.66$, $p = 0.017$, $R^2 = 0.796$) and rodenticides ($F_{1, 5} = 23.47$, $p = 0.008$, $R^2 = 0.854$) were significantly increased throughout the years (Figure 13.3).

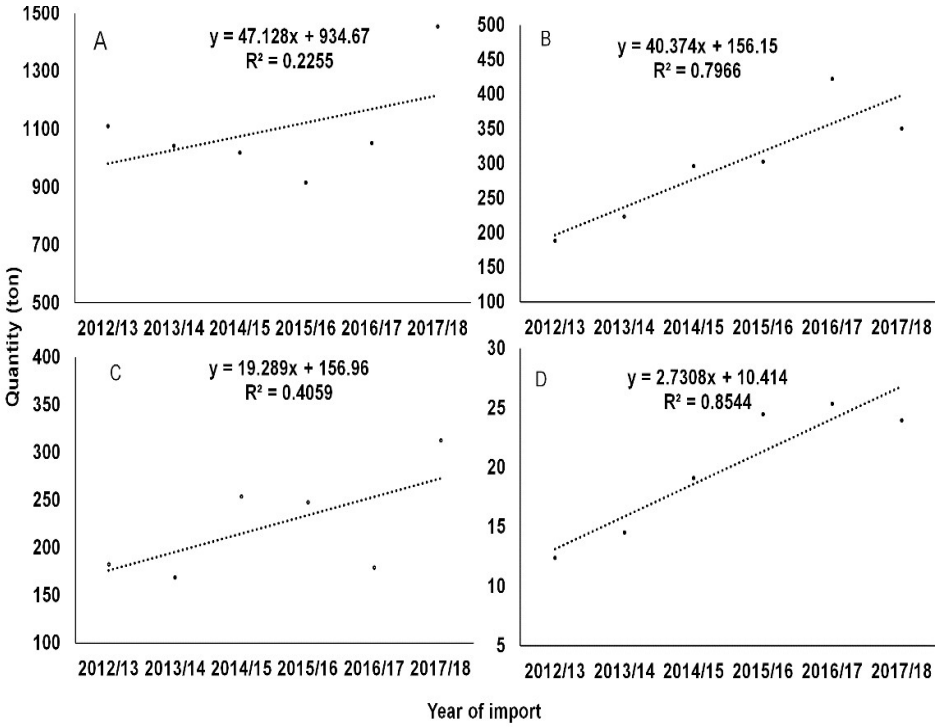



**Figure 13.3.** Linear relation of year of import with import quantities (tons) of four major pesticides. A-Insecticides, B-Fungicides, C-Herbicides, and D-Rodenticides.

FAOSTAT (2020) data revealed that China used maximum amount (1,391,351 tons) of pesticides which was average of the years from 1990 to 2017, where US used second highest amount (406,645.3 tons). When compared to the other top countries, Nepal used only 226.45 tons during 1990 to 2017, which was far low (Figure 13.4). The total pesticide used during 2007 also showed that China occupied first place to consume highest amount (1,763,000 tons) of pesticide while Nepal consumed only 572.97 tons (FAOSTAT, 2020). Annual consumption of active ingredients of pesticide per hectare was calculated 0.396 kg/ha for Nepal, which was very low when compared to the other nations (PRMS, 2014; Sharma, 2015) (Table 13.2). Though the annual consumption of pesticide is very low in Nepal, concern is that most of the pesticide (89%) was only used in vegetables (PRMS, 2014). The consumption of pesticide in vegetable was raised from 1.45 to 1.6 kg a.i./ha (Sharma, 1994; Thapa, 1997; PRMS, 2014).

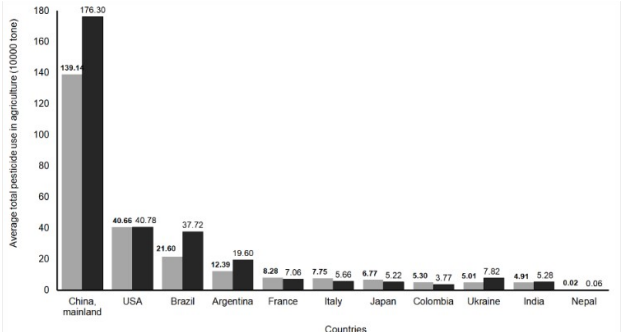



**Figure 13.4.** Average pesticide use in Agriculture. Grey bars indicate the average of the yearly total pesticides used during 1990 to 2017. Black bars indicate the average total pesticides used in 2017.

**Table 13.2.** Annual pesticide consumption of different countries

| Country | Annual pesticide consumption ( a.i. kg/ha) | Source |
|---|---|---|
| India | 0.50 | (Dhital et al., 2015; Yadav et al., 2015) |
| Mexico | 0.75 | |
| Germany | 3.00 | |
| UK | 9.40 | |
| Japan | 12.00 | |
| China | 14.00 | |
| Taiwan | 17.00 | |
| Nepal | 0.142 | (Sharma et al., 2013) |
| Nepal | 0.396 | (PRMS, 2014; Sharma, 2015) |

## Pesticide Use Pattern

Various surveys have been conducted with farmers, retailers, dealers and even with technical persons who especially deal with pest problem on crops. The studies were carried out to find out the current situation of pesticide use pattern (type and frequency of pesticide use), safety measure opted during pesticide handling, frequency of sprays, knowhow of waiting period, pesticide and disposal of their containers, social economic concern of farmers, health problems and risk associated with handling of pesticides as the key issues. Studies on the pesticide use surveys and the key issues raised are reviewed.

A survey at Chitwan district revealed that farmers used pesticide frequently, particularly in potato, tomato, rice, cauliflower, eggplant, chilli, beans, gourds, wheat and mustard. Either the presence of pest or its damage symptom was the reason behind applying pesticides and the waiting period is not maintained after the spray (Shrestha & Neupane, 2002). Farmers of Dhading district used organophosphates and carbamates in higher doses and frequencies, pesticides were applied without adequate understanding of recommended dose, method of application and majority were not acquainted with Integrated Pest Management (IPM) (Giri et al., 2004). However model of IPM and strategies on use of pesticide in agriculture was given by Manandhar (2016). Ghimire and

GC (2018) reported that fungicides are the major form of pesticides used in Nepal and trend of pesticides consumption is increasing for agricultural purposes. A survey at Bara, Dhading and Kavre districts showed that farmers give less preference to botanicals and biopesticide, use higher quantities of chemical pesticides, generally do not follow time lapse between last picking and spraying and precautionary measures for proper disposal of containers (Sharma, 2015).

Dhital et al. (2015) had reviewed on pesticide consumption by different countries and pesticide used in agriculture and its effect on public health. It is reported that annual consumption rate of pesticide is 0.396 a.i. kg/ha and vegetables consume 89% of the pesticide imported which is about 1.6 kg a.i./ha (PRMS, 2014). Also, a survey conducted at 19 districts revealed that farmers largely depend upon pesticide dealers and neighbour's advice to purchase pesticide which leads to abuse and misuse of highly toxic chemicals. Misuse of pesticides was further evident by the study conducted by Sharma et al. (2013). They have found misuse of pesticides in commercial pocket areas and also using of banned and highly hazardous pesticides that may pose great health risk to both consumer and farm families due to pesticide exposure. Palikhe (2002) reported that there is an illegal trans-boundary movement of banned pesticides and farmers consider pesticide as medicine rather than poison. Aryal and Bista (2002), and Bista et al. (2004) have reviewed pesticide stock inventory of obsolete pesticide and their mode of contamination. Obsolete pesticide stock from Nepal has been collected and disposed in Germany (Sharma et al., 2013).

A survey done in 18 potatoes growing districts showed that pesticides users are poor in reading instruction on label, use no safety measures other than covering their mouth with some cloth while spraying pesticides, which reflects poor level of awareness among the pesticide users (Giri et al., 2014). Bhandari et al. (2018) reported that farmers use 2.9 kg a.i./ha of pesticide per crop per season in Rupandehi district, where farmers are aware of risk associated with own health and other animals but do not adopt proper safety measures during pesticide handling. Survey conducted at 19 districts among the vegetable farmers revealed that farmers don't apply safety precautions although they have good level of knowledge on adverse health effects due to pesticides (Aryal et al., 2016). Rijal et al. (2018) had reviewed on adverse effects on health due to lack of personal protection equipment. According to Khanal and Singh (2016), commercial farmers of Chitwan district do not follow proper and safe handling of pesticides, they smoke and chew tobacco while spraying, improperly dispose used containers and also use pesticides extensively. A survey done at Kavrepalanchowk district showed that farmers are aware of harmful effects of pesticides to human health, livestock, plant diversity and their environment, but females are at higher risk due to less knowledge on pesticide use, safety measures and awareness (Sapkota et al., 2020). A survey of potato growers from Kavrepalanchowk revealed that 93% of the growers apply pesticide in their field, and improper disposal of pesticide container is very common among them (Sapkota et al., 2020). Budhathoki et al. (2019) reported that women farmers from Bhaktapur have higher exposure to pesticide and the majority of farmers get technical advice from pesticide seller and neighbour. Gyawali (2018) had reviewed on pesticide consumption in Nepal, its impact on human and environment, and RBPR analysis. A survey conducted at Baglung, Dhading, Bara and Dhankuta districts, where frequency of using of pesticide is high in summer vegetables, indicated various poisoning symptoms like headache, skin irritation,

nausea, eye irritation, vomiting, diarrhoea, dizziness, low appetite, and stomach pain (Maharjan et al., 2004). GC and Neupane (2019) reported that almost 90% of pesticides were purchased from India, and acute health problems like skin irritation, dizziness, lethargy, swelling of body and chronic problem with birth abnormalities are found associated with farmers. Kalauni and Joshi (2019) had reviewed on pesticide import, use, consumption and residue status among food crops in Nepal. A survey done with vegetable farmers of Dhading reported that farmers use maximum pesticides, mostly in tomato, only 56% follow the waiting period, only some sort of mask is used as personal protective equipment (PPE) and headache is the major health issue (Bhandari et al., 2020a). From different studies, it was evident that, most of the farmers gained the knowledge on health issues with pesticide use but still they are not using the proper safety measures. Similarly, the improper disposal of pesticide container after using is also a pertinent issue. To make farmer use safety measures during pesticide spraying and properly dispose the container after spraying should be the major focuses while designing awareness programs.

## Pesticide Residue Analysis

The residue analysis study needs highly sophisticated equipment, trained manpower, internationally recognized procedures and methodologies. It also involves highly hazardous chemicals. Although the Government of Nepal has prioritized this work, and became the signatory of many international treaties as well as formulated acts and regulation regarding the formulation, business and use of pesticides; however, still its implementation part is not stringent. Right now there are few organizations and some independent research involved in residue analysis. There are literatures available where pesticide residual analyses works have been carried out in fruits, vegetables, soil, water, food materials and even in air samples.

### *Pesticide Residues on Agriculture Commodities*

The study conducted in order to assess the pesticide residues in major consumer preferred vegetables (tomato and cauliflower) reveals that the residue levels of dimethoate, chloropyrifos, monocrotophos and methyl parathion on tomato fruits, after 1 to 15 days of application, were found varied from 0.63 to 0.025 ppm, 0.24 to 0.116 ppm, 0.178 to 0.087 ppm and 1.43 to 0.005 ppm, respectively. Similar trend of gradual decline in pesticide residue level was observed in the following year with the same pesticides and crops (Table 13.3). Besides, residue level was also observed highest in the samples collected after 24 hours of pesticide application (Entomology Division, 2005). Similarly, residue level of four pesticides in cauliflower curd on both 1 to 15 days and 3 to 25 days interval indicated significant levels of residue from all the samples treated by tested pesticides with the recommendations. The observed level of malathion, cypermethrin, fenvalarate, dimethoate, dichlorvus and endosulphan in two consecutive years varied from 3.69 to 0.00 ppm, 0.45 to 0.32 ppm, 3.34 to 2.19 ppm, 0.26 to 0.03 ppm, 0.0249 to 0.0004 ppm and 1.3918 to 0.0096 ppm, respectively (Table 13.4). There was recurrent decrease in residual level of pesticides with the increasing time period after their application. However, the rate of decline was not similar and was relative to different pesticide; malathion showed the highest declination while fenvalarate was found as least degradable as compared to others (Table 13.4).

**Table 13.3.** Review on the residues of different insecticides on tomato at Entomology Division during 2004/05 and 2005/06

| Chemicals | Days after application | Residue level 2004/2005 (ppm) | Residue level 2005/2006 (ppm) |
|---|---|---|---|
| Chloropyrifos | 1 | 0.24 | 3.0375 |
| | 3 | 0.238 | 2.0796 |
| | 7 | 0.17 | - |
| | 15 | 0.116 | 0.7239 |
| Dimethoate | 1 | 0.63 | 0.6383 |
| | 3 | 0.166 | 0.689 |
| | 7 | 0.116 | 0.3748 |
| | 15 | 0.025 | 0.0622 |
| Monocrotophos | 1 | 0.178 | 0.7588 |
| | 3 | 0.153 | 0.6215 |
| | 7 | 0.140 | 0.3603 |
| | 15 | 0.087 | 0.3284 |
| Methyl parathion | 1 | 1.43 | 1.1325 |
| | 3 | 0.745 | 0.8866 |
| | 7 | 0.145 | 0.1809 |
| | 15 | 0.005 | 0.0166 |

Source: (Entomology Division, 2005, 2006; Paneru et al., 2010, 2011, 2012)

**Table 13.4.** Review on the residues of different pesticides on cauliflower curd at Entomology Division during 2006/07 and 2007/08

| 2006/2007 | | | 2007/2008 | | |
|---|---|---|---|---|---|
| **Chemicals** | **Days after application** | **Pesticide Residue level (ppm)** | **Chemicals** | **Days after application** | **Pesticide Residue level (ppm)** |
| Malathion | 1 | 3.69 | Dichlorvus | 1 | 0.0249 |
| | 3 | 0.52 | | 3 | 0.0027 |
| | 7 | 0.02 | | 7 | 0.0004 |
| | 15 | 0.00 | | 15 | - |
| Cypermethrin | 1 | 0.45 | Cypermethrin | 3 | 2.7401 |
| | 3 | 0.40 | | 7 | 1.3099 |
| | 7 | 0.37 | | 15 | 0.3835 |
| | 15 | 0.32 | | 25 | 0.1650 |
| Fenvalerate | 1 | 3.34 | Fenvalerate | 3 | 6.8293 |
| | 3 | 4.84 | | 7 | 5.4785 |
| | 7 | 2.21 | | 15 | 5.7977 |
| | 15 | 2.19 | | 25 | 0.8585 |
| Dimethoate | 1 | 0.26 | Endosulphan | 3 | 1.3918 |
| | 3 | 0.58 | | 7 | 1.1239 |
| | 7 | 0.05 | | 15 | 0.1854 |
| | 15 | 0.03 | | 25 | 0.0096 |

Source: (EntomologyDivision, 2006, 2007; Paneru et al., 2010, 2011, 2012)

One of the studies showed none of the samples contained residue of toxic chemicals in fresh cabbage collected from Bhaktapur, however sensitivity of gas chromatograph was 1 or >1 ppm (Entomology Division, 1998). Cypermethrin and fenvelerate residues were higher than ADI at 15 days after last spray in cauliflower (Paneru et al., 2010). The residue of dichlorvos was less than its ADI level in cauliflower at 3 days onward (Paneru et al., 2011). Similarly, residue of malathion was higher than its ADI level up to 3 days in cauliflower (Tables 13.3 and 13.4) (Paneru et al., 2012). According to IPEN (2005), out of 17 potato samples analyzed for Persistent organic pollutants (POPs), only four samples showed some residues above the detection limits (DL = less than 0.001 mg/kg) (Table 13.5). Residue analysis of 23 pesticides (organophosphates, organochlorines, acaricides, fungicides and insecticides of biological origin) in three main vegetables (eggplant, chilli and tomato) showed residues in 93% of the eggplant samples and in all of the chilly and tomato samples (Bhandari et al., 2019). The most frequently detected pesticides in these vegetables were carbendazim and chloropyrifos, and multiple residues were observed in 56% of the eggplant samples, 96% of chilli samples and all of the tomato samples (Bhandari et al., 2019). Similarly, pesticide residues in 4% of the eggplant, 44% of the tomato and 19% of the chilli samples exceeded the EU MRLs. Highest acute hazard quotient (aHQ) was for triazophos (tomato) in adolescents (aHQ=657) and adults (aHQ = 677), showing the highest risks of dietary exposure (Bhandari et al., 2019). Dhakal (2010) reported that organophosphate, organochlorine and pyrethroids contaminated percentage of fruits was 5%, 4% and 3%, respectively. Nepalese tea was below the MRLs for 16 types of pesticides established by codex, India, Japan and EU countries (Koirala et al., 2008). One thousand and thirty four samples were analyzed during 1995-2004 in which 12% residue (malathion 3.9%, β-hexachlorocyclohexane (BHC) 3.1%, methyl parathion 2.8%, DDT 1.8% and parathion 0.3%) was found with highest level of contamination in root vegetables (11.9%) followed by leaf vegetables (10.9%) (Koirala et al., 2009). Bhattarai et al. (2019) reviewed on problems and challenges in pesticide residue. Studies on the residue level on vegetables and tea are listed in Table 13.5 with location of the sample collection.

**Table 13.5.** Review on the residues of different pesticides on various agricultural commodities as reported in different literatures

| S.N. | Crop | Chemicals | Maximum Residue | Location | References |
|---|---|---|---|---|---|
| 1 | Apple | Carbendazim | 0.018µg/kg | Kalimatimarket | (Giri, 2010) |
| | | Diphenylamine | 0.002µg/kg | Asonmarket | |
| 2 | Broad bean | Dichlorvous | 0.0038ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| | | Methyl parathion | 0.0054ppm | | |
| 3 | Cabbage | Dichlorvous | 0.0046ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| 4 | Cauliflower | Dichlorvous | 0.0031ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| | | Methyl parathion | 0.0038ppm | | |
| 5 | Chilly | Methyl parathion | 0.025ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| | | Carbendazim | 1.11-95µg/kg | Rupandehi | (Bhandari et al., 2019) |
| | | Chloropyrifos | 1.29-491µg/kg | | |
| 6 | Cucumber | Metalaxyl | 0.025 mg/kg | Chattradeurali, Dhading | (Giri, 2010) |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Egg plant | Carbendazim | 1.21-154µg/kg | Rupandehi | (Bhandari et al., 2019) |
| | | Chloropyrifos | 1.19-45.3µg/kg | | |
| 8 | Elephant ear plant | Dichlorvous | 0.004 ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| | | Methyl parathion | 0.113 ppm | | |
| 9 | Garlic green | Dichlorvous | 0.01880 ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| 10 | Lettuce | Dichlorvous | 0.012 ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| 11 | Potato | Mancozeb | 0.16ppm | Chitwan | (Manandhar, 2006) |
| | | DDT residue | 0.016mg/kg | Bhaktapur | (IPEN, 2005) |
| | | | 0.041 mg/kg | Indian Bangali | |
| 12 | Spinach | Dichlorvous | 0.008 ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| | | Chloropyrifos | 0.007 mg/kg | Bhaktapur | (Giri, 2010) |
| 13 | Spring onion | Dichlorvous | 0.005 ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |
| 14 | Tea (medium quality) | Ethion | 0.27mg/kg | Jhapa | (Giri, 2010) |
| 15 | Tea (high quality) | Endosulphan | 0.57mg/kg | | |
| 16 | Tea (organic) | Cypermethrin | 0.55mg/kg | | |
| 17 | Tomato | Cypermethrin | 0.84ppm | Kavrepalanchowk | (Manandhar, 2006) |
| | | Mancozeb | 1.64ppm | | |
| | | Cypermethrin | 0.84mg/kg | Dhading | (Giri, 2010) |
| | | Carbendazim | 1.45-337µg/kg | Rupandehi | (Bhandari et al., 2019) |
| | | Chloropyrifos | 1.07-1772µg/kg | | |
| 18 | Turnip | Dichlorvous | 0.03 ppm | Kavre, Bhaktapur | (Rawal et al., 2012) |

## *Pesticide Residues in Food Items*

A total of 527 samples of rice, wheat and milk showed the DDT residue during a period of six years from 1981 to 1986. Out of total 166 tested rice samples, the percentages of contaminated sample varied from 100% (in 1981) to 71% (in 1985 and 1986). Samples in which residue percentage that exceed the MRL (0.01mg/kg) was in range from 90% (in 1983) to 29% (in 1986) (Joshi, 1988). Similarly, contamination percentages varied from 100% (in 1982 and 1983) to 76% (in 1986) in which sample percentage above the residue limit 0.1 mg/kg was ranging from 100% (in 1982) to 28% (in 1986) in the cases of 188 samples of wheat. One of the flour samples collected from Kathmandu showed the maximum residue of 5 ppm. From the year 1981 to 1983, 66 milk samples were tested in which 55 samples contained higher amount of DDT above MRL, i.e. 0.05 mg/kg; which makes – milk is one of the highly risky food commodities. The author further reported that out of 121 samples of milk (88 in 1985 and 33 in 1986), 93% and 40% of the milk samples exceeded MRL in the respective years, and 1.09 ppm was the highest amount of DDT residue obtained during the study period. Fifty five samples of pulses, maize, oils, oil seeds and 70 fruits were analyzed for pesticide residue in which 13% of the fruits samples exceeded the WHO/FAO limit (1 ppm). However, the fruits that were contaminated with more than 0.1 ppm DDT residue were around 69 percent (Joshi, 1988).

## *Pesticide Residues on Air, Soil and Water Bodies*

A study conducted at Entomology Division, Nepal Agricultural Research Council (NARC), Nepal stated that less than 1.0 ppm γ-BHC existed in water and fish of Phewa, Rupa and Begnas lakes of Kaski district (Entomology Division, 1998). Altogether, six composites oils (three from Kathmandu, one from Kavre and two from Bhaktapur), out of 16 samples, showed some indications of lindane at detection level (0.001 to 0.002 ppm), which were far below the USEPA 1999 standard values for DDT (0.053ppm) and lindane/BHC (0.023ppm) (IPEN, 2005). Manandhar (2002) reported that out of total 25 samples analyzed for POP residues (soil 21 and water 4), 13 and 7 samples of soil showed α-BHC and γ-BHC, respectively, in which maximum level of γ-BHC was 0.001 ppm and maximum level of α-BHC was 0.003 ppm and aldrinin in one sample. Similarly in water, α, γ and δ isomers of pesticide were detected in three out of four samples analyzed and the residual levels of BHC remained within the WHO guideline for drinking water in all the analyzed water samples (Manandhar, 2004). According to Bhandari et al. (2020b), out of 147 samples, 60% soil sample with pesticide residues were found more frequently in topsoil, the concentration of pesticides ranged from 1.0 to 251µg/kg, and although chlorpyrifos was the predominant contaminant in soil, DDT ion was also present with negligible amount. The mean concentrations of organochlorine pesticides (OCPs) in the air samples from Dingri and Rongbuk vallies of Mt. Everest were 19.2, 11.2, 7.7, 8.9, 10.4, 27.6, 5.1, 5.1 and 3.7 $pgm^{-3}$for α-HCH, β-HCH, γ-HCH, HCB, heptachlor, α-endosulphan, p,p'-DDE, o,p'-DDT and p,p'-DDT, respectively (Li et al., 2006). Yadav et al. (2018) reported that the overall concentration of POPs (OCPs+PCBs) in Birgunj, Biratnagar, Kathmandu and Pokhara were 1307, 2023, 913 and 724 pg $m^{-3}$ respectively, which showed that concentration of POPs were twice as high in plain than hilly areas. DDT and HCH were dominant organochlorine pesticide in atmosphere of Kathmandu, Pokhara and Hetauda. It was reported that $3.3 \times 10^3$pg $m^{-3}$of HCHs and total endosulphan (α and β isomers) in Hetauda (14 pg $m^{-3}$) were highest, followed by Kathmandu (10 pg $m^{-3}$) and Pokhara (7.0 pg $m^{-3}$), and isomers of DDT were also found in all the three cities (Pokhrel et al., 2018). Average concentration of DDTs was 0.19 ng $g^{-1}$ and 0.08 ng $g^{-1}$ for HCB were found in the samples from Lukla, Namche and Pheriche of Sagramatha National Park, and only p,p'-DDE was measured at a concentration greater than the detection limit (Guzzella et al., 2011). These studies suggest that the Himalayan region could be the place where POP pesticides might have settled.

## *Pesticide Residues on Human Blood*

Analysis of 50 human blood samples from Ludhiana and Nepal revealed that pesticide residues occurred with a frequency of 96 and 94 percent, respectively, in which the levels were higher in Nepalese population (Shrestha et al., 2011). The residue was higher in Nepalese population because the children were residing nearby pesticide warehouse for more than 30 years. Residue analysis on blood samples of school children residing adjacent to the warehouse containing pesticides since 1975 showed DDT (0.079 mg), endosulphan (0.098 mg) and chlorpyrifos (0.245 mg) per liter. Among endosulphan

residues, levels of α-endosulphan, β-endosulphan and endosulphansulphate were 0.034, 0.023 and 0.041 mg/L, respectively (Shrestha et al., 2011). Acetylcholinesterase (AChE) activity on the blood of the farmers due to the exposure to organophosphate was analyzed where activity was reduced significantly, but not enough to claim clinical symptoms (Atreya et al., 2012).

## Rapid Bioassayof Pesticide Residues

Rapid bioassay system is aimed to detect organophosphates and carbamates as well as ethylene bisdithiocarbamate fungicides using housefly acetylcholinesterase and *Bacillus thuringiensis* as the probes (Chiu et al., 1991; Kao et al., 2010). This rapid monitoring system gives the opportunity to general public by stopping the pesticide contaminated shipments in the market. AChE isolated from heads of housefly (*Musca domestica)* has been proved to be highly sensitive and is being used for the pesticide residue analysis. The technology is simple, fast and the results are to be interpreted in toxicological sense. This technique have been accepted in Taiwan, Korea, Vietnam, Philippines, Thailand and Panama because this technique prevents the contaminated produce to reach to the public (Kao et al., 2010). Assay procedure was designed by Pesticide Research Laboratory, Applied Zoology Division, Taiwan Agricultural Research Institute (TARI), Taichung, Taiwan which has been in use in Taiwan since 1985 (Kao et al., 2010) and introduced in Nepal by Entomology Division, NARC (Entomology Division, 2013). After the training on RBPR analysis at the TARI from 18 to 25$^{th}$ June 2012, the first author of this chapter has initiated and established the RBPR laboratory at Entomology Division, NARC, and initiated the tests on organophosphates and carbamates insecticides on vegetables and tea samples. In the same year, samples were collected from 26 tea orchards belonging to different farmers during survey at different places of Jhapa districts. All together 130 samples were collected (5 sample from each orchard). Similarly, four vegetable samples from Jhapa and nine from Kathmandu were also collected and analyzed replicating thrice through RBPR method. Out of 130 green tea leaf samples analyzed, 83.08% (108) samples were found to be inhibiting the AChE below 35%. 13.85% (18) samples showed AChE inhibition between 35 to 45%. Three percent (4) of the samples showed the inhibition of AChE above 45%. Similarly, all the 4 different vegetable samples (pointed gourd, cucumber, lady's finger, capsicum each) from Jhapa showed the AChE inhibition below 35%. Out of 9 vegetable samples (cauliflower, cabbage, tomato, eggplant, and bitter gourd from Baneswor, and cauliflower, cabbage, eggplant and bitter gourd from Koteshwor) analyzed, 6 showed the inhibition below 35%, while for 3 samples (eggplant from Baneswor, and eggplant and bittergourd from Koteshwor), inhibition rate fell between 35 to 45% (Entomology Division, 2013).

In the successive year of 2014, out of 51 vegetable samples, obtained from Kalimati vegetable market, with the help of Kalimati Fruits and Vegetable Market Development Board (KFVMDB), analysis showed that only one vegetable (bitter gourd) had AChE inhibition between 35 to 45% (Entomology Division, 2014). After successful application of

RBPR analysis of organophosphates and carbamates at Entomology Division, NARC, the technique was transferred to the four officers from Plant Protection Directorate (PPD), Nepal, and two from Department of Food Technology and Quality Control (DFTQC) via training during Chaitra 22-25, 2070 BS (April 5-8, 2014) (Entomology Division, 2014). Thereafter, the RBPR laboratory was established at Kalimati Vegetable Market on June 18, 2014 under PPD (Adhikari, 2017) and became the official screening process for the fruits and vegetables. Since then, RBPR laboratory was extended to the different quarantine facilities of the country. Adhikari (2017) has elaborated the results of the pesticide residue analysis by RBPR method employed under various laboratories in a comprehensive manner and showed that the pesticide contaminations are reduced in the recent days than the early years of establishment of RBPR laboratories. This RBPR analysis method is effective when the analysis is done firstly to the ready-to-harvest stage in producing areas and then to the delivery system, i. e. wholesale and retail markets (Kao et al. 2010). Currently, the RBPR laboratories under quarantine facilities were under the jurisdiction of Central Agricultural Laboratory (CAL), DoA, Nepal.

## Process of RBPR Analysis

### *Insecticides Residue Assay*

Extraction of AChEs from housefly head is followed from the procedure outlined by Guilbault et al. (1970), and the scheme is presented by Chiu et al. (1991). The materials and method below is based on the standard protocol formulated by TARI, Taiwan (Chiu et al., 1991; Kao et al., 2010).

*Materials required*

1. 0.1M phosphate buffer (PBS), pH 7.0
2. Acetylcholine iodine (ATCI), 21.6 mg/mL distilled water
3. 5'5-dithio-bis(2-nitrobenzonic acid) (DTNB), 19.8 mg/5 mL PBS (pH 7.0)
4. Ethanol
5. AChE solution with enzymatic activity adjusted to suitable range for the assay

*Extraction*

1. Each sample constituted of 1 g or 4 leaf discs of plant tissue of 4.5-6 $cm^2$ each.
2. After chopping the leaf of vegetable into fine pieces, the sample is transferred into a glass vial (1 cm diameter × 7 cm in length) for the extraction.
3. The plant sample is extracted with 1 mL and 2 mL of 95% ethanol for carbamate and organophosphate pesticides, respectively, and vibrated on test tube mixer (Vertex) for 20 sec.
4. 100 mL of bromine water (0.4%) is added in the tube for the analysis of organophosphate pesticide.
5. After shaking, sample extract is drained to a new test tube in 3 min sharp.
6. Additional standing for 20 min in order to evaporate excess of bromine.

*Assay procedure and reading*

1. In a glass cuvette, 3 mL of phosphate buffer (PBS) is placed.
2. 20 µL of AChE solution and 20 µL of the sample extract (20 µL 95% ethanol for blank) are added in the PBS containing cuvette.
3. Run stop watch.
4. Mixed for 5 sec, kept for standing for 2.5 min and then 100 µL of 5,5'-dithio-bis (2-nitrobenzoic acid) (DTNB) is added.
5. After 3 min, 20 µL of acetylthiocholine iodine (ATCI) is added and the content is mixed for five sec to start the enzymatic reaction.
6. Read the absorbance by placing cuvette in a spectrophotometer for 1 min and record the data of absorbance in every 10 sec.
7. The increasing absorbance at 412 nm is recorded and is compared to the insecticide-free blank for inhibition.
8. In a fixed reaction period, the absorbance of sample is compared to the normal AChE reaction, and the percent inhibition is calculated as follow:
9. $$\% \text{ inhibition} = \frac{\text{Absorbance change (normal) - Absorbance change(sample)}}{\text{Absorbance change (normal)}} \times 100$$

## *Fungicides Residue Assay*

*Materials*

1. Extracting solution: aqueous solution of 1000 ppm ethylenediaminetetraacetic acid (EDTA) containing 2% dimethyl sulphoxide (DMSO)
2. Metabolic indicator: 2,3,5-triphenyltetrazolium chloride (TTC) in 2% (w/v) solution
3. Cultural medium for *Bacillus thuringiensis*
4. Stop solution: 0.5N HCl containing 5% triton
5. Slant medium: 30.5 g antibiotic medium from Difco Laboratories #1 in 1000 mL distilled water

*Assay procedure and interpretation of the result*

1. Add 1 mL of *B. Thuringiensis* suspension into the flask containing sample extract and incubate in constant temperature water bath (37 $^{\circ}$C) with shaking at 140 rpm for 90 min.
2. At centrifugation, 100 µL of 2% TTC solution is added into the incubation flask and continue incubatation and shaking for another 30 min in the dark.
3. At the end of incubation, 1 mL of 0.5N HCl in 5% triton is added into the flask and mix well to stop the reaction and then dissolve the precipitation for a red colour inspection.
4. The result should be examined first by naked eyes and then compared to the blank for the colour difference.
5. Spectrophotometer examination is generally not needed for the severe cases since the colour difference will beeasily distinguished.

6. Only the sample with colour wondering between red and yellow needs to be centrifuged and compared in the visible spectrophotometer at 484 nm for the absorption difference.
7. $$\% \text{ inhibition} = \frac{\text{Absorbance (fungicide free blank) - Absorbance change(sample)}}{\text{Absorbance change (fungicide free blank)}} \times 100$$

Inhibition of the AChE below 35% is considered as a safe limit for the market assay. The produces with AChE inhibition between 35 to 45% (which is the category falls under warning the shipment) are kept for the quarantine and after further examination can be sent to the market for sell. Inhibition of AChE above 45% needs to be discarded for shipment into the market and needs to be destroyed. The positive response is purely in toxicological sense, which confirms the presence of RBPR target pesticides. The positive response can be used as an indicator for potential hazardous levels of pesticide residue in samples. Whether the samples should be further analyzed by other methods (for example, chemical analysis) is depended on the decision of inspecting institution.

This method can be applied not only to fruits and vegetables but also to tea, grains and spices. The positive response can be used as an indicator for potential hazardous levels of pesticide residue in samples. The detailed chemical analysis needs advanced analytical instruments, such as gas chromatography and high performance liquid chromatography, which is time consuming and tedious. By the time of analysis completed using advanced equipment, vegetables have already been consumed and therefore such an analysis is mostly used for investigation purpose only (Kao et al., 2010).

## Conclusion

The pesticide use in Nepal is far lower than other countries, but problems still arise because of the improper pesticide use without maintaining waiting period. The major problem is the major proportion of pesticide imported is used in vegetables. Studies were found focusing on pesticide use surveys which reveals the misuse and overuse of pesticides in various instances. High frequency and cocktail spray of different pesticides were evident while using pesticides, which are still exist. Poor safety measures and lack of proper gears during pesticide application are one of the great concerns that pose the pesticide applicators at great health risk. Though the farmers now are aware about the health related issues, they are not using proper protective gears while applying the pesticides in the field, which often give rise to some of the health ailments, like headache, vomiting, dizziness, sweating, nausea, etc. Knowhow of waiting period among the farmers is better than before, but could not wait for the perishable commodity. Some farmers even grow there vegetables separately in kitchen garden to avoid contaminated food, but they were unaware that they might have more risk than consumers as they were frequently exposed to the pesticide while handling it. The improper disposal of the used container of pesticide remains same as it was before. Reviewing earlier survey report and latter ones, the level of knowledge about the proper handling of pesticide by farmers has been increased a little, but not enough to safeguard human and environmental health. The areas where the training of IPM has reached, those farmers are comparatively more aware of the pesticide handling issues than the farmers of other areas. Therefore, more efforts

and interventions are still needed to make farmers aware about the every aspects of pesticide use. Besides, the rule and regulation should be implemented stringently for those who being stubborn and do not follow the rules. Pesticide use in current farming system seems inevitable as to increase the productivity by reducing the pest problem, but application should be in judicious manner. Pesticide use has to be combined with different other IPM components, like cultural, biological, physical, mechanical and regulatory in a compatible manner.

To know whether the pesticide use was done in proper way or not in the fields can be confirmed with the residue analysis of the agricultural produce. Research indicated that even with application of recommended doses, certain pesticide still persists above ADI even after certain interval of time. It has been evident from the above review that there are contaminations of POP pesticides still exist and the author argues that the POP problems could be both arisen from the recent as well as historical use. Residue analysis should be carried out in agricultural crop to establish Good Agriculture Practice (GAP). MRL establishment needs a lot of researches on pesticide residue trial (EFSA, 2015; OECD, 2016) and results of which are used to estimate MRLs (OECD, 2016). The process for establishing MRL could take longer periods. It can take up to 24 months to publish MRLs of the commodities after application is registered for approval to concern authorities (European Commission, 2018). Therefore, for a country like Nepal, can adapt the worldwide acceptable MRL level of codex, EU, etc. until to be able to involve in rigorous research to establishment of own MRLs level. However, efforts have been made by DFTQC to set MRL levels for different food items (Lama, 2009) and it was proposed for fruits and vegetables (Kalauni & Joshi, 2019). Some authors have recommended to establish qualitative as well as quantitative analysis facilities to know the status of pesticide residue in marketable agricultural commodities concerning commercial and trade values (Giri et al., 2016; Manandhar, 2016). The RBPR qualitative analysis, which is a quick method to analyze product whether it is fit for consumption or not, has been established in various organizations, but could be coupled with analysis or ready-to-harvest products and market products. Other commodities like grain and tea also could be included in RBPR analysis. Different works of pesticide residues, such as dissipation study, research on MRL setting, monitoring on marketable agriculture produce and quality control of imported pesticides should well be delegated among the organizations like NARC, DoA, DFTQC, IAAS, AFU, NAST and relevant stakeholders), and their role should be clearly defined.

**Abbreviations:**AChE = acetylcholinesterase; ADL = acceptable daily intake; AFU = Agriculture and Forest University; BHC = β-hexachlorocyclohexane; DDT = dichlorodiphenyltrichloroethane; DFTQC = Department of Food Technology and Quality Control; DoA = Department of Agriculture; EU = European Union; FAO = Food and Agriculture Organization of the United Nations;GC-MS = gas chromatography-mass spectrometry; GoN = Government of Nepal; HCH = hexachlorocyclohexane; IAAS = Institute of Agriculture and Animal Science; IPM = integrated pest management; LC-MS = liquid chromatography-mass spectrometry; MoH = Ministry of Health; MRL = maximum residue limit; NARC = Nepal Agricultural Research Council; NAST = Nepal Academy of Science and Technology; OCP = organochlorine pesticides; PCB = polychlorinated biphenyl; POP = persistent organic pollutants; PPD = Plant Protection Directorate; PQPMC = Plant Quaratine and Pesticide Management Centre; RBPR = rapid bioassay of pesticide residue.

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# Author's Biography



Dr. Sunil Aryal is Senior Scientist at National Entomology Research Center, National Agriculture Research Institute (NARI), Nepal Agricultural Research Council (NARC). He has been working at NARC since 1998. He received his M. Sc. (Entomology) degree from Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Rampur, Chitwan, Nepal and Ph. D. from Andong National University, Gyeongsangbuk-do, Republic of Korea. He received "Nepal Bidhya Bhusan KA" in 2019 from Honorable President of Nepal. His areas of work are plant-insect interaction, integrated pest management, pesticide residue analysis and biological control. He has published a training manual, more than two dozens of research articles in international and national journals, proceedings, book chapters and farmers friendly booklets.



Dr. Naresh Dangi is scientist at National Entomology Research Center, National Agriculture Research Institute (NARI), Nepal Agricultural Research Council (NARC). He received his M.Sc. Ag. (Entomology) degree from Institute of Agriculture and Animal Science, Tribhuvan University Nepal and Ph.D. (Applied Entomology) from Andong National University, Republic of Korea. He received "Nepal Bidhya Bhusan KA" in 2019 from Honorable President of Nepal. Dr. Dangi, currently working on entomopathogenic fungus, toxicology, pest management and taxonomy (Simulium spp). He has published one training manual, and more than dozens of research articles in international and national journals.



Ms. Resona Simkhada is a Technical Officer at National Entomology Research Center under Nepal Agricultural Research Council (NARC) since 2012. She received her Master's degree in Agriculture (Entomology) from Agriculture and Forestry University in 2018. She had received Nuffic scholarship for short training courses in Integrated Pest Management, and Food Safety and Phytosanitary measures in global horticultural supply chains. She has been engaged in integrated pest management and biological pest control. She has published about half a dozen research papers in national journals.

# Chapter 14

## Progress and Potential of Bio-pesticides in Pest Management

**Resham B. Thapa**
*Institute of Agriculture and Animal Science*
*Tribhuvan University, Kirtipur, Nepal*
Email: profrbthapa@gmail.com

*Insect pests, diseases and weeds are major issues in crop production throughout the world. There are estimates of 67,000 different crop pest species – including plant pathogens, weeds, invertebrates and some vertebrates, and altogether they cause over 40% reduction in the world's crop yield. For their control especially in commercial agriculture, indiscriminate use of chemicals has resulted in enormous challenges to farmers, consumers and the environment as a whole. During the last few decades, public awareness about the adverse effects of pesticides on the safety of foods and on the environment has increased, which has forced to explore alternatives to widely used chemical pesticides, and especially bio-pesticides have become a priority with major improvements to pest management technology and practices in Integrated Pest Management (IPM) programs. Hence, bio-pesticides have been widely promoted as safe and environmentally friendly pest management measures and expected to increase their use in the future. This article reviews progress and potential of bio-pesticides to maintain pests below economic threshold and to sustain increasing agricultural production in an eco-friendly manner.*

**Keywords:** Bio-pesticides; environment; health safety; pest management.

## Introduction

The world population of 6 billion figure in 1999 reached 7.8 billion in 2020 and is expected to reach 9.7 billion (Web, 1), and food demand is predicted to increase 70% between 2007 and 2050 (FAO, 2009). The worlds land area comprises 130.7 million $km^2$ and about 38% land cover is occupied by agriculture, which means less than half of this land area is suitable for agriculture, including grazing, and arable land expansion is limited (Fischer et al., 1999). The population of Nepal has also been increasing; it was estimated at 26.5 million as of 2011, is projected to grow to 30.4 million by 2021 and 33.6 million by 2031 (CBS, 2014), and threat to food security is the main issue (CIAT et al., 2017).

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Crop loss due to pests (insect pests and diseases) is about 35% in the field and 14% in storage, giving a total loss of about 50% of agricultural crops annually. Thus, the world food production is adversely affected by pests during crop growth, harvest and storage (Dhaliwal & Arora, 2001; Kulkarni et al., 2009). A crop and plant have to compete with 30,000 species of weeds, 3,000 species of nematodes and 100,000 species of plant eating insects.

## Chemical Pesticide Problems

Intensive cultivation of crops with indiscriminate use of chemicals poses enormous challenges to the growers, consumers and environment leading to health and environmental hazards. According to Koul et al. (2008), about 2.5 million tons of pesticides are used on crops each year and the worldwide damages caused by pesticides to life reach $100 billion annually. According to WHO (2019), over three million cases of pesticide poisoning occur every year, resulting in an excess of 250,000 deaths worldwide.

Pesticides are inherently more toxic than bio-pesticides and affect broad spectrum of non-target organisms, such as beneficial insects, birds, wildlife, aquatic animals and mammals. Nepal imports pesticides from different countries and 2,275 trade names of pesticides are registered under 124 common names (Table 14.1) for pest management in comparison to 78 bio-pesticides under only 11 common names (PRMD, 2016).

**Table 14.1.** Registered pesticides in Nepal.

| S.N. | Pesticide category | Common name | Trade name |
|---|---|---|---|
| 1 | Chemical pesticides | 113 | 2197 |
| 2 | Bio-pesticides | 11 | 78 |
| | Total | 124 | 2275 |

Source: (PRMD, 2016)

## Bio-pesticides as Alternatives

Public awareness about the adverse effects of pesticides on the safety of foods and on the environmental impacts has increased in recent years. So, worldwide efforts have been to address the problems, such as high cost of pesticides and environmental pollution. Microbial facilitation in SAARC countries is good indication in this direction (Chaudhary et al., 2017; Tiwari, 2017). Bio-pesticides have been promoted as safe and eco-friendly pest management means as an alternative to chemical pesticides (Anwer, 2018; Gurung & Azad, 2013). Microbial pesticides can be smart inputs and components of IPM program (Kesho, 2020). However, the share of bio-pesticides in pest management is very nominal, which is less than one percent in terms of quantity and price as well in Nepal (PRMD, 2016).

| Pest problems | Pesticide problems | Bio-pesticides in pest management |
|---|---|---|
| Food plants of the world are damaged by more than 10,000 species of insects, 30,000 species of weeds, 100,000 diseases (caused by fungi, viruses, bacteria and other microbes) and 1,000 species of nematodes (Dhaliwal et al., 2007). | Globally US$ > 25 billion is spent on pesticide each year, which causes human health hazards, environment pollution, pest resistance, additional cost to farmers for pest control. | Ecofriendly pesticides<br>Environment safety<br>Low residual toxicity<br>Host specific in action |

Importing of microbial pesticides in Nepal started after 2000. Gurung and Azad (2013) reported 45 different formulations available in the Nepalese market, followed by Sri Lanka with 34 products and Pakistan 16 products. In Bangladesh, Bhutan and Afghanistan, there are 13, 10 and 3 bio-pesticides currently in use by farmers, respectively. Recently, Pesticide Registration and Management Division (PRMD) has registered 78 microbial pesticide products including *Bacillus subtilis*, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, nuclear polyhedroses virus (NPV), *Paecilomyces lilacinus*, *Pseudomonas fluroescens*, *Trichoderma harzianum*, *Trichoderma viride* and *Verticillium lecanii*. In addition to imported products, a few local isolates of *B. bassiana*, *M. anisopliae* and *Steinernema* spp. are found to be effective in pest management (Kumar & Singh, 2015; Lacey, 2017). In 2016, bio-pesticides accounted for 5.6% of the total crop protection sales compared to 0.4% in 1993. So there is steady increase of bio-pesticides in crop protection.

Nepal has enacted Pesticide Act-1991 to make provisions for import, export, production, purchase, sale and use of pesticides. Plant Protection Directorate (PPD) has been designated as the National Plant Protection Organization (NPPO) in the country by Nepal Gazette Part 5, Section 63 and No 44. PRMD under PPD engages in pesticide regulation and registration activities. Nepal has recognized the IPM as a major strategy for pest management since 1997. Further, due importance has been given for IPM programs in Agriculture Policy-2004 as well as in Agriculture Development Strategy 2015-2035 (ADS, 2015). Technical and research back up for plant protection services are provided through National Agricultural Research Council (NARC). Accordingly, some bio-pesticides have been used in agricultural pest management, and horticulture discipline is of major concern because of fresh vegetables and fruits marketing and consumption.

Till now, 452 biocontrol agents are used in the production of 2,000 commercial products worldwide. It includes 149 micro-organisms, 89 natural products, 140 macro-organisms, and 74 semio-chemicals (Dhaliwal et al., 2013; Kesho, 2020; Nawaz et al., 2016). There are at least 1,500 naturally occurring insect-specific micro-organisms, 100 of which are insecticidal (Khachatourians, 2009). Microbial control agents based on naturally occurring fungi, bacteria, viruses or nematodes have offered some realistic alternatives to chemical pesticides when used as part of an ecologically based integrated pest management (EBIPM) or area-wide pest management strategy (AWPM) (Koul et al., 2008).

The various natural enemies used to control pests are grouped into macrobial and microbial control agents. The former includes predatory and parasitic insects and predatory vertebrates, such as birds, reptiles, mammals, etc. The latter includes parasitic nematodes,

protozoan diseases, parasitic fungi, disease causing bacteria and viruses. Many works on utilization of beneficial insects and management of the harmful ones began since human beings learned agriculture. Natural enemies attack various life stages of insects and their effect ranges from a temporary or minor to the death of the host insects (Dhaliwal & Arora, 2001; Thapa, 1994, 2003). There are over 300,000 species of insects in the world that feed entirely or in some degree on other insects (over 216 Families). Some commonly used natural enemies against insect pests, especially in vegetable crops, are presented in Tables 14.2-14.5. Mass rearing technique of predators, like green lace wing (*Chrysoperla carnea*), larval parasitoid like *Cotesia plutellae* and egg parasitoid like *Trichogramma chilonis* has been developed by Entomology Division, NARC.

**Table 14.2.** Use of predators and parasitoids for controlling vegetable pests

| S.N. | Natural enemies | Predatory stages | Preys |
|---|---|---|---|
| 1 | Ladybird beetles | Larvae and adults | Feed on aphids, mites, thrips, scale, mealy bugs |
| 2 | Ground beetles | Larvae and adults | Feed on various soil dwelling insects |
| 3 | Rove beetles | Larvae and adults | Feed on various soil dwelling insects |
| 4 | Tiger beetles | Larvae and adults | Feed on various insects on ground surface |
| 5 | Lace wings | Larvae and adults | Feed on aphids, whitefly, thrips, mites, mealybugs |
| 6 | Hover flies | Larvae only | Larvae spear aphids with jaws and suck juices |
| 7 | Robber flies | Adults and larvae in some cases | Feed on various insects |
| 8 | Wasps many species | Adults and prey fed to larvae | Feed on various insects, mainly caterpillars |
| 9 | Predatory bugs | Nymphs and adults | Pierce aphids, moth eggs and caterpillars |
| 10 | Spiders many species | Adults and juveniles | Feed on range of insect species |
| 11 | Predatory mites | Adults and juveniles | Predate on plant feeding mites |
| 12 | Vertebrates species | Adults | Feed on various insect species |
| 13 | Parasitic many wasps | Adults | Female lays eggs on preys - eggs, larvae, pupae<br>Aphid - *Trioxys* spp., *Aphidius* spp.<br>Whitefly - *Eretmocerus* spp., *Encarsia* spp.<br>Eggs - *Trichogramma* spp.<br>Larva - *Apanteles* spp., *Cotesia* spp.<br>Pupa - *Xanthopimpla* spp. |

Source: Modified from Neupane (2008)

The microbial pathogens are specific to the pest species. Over 90 different species of bacteria, 750 fungal species (100 genera) and 250 viruses are associated in insects causing diseases. One of the best studied species among bacteria is *B. thuringiensis* (Berliner).

Similarly, *Metarhizium, Trichoderma, Beuveria* from fungi and NPV and cytoplasmic polyhedroses virus (CPV) viruses are more promising as insect pests control agents (Chandy, 2013; Muniappan & Heinrichs, 2016; Neupane, 2008). Their uses in target crops/pests/pathogens are presented in Tables 14.3 and 14.4).

**Table 14.3.** Use of microbial bio-pesticides for controlling vegetable and other crop pests

| S.N. | Microbes | Product | Target pest | Major crop |
|---|---|---|---|---|
| 1 | Bacteria | *B. thuringiensis*<br>*Bacillus sphaericus*<br>*B. subtilis*<br>*Pseudomonas fluorescens* | Moths, mosquitoes, flies fungal pathogens | Vegetable, cereal, oilseeds, peas, soybean groundnut and cotton |
| 2 | Fungi | *T. viride*<br>*T. harzianum*<br>*Trichoderma hamatum*<br>*B. bassiana*<br>*V. lecanii*<br>*M. anisopliae* | Fungal pathogens, insect pests like bollworm, white flies, root grubs, tea mosquito bugs | Vegetable, cereal, pulses, oilseeds, plantations, spices, sugarcane and cotton |
| 3 | Virus | Nuclear polyhedroses virus (NPV) | American bollworm, tobacco caterpillar and shoot borer | Vegetable, sunflower, cotton, tobacco and sugarcane |

Source: (Chandy, 2013)

**Table 14.4.** Use of *Trichoderma* spp. for controlling various pathogen pests

| S.N. | Antagonist | Pathogens | Host | Application |
|---|---|---|---|---|
| 1 | *Trichoderma* spp. C62 | *Sclerotium cepivorum* | Onion | Soil |
| 2 | *Trichoderma* spp. | *Rhizoctonia. Solani* | Lettuce | Spores added to soil |
| 3 | *T. harzianum* | *Fusarium graminearum* | Radish | Soil |
| 4 | *T. harzianum* T95I | *Pythium ulktimum* | Cucumber | Soil |
| 5 | *Trichoderma koningii* | *Sclerotium rolfsii* | Tomato | Soil |
| 6 | *T. koningii* | *Pythium* spp. | Pea | Seed and soil |
| 7 | *T. harzianum* | *Pythium ultimum* | Pea | Seed |
| 8 | *T. hamatum* | *Rhizoctonia. Solani* | Radish | Soil |
| 9 | *T. viride* | *Pythium ultimum* | Chilli, tomato, brinjal, okra | Seed and soil |

Source: (Muniappan & Heinrichs, 2016)

Suppression of insect pests using locally available plant materials is a very old practice. According to Talukder (2006), there are 43 plant species as insect repellents, 21

plants as insect feeding deterrents, 47 plants as insect toxicants, 37 plants as grain protectants, 27 plants as insect reproduction inhibitors, and 7 plants as insect growth and development inhibitors. Essential oils from plants are also used as bio-pesticides, especially as insecticides. Nepal possesses more than 324 plant species having pesticidal properties, of which 21 plant species are considered as very effective against insect pests (Neupane, 2000, 2003). Paneru (2005) reviewed some plant materials being used in vegetable insect pests in Nepal (Table 14.5). Among the botanicals, neem (*Azadirachta indica*), sweet flag (*Acorus calamus*) and tobacco (*Nicotiana tabacum*) are most promising in pest management.

**Table 14.5.** Use of botanicals for controlling vegetable insect pests

| S.N. | Insect pests | Vegetable | Measures |
|---|---|---|---|
| 1 | *Lipaphis erysimi* (Mustard aphid) | Cabbage | Use of nicotine sulphate 40% (Tobacco product). Tobacco soap and water solution in a ratio 1:1:20 was effective for 4-5 days. |
| 2 | *Pthorimea operculella* (PTM) | Potato | Use of *Chenopodium* sp., *Mentha* sp., *Artemesia* sp., *Eucalyptus* sp. leaves with stems at 300-330 g per 8 kg potato tubers. |
| 3 | *Pridenia litura* (Tobacco caterpillar) *Athalia proxima lugens* (Mustard sawfly) *Phyllocnistis citrella Phytomyza horticola* (Leafminer) | Vegetable | Tobacco decoction (250 g tobacco + 30 g liquid soap + 4 L of water boiled for 30 min and dilute the decoction at 1:4 parts water). |
| 4 | *Aulacophora foveicollis* (Red pumpkin beetle) | Zukini | Fresh leaf water extracts of *Artemisia vulgaris* (blended in water, kept it for 1 hr and muslin cloth strained solution) at 25 g/L water. |
| 5 | *Phylotreta* spp. (Flea beetle) | Cole crops | Aqueous solution of pyrethrum @ 3 g/L water. |
| 6 | *Pieris brassicae* (Cabbage butterfly) | Cole crops | Elderberry (*Sambucus hookeria*) twigs and flowers cooked for 30 min with water and then use in a ration of 1:7 weight by volume. |
| 7 | *Dorylus orientalis* (Red ant) | Potato | Soil application of shade dried chopped leaves of *Artemisia vulgaris* and *Eupatorium adenophorum* (fresh leaves at the rate of 5 metric ton/hectare). Soil drenching of aqueous solution of azadirachtin (0.00045%) near plant stems or 5 g tobacco dust per litre solution of cattle urine, and water (1:5 ratio) mixed and kept for 24 hr at 100 mL/plant at tuber initiation and 30 days after the first treatment. |

Source: (Neupane, 2000; Paneru, 2005)

The most common approaches using semio-chemicals are those that are derived and/or used against insect pests and include pheromones, kairomones, allomones, and

other classes of behaviourally active compounds. They are used to control pests by nontoxic mechanisms or used to monitor pests, or to disrupt their physiological process. Over 75 semio-chemicals have been used in mating disruption, lure and kill, or insect monitoring strategies, which is a useful component of an integrated pest management (IPM). Caritas Nepal (2019) also has been using over a dozen of pheromone lures and has been successful in some situations with a number of insects (Table 14.6).

**Table 14.6.** Use of pheromone/lures for controlling vegetable and other crop pests

| S.N. | Name of lure | Insect pest | Crops |
|---|---|---|---|
| 1 | Methyl uginol | Fruit fly | Citrus, mango |
| 2 | Cu-lure | Fruit fly | Cucurbits |
| 3 | Bactocera compositae | Fruit fly | Cucurbits , Citrus, mango |
| 4 | Helilure | Tomato fruit borer | Tomato, gram, pigionpea |
| 5 | Spodolure | Tobacco caterpillar | Tobacco, potato, tomato, cauliflower |
| 6 | DBM/plutellalure | Diamondback moth | Crucifer vegetables |
| 7 | Leucinodeslure | Brinjal shoot and fruit borer | Brinjal |
| 8 | PTM 1, 2-lure | Potato tuber moth | Potato |
| 9 | Scirpolure | Yellow stem borer | Rice |
| 10 | Pectinolure | Pink borer | Cotton |
| 11 | Ermit and erminlure | Spotted borer | Cotton |
| 12 | TLM/tutalure | Tomato leaf miner | Tomato |
| 13 | Chilolure | Sugarcane borer | Sugarcane |
| 14 | Zailolure | Coffee white stem borer | Coffee |
| 15 | Eriaslure | Okra borer | Okra |

Cu = Cucurbit fruit fly, DBM = Diamnodback moth, PTM = Potato tuber moth, TLM = Tomato leaf miner.
Source: (Caritas Nepal, 2019)

Plant-incorporated protectants (PIPs) have been developed, where genetic material has been added to a plant to produce pesticidal substances against target pests, genes used to transform crops to express resistance to insect, fungal, and viral attacks, or to render them tolerant of herbicide application. Genetically modified (GM) plants are like endophytes as a form of bio-pesticide, offering a product that delivers a naturally occurring anti-pest compound(s) produced within the plant. Suryavanshi and Singh (2014) listed GM crops in different categories (type) (Table 14.7). The number of transgenic plants, those expressing foreign genes is increasing but the technology remains controversial in many countries.

**Table 14.7.** Use of genetically modified crops for controlling vegetable and other crop pests

| S.N. | GM crop type | Examples |
|---|---|---|
| 1 | Herbicide resistance | Corn, soybean, cotton, rice, wheat, carnation, chicory, canola, sunflower, tobacco and sugar beet |
| 2 | Insect pest resistance | Cotton, corn, rice, tomato, potato and brinjal |
| 3 | Viral resistance | Papaya, squash, plum and potato |
| 4 | Slow ripening and softening | Tomato and melon |
| 5 | Improved quality | Canola, soybean oil and Golden rice (a variety of rice produced through genetic engineering to biosynthesize β-carotene, a precursor of vitamin A) |
| 6 | Male sterility | Canola and corn |
| 7 | Pigmentation pattern | Carnation |
| 8 | Reduced nicotine content | Tobacco |

Source: (Suryavanshi & Singh, 2014)

## Effects on Non-target Organisms

It shows that most of the bio-pesticides are safe to non-target organisms and as indicated with their oral $LD_{50}$, i.e. the amount of a pesticide that kills half of the animals in a laboratory test and measured in mg/kg body weight (Tables 14.8 and 14.9). However, for all pesticides, it is also important to follow guidelines for spray volume, application rates, droplet size, water pH, compatibility with tank-mix partners, time and frequency of application, and other details to ensure their efficacy (van Zyl et al., 2010; Wang & Liu, 2007; Whitford et al., 2009).

**Table 14.8.** Toxicity to natural enemies

| S.N. | Insecticides | Contact (Immediate) | Residual (Long-term) |
|---|---|---|---|
| 1 | Microbials (Bt) | None | None |
| 2 | Oil, Soaps | Moderate | None |
| 3 | Botanicals | Moderate | Short |
| 4 | Pyrethroids | High | Long |
| 5 | Prganophosphates/Carbamates | High | Moderate to long |
| 6 | Neonecotinoids | Moderate to high | Long |

**Table 14.9.** $LD_{50}$ of some bio-pesticides

| S.N. | Pesticides | Oral $LD_{50}$ (mg/kg) |
|---|---|---|
| 1 | *C. minitans* | Non-toxic |
| 2 | *N. locustae* | Non-toxic |
| 3 | *B. thuringiensis* | > 5000 or Non-toxic |
| 4 | *Streptomycin* | >5000 |
| 5 | *Azadiractin* (neem) | 5000 |
| 6 | Spinosyn A | 3783 |
| 7 | Pyrethrins | 50 |
| 8 | Abamectins | 10 |

## Global Potential

Table 14.10 represents global bio-pesticide market by regions. The global bio-pesticides sector was estimated to be worth around US$3.5 billion per annum in 2018 that continued with very strong growth. Projections to 2025 indicate a market size of around $8 billion – with a compound annual growth rate (CAGR) of over 15% (Damico, 2018). North America and Mexico is the fastest growing market with 16.4% CAGR during 2018-2023 and Indian bio-pesticides market produced returns of $102 million in 2016 and is expected to provide $778 million by 2025, growing at a CAGR of 25.4% (Cornelius et al., 2019). The fruit and vegetable sectors, which account for about 90% of bio-pesticide usage, their market share is 18.5%. The trend of biologicals and conventional new products for crop protection is presented in Figure 14.1, which reveals that use of chemical pesticides is decreasing and bio-pesticide increasing steadily over the years.

**Table 14.10.** Global bio-pesticide market (US$ million)

| S.N. | Region | 2012 | 2015 | 1018 | CAGR (%) 2012 to 2018 |
|---|---|---|---|---|---|
| 1 | North America (USA/Canada) | 625 | 975 | 1430 | 18.0 |
| 2 | Europe | 420 | 660 | 965 | 18.1 |
| 3 | Latin America (including Mexico) | 265 | 545 | 902 | 27.9 |
| 4 | Asia | 300 | 460 | 720 | 18.6 |
| 5 | Rest of the world | 50 | 80 | 120 | 18.3 |
| | Total | 1660 | 2720 | 4137 | 19.9(?) |

Source: (Damico, 2018)

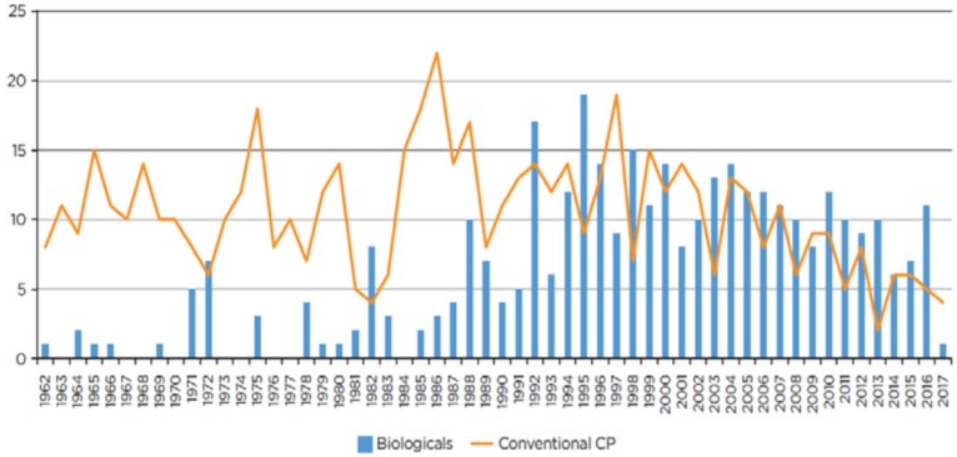



**Figure 14.1.** Annual new product introductions for biological and conventional crop protection.

Generally, the use of bio-pesticides is increasing by 10% every year. By 2025, the Asia Pacific bio-pesticides market is estimated to reach a valuation of US$ 2,934 million incrementing the demand at a growth rate of 14.2% (Bullion, 2019). So, there is good opportunity to explore, formulate and utilize bio-pesticides for pest management following IPM (Thapa, 2003).

## New Direction

Few researches on bio-pesticides are being carried out in Nepal. Some attempts have been made to popularize microbial pesticide through Community Resource Centers (CRC) promoting microbial pesticide production on a larger scale. CRC produce microbial pesticides on locally available substrates. *Trichoderma*, NPV and *M. anisopliae* and *Steinernema lamjungense* are produced in designated CRC across the country.

The availability of staff with specific skills in area of microbial pesticides is however still very limited in Nepal. Therefore, training in appropriate technologies and guidelines has a significant impact popularization of microbial pesticides. In Nepal, there are more than 100 officers and over 200 Junior Technician/Junior Technical Assistant (JT/JTAs), who are skilled human resources across the country to look after plant protection activities including bio-pesticides use and popularization (Thapa, 2014). However, they don't have specific knowledge on microbial pesticides and their skills and knowledge have to be enhanced. Furthermore, there is no adequate laboratory facility for regular quality monitoring activities. Finally, policy measures need to be strengthened in order to reduce excessive use of chemical pesticides and promote the use of microbial pesticides (Tiwari, 2017). Unlike chemical pesticides, there is possibility of producing microbial pesticides directly by farmers themselves. This concept can be promoted on a larger scale within farming community.

## Limitations

According to Saritha and Tollamadugu (2019), the limitation in promotion and consumption of bio-pesticides including bio-fertilizers are grouped under five major constraints.

1. Resource constraints
    - Lack of suitable resource constraints/unavailability of suitable strains
    - Ignorance of manufacturers on the quality of product
    - Non-availability of quality resource/quality control methods
    - Infrastructural constraints, like space availability for establishment of laboratory, production and storage
    - Lack of cold storage equipment for inoculum
2. Market constraints
    - Lack of farmers' awareness/quality assurance and constraints on marketing
    - Financial constraints related to banks loan for farmers
    - Smaller production units suffer due to less returns on sale with respect to the loan payment
3. Production constraints
    - Lack of research and development for quality assurance and hence limited production
    - Inability to meet the seasonal demand/requirement due to shortage of skilled personnel
4. Field constraints
    - Unfavorable environmental factors, like soil and climatic factors, microbial factors, and production
    - No immediate visual results as that of inorganic chemicals
    - The lack of awareness in cropping operations and short span of sowing/plantations in specific locality
5. Technical constraints
    - Unauthenticated inoculum/microbes, mishandling techniques, and mutations
    - Lack of awareness on the benefits of technology
    - Problems in the adoption of technology due to different methods of inoculation

Ravensberg (2011) made SWOT analysis for bio-pesticides, which reveals the critical factors in the successful commercialization of microbial pest control products (Table 14.11).

**Table 14.11.** Strengths, weaknesses, opportunities and threats for bio-pesticides

| Strengths | Weaknesses |
|---|---|
| • Specific host range<br>• Unique mode of action (EPNs)<br>• Excellent tool in IPM systems<br>• No residue (exempt of MRL)<br>• No or short pre-harvest interval<br>• No or short worker re-entry interval<br>• Compatible with natural enemies, pollinators<br>• Compatible with other microbial pest control agents<br>• Probability of (cross-) resistance low<br>• Excellent tool in resistance management program<br>• Safe for humans and the environment<br>• Safe for plants<br>• Approved for organic production | • Efficacy moderate and variable<br>• Relatively high end-user price<br>• Narrow target spectrum<br>• Speed of kill slow and insect-stage dependent<br>• Short residual activity<br>• Sensitive to abiotic factors<br>• Limited storage stability (at low temperature)<br>• Refrigeration requirement<br>• More complicated application technology, spraying necessary, good coverage necessary<br>• Not very user-friendly<br>• Incompatibility with chemical pesticides<br>• Knowledge-intensive products that demand know how transfer<br>• Often only work as part of IPM program |
| **Opportunities** | **Threats** |
| • Growing demand for residue-free or no residue in food<br>• Withdrawal and reduction of use of chemicals due to new regulations<br>• Developmental costs low to reasonable<br>• Combination with chemicals extend the product life of risk-resistant pesticides<br>• BCAs are a natural resource and offer sustainable crop protection<br>• Environmental benign, no environmental pollution due to production and use<br>• Increase or maintain biodiversity since they are more target specific than chemicals<br>• Consumer awareness<br>• Harmonization of registration<br>• Organic food production<br>• Growing of sustainable agriculture and IPM<br>• Increasing availability of high quality bio-pesticides, with user confidence in bio-pesticide use in general<br>• Increasing markets where use of chemicals is forbidden, such as forestry, amenity areas, home and garden, natural environments, etc. | • Novel safer chemical pesticides<br>• Growers' skepticism based on expectation level of chemicals<br>• Small market sizes<br>• Transgenic crops<br>• Increasing regulatory burden<br>• Biodiversity and access benefit sharing regulations<br>• Bioterrorism regulations<br>• Fear of microbes by the public<br>• Limited public research funding<br>• Lack of user education and extension services<br>• Weak economic position of farmers<br>• Unregistered ineffective "snake oils"<br>• Import of low quality products |

Souce: (Ravensberg, 2011)

## Conclusion

Bio-pesticides can serve as good alternatives for crop protection to chemical pesticides. This method is useful for resistance management and fits well with IPM. IPM is essential in commercial agriculture because it offers a wide range of techniques and practices to prevent or minimize damages from pests without affecting soil, water or beneficial organisms. So, development of IPM package of practices with bio-pesticides for crops is necessary. Regulatory changes, consumer demand for low residues, and the need for even more productive farming practices are inescapable market forces. There are also more than 10,000 factsheets also known as pest management decision guides (PMDG) produced by top global institutions and partners which promotes such proven technologies. Bio-pesticides offer solutions in all of these areas and increasing the acceptance of bio-pesticides as an effective means in crop protection programs. However, more research is required to prove their multiple uses for mankind. The conclusions are as follows:

- Current growth rate of bio-pesticide is 15.6% (5 year compound annual growth rate) compared to 3% of synthetic pesticides, i.e. bio-pesticide is accelerating its pace to crop pest management.
- Bio-pesticides are environmentally friendly and many products are with no maximum residue limit (MRL), and require no harvest interval.
- Research in this area is still in its infancy, for which a multidisciplinary approach is necessary.
- Setting specific standards for quality at national and international level is needed to ward off challenging pest species.
- Financial support/funding is major problem for bio-pesticide production and marketing.
- Effective application technology and interaction with chemical pesticides is a complex issue.
- It requires training and well equipped laboratory for research and development of bio-pesticides.
- The role of the private sectors in production, distribution and marketing of bio-pesticides is imperative. For this, appropriate policy support is necessary to bring private and public sectors to work together for facilitation of bio-pesticide production and use.

**Abbreviations:** $LD_{50}$ = Median lethal dose; NARC = National Agricultural Research Council; NPPO = National Plant Protection Organization; PPD = Plant Protection Directorate; PRMD = Pesticide Registration and Management Division.

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# Author's Biography



Prof. Dr. Resham Bahadur Thapa was born in Kavrepalanchowk district on February 25, 1952. He passed SLC from Nepal SLC Board in 1970 and was awarded USAID Participant Fellowship to study BScAg in India, USAID/ USU/IAAS-I & II Phase Scholarships for MSc in USA and PhD in the Philippines. After graduation, he devoted his whole life in teaching and research at IAAS/TU in the field of agriculture especially Plant Protection, Honeybees and Crop Pollination, Sericulture Development, Pesticide Pollution and Integrated Pest Management. He served as Expert/Short-term consultant in various national/international organizations; and as Editor-In-Chief, Department Chairperson, Director of Research and Publications, Assistant Dean (Academics and Examination) and Postgraduate Program Coordinator. He also participated in various trainings like Sericulture, Plant Protection, Value Chain, Editorial Management, Climate Change, Biometrics and Bio-pesticide. He has been teaching BSc/MSc/PhD students for more than 40 years, supervised >200 students in lab and field research, produced reports, written a dozen of books/lab manuals and published >200 research articles in national/international Journals. During the period, he has received "Best Teacher's Award", "Mahendra Vidhya Bhusan" and "Dirgh Sewa Padak".

# Chapter 15

## Major Diseases of Vegetable Crops and Their Management Practices in Nepal

**Ram Devi Timila and Hira Kaji Manandhar***
*Nepal Plant Disease and Agro Associates (NPDA), Balaju-Chakrapath, Kathmandu, Nepal*
* Email: hirakaji@gmail.com

*With the investigation on plant diseases began in 1963 at Plant Pathology Section under the Department of Agriculture (now under Nepal Agricultural Research Council), a number of diseases in vegetable crops have been identified and recommended their management options. The diseases are mainly fungal, some are bacterial and nematodal, and several are viral. With the increased and intensive cultivation of different types of vegetables and also climate change impact, the incidence and severity of diseases have increased. New diseases have appeared with introduction of new crop species and varieties. Outbreaks of some of the diseases, such as club root, white rot/stalk rot, head rot, bottom rot, wire stem, root rot and black rot diseases in brassicas; late blight, bacterial wilt, bacterial stem rot, viral diseases and root-knot nematodes in tomato; phytophthora blight and viral diseases in pepper; gummy stem blight, downy mildew and viral diseases in cucurbits; rust and anthracnose in leguminous vegetables; and purple blotch, downy mildew, rust as well as botrytis bulb rot in onion and garlic are the constraints causing considerable crop and yield losses. Management of diseases is a challenge in vegetable production. Presently, organically managed and reduced pesticide use is the priority option for disease management. Availability of disease resistant or tolerant varieties in vegetable crops is very limited. Hence, for the effective management of diseases, combination of various methods as per the principles of integrated disease management, such as cultural practices, host resistance, biological and chemical controls have been recommended. For this, timely and proper diagnosis of diseases is essential for choosing effective management options. This chapter provides information on economically important major vegetable diseases and options for their management.*

**Keywords:** Disease management; sign and symptoms; significance; vegetable diseases.

## Introduction

Investigation on plant diseases, including of vegetables began in 1963 in Nepal at the Plant Pathology Section under the Department of Agriculture (Amatya et al., 1992) (later

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became Plant Pathology Division and now National Plant Pathology Research Centre under the Nepal Agricultural Research Council, NARC). Since then, a number of plant diseases, including of vegetables (Table 15.1) have been identified, researched and their management options developed and recommended. Of them, economically important ones are fungal diseases; few are bacterial and nematodal diseases. A number of viral diseases have been identified, and they are occurring in complex and causing threats mainly to vegetable cultivation. With the increased commercial cultivation of vegetables, new diseases are appearing, which might have been introduced with new crop species and cultivars. Also, diseases of minor importance are becoming major ones, which could be possibly due to climate change and also due to changes in cultivation practices.

Diseases not only reduce yield but also affect quality, self-life and consumer's satisfaction and choice. Earlier, disease management in vegetable crops was concentrated on the use of chemical pesticides and options for choosing resistant varieties and other safe measures were limited (Amatya et al., 1992). Management of diseases in vegetable production is a challenge, because use of chemical pesticides is of health and environmental concerns. Additional risks are with those vegetables which are consumed as raw. Till now, very limited or no resistant/tolerant vegetable varieties to diseases are available. So, organic management and reduced pesticide use have become the priority options for disease management. In this regard, biological control is currently receiving much attention. But it is a fact that not one single option is sufficient for the management of vegetable diseases. For that reason, integrated disease management (IDM) is a must. In this chapter, selected major diseases of vegetables and their management options are described in brief. Viral diseases are dealt separately because of their complex nature in occurrence and common management practices. For general information and use, there are two books published in Nepali, one by Krishna Shrestha (Shrestha, 1990) and the other recently by Plant Pathology Division of NARC (Baidya et al., 2019).

**Table 15.1.** Vegetable diseases and their status in Nepal

| Host group | Disease | Causal organism | Distribution | Status |
|---|---|---|---|---|
| Brassicas | Alternaria leaf spot | *Alternaria brassicae, A. brassicicola, A. raphani* | Widespread | Major |
| | Clubroot | *Plasmodiophora brassicae* | MH, HH | Major |
| | Downy mildew | *Peronospora parasitica* | MH, VL | Major |
| | White rot / Stalk rot | *Sclerotinia sclerotiorum* | MH, HH | Major |
| | White rust | *Albugo candida* | MH, IT | Minor |
| | Powdery mildew | *Erysiphe cruciferarum* | MH | Minor |
| | Rhizoctonia head rot, bottom/root rot | *Rhizoctonia solani* | MH, VL | Major |
| | Black rot | *Xanthomonas campestris* pv. *campestris* | Widespread | Major |
| | Bacterial leaf spot | *Pseudomonas syringe* pv. *maculicola* | MH, VL | Minor |
| | Bacterial soft rot | *Erwinia carotovora* | Widespread | Minor |
| | Seedling disease | *Pseudomonas viridiflava* | - | Minor |
| | Mosaic virus | *Turnip mosaic virus* | Widespread | Major |

| | | | | |
|---|---|---|---|---|
| Solanaceous vegetables | **Tomato:** | | | |
| | Late blight | *Phytophthora infestans* | Widespread | Major |
| | Early blight | *Alternaria solani* | Widespread | Major |
| | Septoria leaf spot | *Septoria lycopersici* | Widespread | Major |
| | Powdery mildew | *Leveillula taurica* | Widespread | Minor |
| | Leaf mold | *Fulvia fulva* | MH, VL | Minor |
| | Root rot / Damping-off | *Rhizoctonia solani* | Widespread | Major |
| | Fusarium wilt | *Fusarium oxysporum* | T, IT | Minor |
| | Sclerotinia rot | *Sclerotinia sclerotiorum* | T, IT | Minor |
| | Bacterial wilt | *Ralstonia solanacearum* | T, IT, VL | Major |
| | Bacterial stem rot | *Erwinia carotovora* pv. *carotovora* | MH, VL | Major |
| | Tomato pith necrosis | *Pseudomonas syringe* pv. *corrugata* | MH, VL | Minor |
| | Bacterial leaf spot | *Xanthomonas campestris* pv. *vesicatoria* | MH, T | Minor |
| | Virus complex | *Tomato yellow leaf curl virus* | Widespread | Major |
| | | *Cucumber mosaic virus* | Widespread | Major |
| | | *Tomato mosaic virus* | Widespread | Major |
| | Root-knot | *Meloidogyne* spp. | Widespread | Major |
| | **Pepper:** | | | |
| | Phytophthora blight | *Phytophthora capsici* | MH, VL | Major |
| | Cercospora leaf spot | *Cercospora capsici* | Widespread | Minor |
| | Anthracnose | *Colletotrichum capsici* | Widespread | Major |
| | Powdery mildew | *Leveillula taurica* | Widespread | Minor |
| | Wet rot | *Choanephora cucurbitarum* | T, MH | Minor |
| | Bacterial leaf spot | *Xanthomonas campestris* pv. *vesicatoria* | MH, T | Minor |
| | Bacterial wilt (Capsicum) | *Ralstonia solanacearum* | T, VL | Minor |
| | Virus complex | *Cucumber mosaic virus* | MH, IT | Major |
| | | *Tomato yellow leaf curl virus* | T, IT, VL | Major |
| | | *Chilli veinal mosaic virus* | MH | Major |
| | | *Potato virus Y* | MH | Major |
| | | *Peanut bud necrosis virus* | T | Minor |
| | **Eggplant:** | | | |
| | Phomopsis blight | *Phomopsis vexans* | T | Minor |
| | Bacterial wilt | *Ralstonia solanacearum* | T, IT, VL | Major |
| | Sclerotinia wilt | *Sclerotinia sclerotiorum* | T | Minor |
| | Little leaf | *Phytoplasma* | T | Minor |

| | | | | |
|---|---|---|---|---|
| Cucurbits | Downy mildew | *Pseudoperonospora cubensis* | Widespread | Major |
| | Powdery mildew | *Sphaerotheca fuliginea*, *Erysiphe cichoracearum* | Widespread | Major |
| | Gummy stem blight | *Didymella bryoniae* | Widespread | Major |
| | Phytophthora blight (Point gourd) | *Phytophthora capsici* | T | Minor |
| | Virus complex | *Cucumber mosaic virus* | Widespread | Major |
| | | *Watermelon mosaic virus* | Widespread | Major |
| | | *Zucchini yellow mosaic virus* | Widespread | Major |
| | | *Squash mosaic virus* | Widespread | Major |
| | | *Cucumber green mottle mosaic virus* | Widespread | Major |
| Leguminous (beans and peas) | Bean rust | *Uromyces appendiculatus* | Widespread | Major |
| | Anthracnose | *Colletotrichum lindemuthianum* | Widespread | Major |
| | Collar rot | *Sclerotium rolfsii* | MH | Minor |
| | White mold | *Sclerotinia sclerotiorum* | MH, VL | Minor |
| | Septoria leaf spot | *Septoria vignae* | MH | Minor |
| | Cercospora leaf spot | *Cercospora cruenta* | MH, VL | Minor |
| | Pea rust | *Uromyces fabae* | Widespread | Major |
| | Pea powdery mildew | *Erysiphe polygoni* | Widespread | Major |
| | Ascochyta leaf spot | *Ascochyta pisi* | MH, HH | Minor |
| | Angular leaf spot of bean | *Isariopsis griseola* | Widespread | Minor |
| | Floury leaf spot of bean | *Mycovellosiella phaseoli* | HH (Jumla) | Major |
| | Halo blight of bean | *Pseudomonas syringe* pv. *phaseolicola* | T, MH | Minor |
| | Mosaic virus | *Bean common mosaic virus* | Widespread | Major |
| | | *Cowpea aphid-borne mosaic virus* | Widespread | Major |
| | | *Pea seed-borne mosaic virus* | MH | Minor |
| | | *Broadbean stain virus* | MH | Minor |
| *Allium* (onion and garlic) | Purple blotch | *Alternaria porri* | Widespread | Major |
| | Leaf blight | *Stemphylium vesicarium* | Widespread | Major |
| | Downy mildew | *Peronospora destructor* | MH, VL | Major |
| | Rust | *Puccinia allii* | MH, VL | Major |
| | Southern blight | *Sclerotium rolfsii* | MH | Minor |
| | Bulb rot | *Botrytis allii* | MH | Minor |
| | Bulb canker of garlic | *Embellisia allii* | MH | Minor |
| | White rot of garlic | *Sclerotium cepivorum* | MH, VL | Minor |

| | | | | |
|---|---|---|---|---|
| | Smut | *Urocystis cepulae* | MH, T | Minor |
| | Black mould | *Aspergillus niger* | Widespread | Major |
| | Viruses of garlic | *Onion yellow dwarf virus*, *Garlic common latent virus*, *Leek yellow stripe virus* | Widespread | Major |
| | | *Garlic latent virus, Tymovirus* | MH | Minor |
| Okra | Root-knot disease | *Meloidogyne* spp. | Widespread | Major |
| | Cercospora leaf spot | *Cercospora abelmoschi* | T, MH, VL | Minor |
| | Yellow vein mosaic disease | *Okra yellow vein mosaic virus* | T, IT, VL | Major |
| Spinach | Downy mildew | *Peronospora farinosa* f. sp. *spinaciae* | MH | Minor |
| Coriander | Stem gall | *Protomyces macrosporus* | T, IT | Major |

MH = Mid hills, HH = High hills, T = Terai, IT = Inner terai, VL = Valleys

## Brassica Diseases

Brassica or cruciferous vegetables, also called cole crops, are among the most widely grown vegetables. They are rich in vitamins A and C, and are also good sources of minerals. These vegetables are grown in winter season. They include cabbage, kale, brussels sprouts, knol-khol, broccoli, cauliflower, turnip, radish, many green leafy vegetables, etc. These vegetables are affected by different diseases, such as damping-off, Alternaria leaf spot and stem canker, clubroot, downy mildew, Rhizoctonia diseases, white rot/stalk rot, white rust, black rot, soft rot, turnip mosaic virus, and others.

### *1. Clubroot*

Clubroot, caused by the pathogen *Plasmodiophora brassicae* Woronin, is a devastating disease of brassica vegetables. The disease was first reported in 1993 in Nepal (PPD, 1994). Now, it is problematic in most of the brassica vegetables growing areas of the country in the absence of domestic quarantine. It is a soil-borne pathogen and its resting spores can remain viable for many years. This disease is severe in summer season but also occurs in winter. Due to wide and intensive farming of brassica vegetables, especially of short duration varieties, incidence and severity of clubroot is increasing. The disease is favoured by acidic soil.

**Distribution and significance:** It is distributed in most of the brassica cultivating areas of the mid hills of Nepal and in some places of inner terai, including Chitwan. So far, the disease is distributed in Kathmandu valley, Makwanpur, Dhading, Ilam, Solukhumbu, Dhankuta, Terhathum, Kaski, Sindhupalchowk, Chitwan, Dolakha, Kavrepalanchowk, Nuwakot and Gorkha. The disease is serious in cauliflower, cabbage and broad leaf mustard; however, cress, radish, mustard, turnip, knol-khol and broccoli are also infected. The disease had reduced cauliflower production to 300 kg from its normal production of 5–6 metric tons per hectare during 2002-2003 season in Makawanpur district (Timila et al., 2008). The losses ranged from 27 to 81% in total biomass and 18 to 87% in curd yield of cauliflower; however, 100% crop losses have been observed (Timila, 2012). Yield loss depends on the stage of the crop, earlier the infection higher the loss.

**Sign and symptoms:** Above ground, symptoms in infected plant appear as flagging of leaves during day time, which retain as healthy in the morning and evening. Later, it becomes yellowing and stunting. The roots of such plants show galling/swelling (Figure 15.1) thereby restricting uptake of water and nutrients from soil. Large galls on tap root are more damaging than small spindle-shaped galls or swellings on lateral roots. As the disease progresses, the galls become off-white colour and get darken. Finally, galls become infected by secondary decay organisms and decayed galls release resting spores into the soil which act as the inoculum source for the next season.

**Management:** Clubroot disease is very difficult to manage once established in the field. An integrated approach should be followed to manage this disease. The approach includes crop rotation for 5/6 years cycle with non-host crops, use of resistant varieties, planting disease free seedlings, using 7 or more week old seedlings, application of lime, immediate uprooting after harvest and disposing them properly. Seedlings should be raised in disease free nursery or in solarized seed bed. Application of agricultural lime at the rate of 300 kg per 500 $m^2$ area (one ropani) significantly reduced clubroot severity in cauliflower (Timila, 2008). Cauliflower varieties, such as Clapton A, Clapton B, Clarify A and Clarify B; and cabbage varieties, Tekila and Kilaherb are resistant to the disease (Timila, 2011b), but these hybrids are not available in Nepal. Marpha Chaudapat variety of broad leaf mustard is less susceptible to the disease (Timila & Manandhar, 2015). *Trichoderma asperellum*, a local isolate, is effective in reducing clubroot disease (Timila, 2011a). Application of chemical fungicide, Nebijin (flusulfamide) at the rate of 10 kg per 500 $m^2$ area during land preparation or 2 g per planting hole is effective for the management of clubroot disease (Timila & Neupane, 2009). Since the resting spores can survive passage through the digestive system of cattle, infected crop residue should not be used in making compost.

## *2. Alternaria Leaf Spot / Dark Leaf Spot*

Alternaria leaf spot or dark leaf spot, caused by *Alternaria brassicicola* (Schw.) Wiltshire and or *A. brassicae* (Berk) Sacc., is one of the common foliar diseases of brassica vegetables infecting foliage, pod and seed; and also cabbage head and cauliflower curd. *A. raphani* J.W. Groves & Skolko mainly causes leaf spot in radish, but can infect other brassicas as well. The pathogens are seed-borne (Shrestha, 1977) and also survive in crop debris (Shrestha et al., 2003).

**Distribution and significance:** Alternaria leaf spot is distributed throughout brassica growing areas and causes significant damage under cool and moist weather conditions. The disease is associated mainly with intensive cropping of brassicas. It can cause up to 40% yield reduction in cauliflower due to premature defoliation (Shrestha, 1990). It deteriorates the cauliflower curd and cabbage head and reduces the market quality. Severe spots in broad leaf mustard also affect market quality of the produce. The disease is more severe when the plants are left for seed production and causes significant reduction in seed yield and quality.

**Sign and symptoms:** Dark small spots appear on lower leaves, later develop into circular tan to dark brown spots usually with concentric rings (Figure 15.2). Spots may have yellow halos. Under favourable conditions, abundant dark green conidia appear on the spots. Spots produced by *A. brassicicola* are much darker and smaller than spots produced

by *A. brassicae*. Spots on petioles are brown and oval or elliptical in shape. Infection in cauliflower and broccoli heads causes water-soaked decay, later turning into dark brown to black with sporulation of the pathogen.

**Management:** Seed treatment with thiram or mancozeb (formulation dose 2–3 g/kg seed) is recommended (Manandhar et al., 1992). Mancozeb is also effective for foliar application. Removal and proper disposal of infected older leaves during crop period and of crop debris after harvest are effective measures for management of the disease. Application of potash also helps to reduce the disease (Regmi & Shrestha, 2018).

## *3. Stalk Rot / White Rot*

Stalk rot/white rot, caused by *Sclerotinia sclerotiorum* de Bary, is a serious disease of brassicas. In Nepal, it was first appeared in 1978 in cauliflower in Dhankuta district (Shrestha, 1990). The fungus overwinters as small black resting structures (sclerotia) attached to decomposing infected plant portions and may survive for several years in soil. It produces a small stalked, saucer-shaped fruiting structure (apothecium), which releases ascospores into the air. Spores may infect senescent tissue such as blossoms and leaves and leaf axil or may germinate and colonize plant debris. The fungus has wide host range.

**Distribution and significance**: Earlier, *S. sclerotiorum* was thought to occur in cool, moist areas only, but now it has been found in warm and dry areas in winter period. Crop losses up to 83% have been recorded in Snowball variety of cauliflower (Manandhar et al., 1992). The disease badly affected seed production of cauliflower in Dhankuta and Palpa districts reducing the seed yield from 300 kg to 50 kg per ha within 3 years (1981-1983) (Shrestha, 1990). The disease is equally important for beans and eggplant also.

**Sign and symptoms:** At initial stage, water-soaked lesions appear in collar region of the plant, followed by fluffy white mycelial growth inside the stem and progress upward. It spreads to seed stalks or bolts and gives bleached look (Figure 15.3). Black sclerotia can be seen inside the stem when cut opened, or may be appeared on the plant surface also. Eventually, the infected plants get wilted. Cauliflower curd and cabbage head may be rotted under congenial conditions.

**Management:** Seed treatment with Carbendazim (formulation dose 2 g/kg) is advised as seeds can be concomitantly contaminated. Crop rotation with cereal crops and deep ploughing are highly recommended. Mulching with rice straw wherever feasible is found effective to reduce disease incidence (by 71%) in cauliflower (Timila & Shrestha, 1999). Also, flooding of infected field for three weeks reduces the disease in cauliflower. Foliar spray with carbendazim at the time of curd formation and flowering is effective to prevent from air-borne ascospore infection. Destruction and proper disposal of diseased plants is necessary for disease management.

## *4. Downy Mildew*

Downy mildew, caused by *Peronospora parasitica* (Pers. ex Fr.) and later named as *Hyaloperonospora parasitica* (Pers.) Constant is an important disease of brassica vegetables, particularly in nursery. The disease is more prevalent under cool and moist

conditions. The pathogen is mainly soil-borne but seed could also be contaminated. The disease was first recorded in 1966 in Nepal (Khadka & Shah, 1967).

**Distribution and significance:** Downy mildew is widespread disease of brassica vegetables. It not only damages seedlings but also causes problems on crop near to maturity. Under favourable conditions, the disease may cause 100% seedling loss of cauliflower. Grey or black flecking or streaking of internal tissue in cauliflower and cabbage heads deteriorates the quality of produce. Five to 25% yield reduction could be caused by this disease (Manandhar et al., 1992).

**Sign and symptoms**: In nursery, irregular yellow patches on the cotyledonary leaves appear with white fungal growth on underside of the lesion in leaves. The entire seedling could also be covered with white fungal growth. On older leaves, tan-coloured, irregular patches with downy growth of the fungus on lower surface appear (Figure 15.4). Severe infection on the leaves gives blighted appearance and premature defoliation. Black streaks in curd and seed stalks appear in cauliflower.

**Management:** Planting or seeding in low density, reducing moisture level, crop rotation and removal of crop debris are the basic practices for the management of downy mildew disease. Overhead irrigation should be avoided to prevent the spread of the disease. Combination of seed treatment with metalaxyl 8% + mancozeb 64% (Krilaxyl @ 2 g/kg) and spray on soil surface after seeding is effective to manage the disease in nursery (Timila, 2005b).

## *5. Rhizoctonia Diseases*

Rhizoctonia diseases, caused by *Rhizoctonia solani* Kuhn, (anamorph stage), *Thanatephorus cucumeris* (Frank) Donk (teleomorph stage), can occur in different stages of plants and induces one or more types of symptoms, such as damping-off, root rot, wire stem, head and bottom rot (in cabbage), and web blight. The pathogen is soil-borne and causes gradual decline of plant health, followed by eventual death of the plants. The pathogen has wide host range.

**Distribution and significance:** Rhizoctonia disease is widely distributed in brassica cultivating areas in Nepal. Damping-off may cause huge seedling loss in nurseries. Wire stem and root rot cause significant reduction in plant stand. Root rot phase is the most common that causes slow killing of the plants. Wire stem, however, generally causes poor or retarded growth causing considerable yield loss. Yield losses due to the disease range from 25 to 100%. Hundred percent cabbage heads damage has been reported from Palung and Kavre during 2007/2008 (PPD, 2008).

**Sign and symptoms:** Damping-off usually occurs in small patches. Water soaking lesions, followed by shriveling of the stems at the ground level occur leading to toppling down or collapse of the seedlings and death soon after emergence. Root rot symptoms appear mostly in transplanted and established plants. The rotted root shows brown to black discolouration and peeling of outer tissue. Infected plant shows yellowing and retarded growth, eventually causing wilting of the plant. Similarly, wirestem appears with hypocotyle infection of older seedlings with browning and outer stem tissue decay, mostly with cracking of the epidermis, giving wire-like appearance (Figure 15.5). In

cabbage, bottom rot disease appears on the lower side of the head leaves that are in contact with the soil. Eventually a general black decay occurs at the base of the leaf. Black flattened sclerotia may appear in the leaf axil. Head becomes rotted when the fungus spreads to the head where sclerotia may also appear (Figure 15.6).

**Management:** Because of wide host range, Rhizoctonia disease is difficult to control. However, seed treatment, planting in low density, shallow planting or planting in proper depth, avoiding excess watering, avoiding excessive fertilizer, soil solarization, adequate drainage, etc. are the options to manage damping-off and wire stem diseases. Planting in raised bed is another one of the effective options for the management of disease. Carbendazim is widely recommended fungicide for seed treatment (Bavistin @ 2 g/kg), nursery treatment, transplant treatment or drenching against the disease. For head and bottom rot of cabbage, foliar spray with carbendazim is effective. Recent researches showed that dimethomorph 69% (e.g. Nacrobat) and fenamidone 10% + mancozeb 50% (e.g. Sectin) are also effective (PPD, 2016, 2018). *Trichoderma harzianum* is effective, which reduced Rhizoctonia root rot incidence in cabbage by 89% (PPD, 2015).

## *6. Black Rot*

Black rot, caused by *Xanthomonas campestris* pv. c*ampestris* (Pammel) Dowson, is one of the most important seed-borne bacterial diseases of brassica vegetables. The pathogen is seed-borne and also survives in the infected plant debris as well as cruciferous weed hosts (Shrestha et al., 1977). Due to vascular colonization of leaves and stem by the pathogen, the infected plants later on get predisposed to soft rot organisms.

**Distribution and significance**: Black rot is widespread and the diversity of the pathogen is high (Adhikari & Basnyat, 1999; Jensen et al., 2010). Seed infections ranged from 24.5% in local cauliflower to 39% in mustard (Burlakoti & Khatri-Chhetri, 2004). Very low level of seed infection (3 in 10,000 seeds) is enough to give rise high disease incidence in the field (Schaad et al., 1980). In Nepal, more than 60% yield reduction in cauliflower has been reported due to the disease (Shrestha, 1990).

**Sign and symptoms:** Yellowish, V-shaped/ U-shaped lesions appear starting from leaf margin (Figure 15.7). In seed bed even at very early stage (cotyledonary leaf), infection may cause severe damage. Veins within the lesions are brown to black that proceed to midrib and finally invade stalk and that may get rotten. In heavy infection, lesions get coalesced giving leaf margin scorched appearance. Early invasion of the vascular system may result in severe stunting and plant death.

**Management:** Use of disease free seeds, crop rotation with non-host crops, avoidance of overhead irrigation, removal of symptomatic transplants and their proper disposal and avoidance of working in moist conditions are the recommended measures for the control of black rot disease. Kathmandu Local cultivar of cauliflower is less susceptible to this disease (Shrestha, 1990). Green crown and All Season cultivars of cabbage are reported resistant, and NS-25 and New Top are the tolerant varieties to the disease (Budhathoki, 2006). Seed treatment with copper sulphate or zinc sulphate solution (0.2%) for 10 min is effective to reduce seed infection (Timila, 2001).



**Figure 15.1.** Clubroot of cauliflower plants



**Figure 15.2.** Alternaria leaf spot on cauliflower leaf.



**Figure 15.3.** Sclerotinia rot of cauliflower plant.



**Figure 15.4.** Downy mildew on cauliflower leaf (abaxial surface).



**Figure 15.5.** Wire stem of cauliflower transplants.



**Figure 15.6.** Rhizoctonia head rot of cabbage.



**Fiure 15.7.** Black rot of cabbage plant.

### *7. Other Bacterial Diseases*

Some other bacterial diseases caused by *Xanthomanas* spp. and *Erwinia* spp. including *Erwinia carotovora* (soft rot) have been reported (Thapa & Manandhar, 1992). Shakya and Vinther (1989) reported occurrence of *Pseudomonas viridiflava* in seedlings of Pyuthane radish. The seedlings had black or brown discoloured roots.

## Diseases of Tomato and Pepper

Tomato, pepper and eggplants are the important solanaceous vegetables. These fruits are rich in vitamins A, B, C and E with minerals. Tomato is one of the most widely used fruit vegetables for its high nutrition. It is cultivated during winter in the terai and in summer in the hills. But cultivation under plastic tunnel favoured all year round tomato production and reduced disease attack in the mid hills. Different diseases that attack time to time are one of the limitations for its production. Similarly, pepper is also a high value crop. Various types of capsicum are available and cultivated for their unique pungency and flavour. Its cultivation is one of the good sources of income for farmers.

Tomato crop is mainly infected by a number of pathogens causing late blight, early blight, damping-off, root rots, leaf spots, bacterial wilt, bacterial pith necrosis, bacterial stem rot, bacterial leaf spot, root-knot and various viral diseases. Similarly, Phytophthora blight, Cercospora leaf spot, anthracnose, different virus diseases, bacterial leaf spot and bacterial wilt are the diseases affecting pepper cultivation. Similarly, bacterial wilt, Sclerotinia wilt, little leaf, Phomopsis blight and fruit rot are economically important diseases of brinjal.

### *1. Late Blight of Tomato*

Late blight, caused by *Phytophthora infestans* (Mont) de Bary is a destructive disease of tomato and potato. Late blight can be a serious threat to tomato production particularly under prolonged period of rain, fog or dews with warm temperature. Under 100% humidity, the disease develops very rapidly resulting 100% blight of the entire field within 2 to 3 days. The disease affects tomato grown in the hills during summer, and in the terai and the inner terai during winter.

**Distribution and significance:** The disease is distributed in all tomato growing areas of the country. It damages both the crop and fruit quality. Devastating epidemics have been observed time to time under prolonged period of rain, causing crop losses up to 100% in tomato (Manandhar et al., 1992; Shrestha, 1990).

**Sign and symptoms**: Late blight disease affects leaves, stems, petioles and fruits of tomato. Water-soaked lesions on leaves appear that later on turn into brown to black in colour. In the lesion, white cottony growth develops usually on lower leaf surface under warm humid conditions (Figure 15.8), and the leaves get blighted. On stem, brown to black lesions develop which are easily breakable. In green fruits, symptoms appear as brown to black greasy lesions which may cover entire fruit and white fungal growth may also appear. Fruit lesions are firm and subjected to rotting. Warm temperature with prolonged rain favours the disease.

**Management:** Late blight epidemic is greatly influenced by weather conditions. So, under favourable weather conditions for the disease, its management is very difficult. Removal of volunteer potato and tomato plants as well as its cull piles from the vicinity of the field, enough spacing between plants, avoiding overhead (sprinkle) irrigation, removal of infected lower leaves and infected plant parts and their proper disposal are the common practices to be followed for its management. HRD 17 and Srijana are late blight tolerant varieties (Budhathoki, 2006; Shrestha & Sah, 2014). Roma was recommended as resistant to late blight for hills (Shrestha, 1990). Foliar spray with mancozeb is generally practiced. Metalaxyl containing fungicides (e.g. Krilaxyl) or fenamidone (e.g. Sectin) are effective. However, fungicidal applications may not be effective if timing of spray does not match with the weather conditions conducive for the disease development (Manandhar & Amatya, 1986).

## *2. Bacterial Wilt*

Bacterial wilt, caused by *Ralstonia solanacearum* Smith (formerly known as *Pseudomonas solanacearum*), race 1, is the third most important disease in tomato after late blight and viral disease complex. In Nepal, this disease in tomato was recorded for the first time in 1978 (Shrestha, 1990). The pathogen is soil-borne that affects other solanaceous crops, such as eggplant, potato and pepper. The bacterium remains very persistently in soil if introduced. The disease develops in high temperatures and high moisture conditions of soil. The vascular tissue of the stem is clogged with bacterium and prevents water and nutrients supply in the plant system causing eventual death of the plant.

**Distribution and significance:** Bacterial wilt is distributed in the terai, inner terai and foot hill areas of Nepal. The wilt incidence in tomato and eggplant recorded as high as 80% and 40%, respectively (Timila et al., 1996). During rainy season, 100% crop losses have been observed in some of the varieties, e.g. Pusa Ruby and Lapsi Gede (local). Increased cultivation of tomato under plastic tunnels has lowered the incidence of the disease.

**Sign and symptoms:** The first sign of wilt occurs on the youngest leaves, especially during the hottest part of the day. A few days later, and under favourable conditions to the disease (high temperatures and rainfall), plants wilt suddenly and die. Sudden wilting of plants without yellowing is the characteristic symptom of the disease (Figure 15.9). When cut face of stem from collar region of an infected plant is suspended in clear water (ooze test), milky white bacterial strand is oozed out. Brown discolouration of vascular tissue of the stem of wilted plant near soil level is generally seen.

**Management:** Crop rotation with cereal crops is effective. Widely grown hybrid tomato, Srijana is resistant to bacterial wilt but now has been reported to be affected by the disease. Other hybrids CLN 2026 C, CLN 2026 D (Timila & Joshi, 2014), BL 333 and NS 162, and the open pollinated BL 410 and HRD 17 (Bhandari & Khanal, 2012; Budhathoki, 2006; Timila & Shrestha, 2001) are also resistant to the disease. NCL 1 (CL 1131) is recommended as resistant variety. Garlic clove extract (10–12%) and bleaching powder (0.75 kg/500 $m^2$) are useful (Timila & Shrestha, 2001). Grafting technology using resistant root stocks, such as wild eggplant (*Solanum sisymbriifolium*), has been successful in tomato (Timila et al., 2016).

## *3. Phytophthora Blight of Pepper*

Phytophthora blight, caused by *Phytophthora capsici* Leonian, is one of the most important diseases of pepper. The pathogen can infect pepper (hot chilli and sweet pepper) plants at all growth stages causing root/crown rot, foliar blight and fruit rot. The disease is both seed and soil-borne. Root/crown rot phase is the most devastating phase of this disease. High soil moisture provides favourable conditions for disease development.

**Distribution and significance:** Phytophthora blight in pepper is prevalent in low land and valleys with high rainfall and warm temperature. Almost complete crop losses of pepper in some of the locations of Kathmandu valley have been recorded due to this disease (PPD, 2010). More than 50% crop was damaged in some of the areas of Makwanpur (PPD, 2011) and Dolpa (PPD, 2014) districts. The disease also affects Akbare pepper (PPD, 2013).

**Sign and symptoms**: All plant parts can be affected, but the most common and characteristic symptom is a stem or collar rot. Water-soaked, dark brown lesions on the lower stems appear usually extending upward above the soil line with peeling-off of bark tissue at collar region (Figure 15.10). This stem girdling often results in a sudden wilting of the plant. The foliar phase of this disease commonly occurs at forks in the branches, resulting in girdling, brown to dark brown lesions and causing shoot death beyond the lesion. Infected leaves show water-soaked lesions turning later into tan colour and give blighted appearance. Fruit infection starts with water-soaked, brown discolouration or with appearance of white sporulation on fruit surface or a mass of white fungal growth inside the fruit, causing fruit rot and premature fruit dropping. Seeds usually turn dark brown or black. Green fruits are more susceptible.

**Management:** Good drain system in the field, planting in raised beds without depression at the top**,** avoiding excess water, removal of infected fruits and plant parts, and following crop rotation (excluding the crops like tomato, eggplant and cucurbits) provide good control of the disease. Hybrids Tara, Angarika, NS 1701 and Chandani of pepper are resistant to the disease (Timila, 2013). Metalaxyl containing fungicides are effective for seed, soil and foliar treatments. Copper oxychloride (formulation dose 2 g/L water), which is safer than metalaxyl containing fungicide, is also effective (Timila, 2004). *Trichoderma harzianum* also suppresses the disease (PPD, 2014, 2015).

## *4. Root-knot Disease*

Root-knot disease, caused by *Meloidogyne* spp., is one of the major problems in tomato cultivation. Several species, such as *M. javanica, M. incognita, M. arenaria* and *M. hapla* have been reported (Bharwaj & Hogger, 1984; Manandhar & Amatya, 1992). This soil-borne nematode is common in many vegetable crops including pepper, eggplant, okra and cucurbits in the country (Amatya & Shrestha, 1969).

**Distribution and significance:** The disease is distributed in most of the areas where soil is light and course textured type. Severe infestation causes significant yield reduction and deterioration in fruit quality. It has been reported that on an average of 30 percent tomato fruits were reduced due to this disease in plastic tunnels at Hemja of Kaski district (PPD,

2008). The problem has been increasing rapidly especially due to year round tomato cultivation in plastic tunnel (PPD, 2014). Attack by nematodes also enhances the bacterial wilt in solanaceous vegetables.

**Sign and symptoms:** Retarded growth or the stunting and yellowing of the foliage are the general symptoms associated with the disease. In severe infection, gradual wilting occurs. In the beginning, wilting may be recovered after rain or irrigation but later on the infected plants are permanently wilted. When uprooted, various sized and shaped knots or galls are seen on root (Figure 15.11). At late stage, galls are rotted and nematodes are released in soil.

**Management:** Soil insecticide, such as carbofuran is generally recommended (Manandhar & Amatya, 1992) but that is banned now. Instead, Abamectin 20% GR (@ 1.5 g/plant) is recommended (Baidya et al., 2019). Organic amendments, such as mustard cake (250 g) or biogas slurry (2 kg) per $m^2$ are recommended (Baidya et al., 2013). These amendments not only control nematode but also provide nutrients to plants. Resistant varieties are not commonly available. Budhathoki (2006) has reported Siris, Ureka and NS 709 as tolerant hybrids. Grafted tomato plants in resistant root stock of wild eggplant, *S. sisymbriifolium*, have been successfully used at Hemja (Baidya et al., 2017).



**Figure 15.8.** Late blight of tomato plants.



**Figure 15.9.** Bacterial wilt of tomato plant.



**Figure 15.10.** Phytophthora blight of chilli plants.



**Figure 15.11.** Nematode galls on tomato roots.

## Cucurbit Diseases

Cucurbits are the widely used important summer vegetables grown for their edible fruits and immature shoots as green vegetable. Cucumber is one of the most common cucurbits consumed raw as salad. Various diseases are the limitation for its quality and quantity production. Major diseases that affect in production are downy mildew, gummy stem blight, powdery mildew and virus complex.

### *1. Downy Mildew*

Downy mildew, caused by an obligate fungus *Pseudoperonospora cubensis* (Berk. Curt.) Rostow Zew, is a major foliar disease that occurs in most of the cucurbit plants. The pathogen is both seed and air-borne. The disease is more problematic in cucumber.

**Distribution and significance:** The disease is distributed throughout the cucurbits growing areas in the terai and the mid hills where warm and higher moisture conditions are prevalent. This disease was recorded in 1965 for the first time in Nepal (Khadka & Shah, 1967). The affected foliage in the early plant development stage causes a reduction in photosynthetic activity that results in premature drying of leaves, stunted plant growth, misshaped and under-sized fruits, and reduced yield, especially in cucumber. Premature defoliation may also result in sun-scalding of fruits due to direct exposure to sunlight. Severe crop loss was observed in cucumber due to premature drying of the leaves (Timila, 2010).

**Sign and symptoms:** Infection starts with yellowish, angular or rectangular lesions on lower leaves delimited by veins and spread to upper leaves (Figure 15.12). The lesions turn later into chlorotic to bright yellow in colour and then eventually turn into tan or brown and necrotic lesions. Under humid conditions, downy growth with gray to dark purple sporulation of the fungus appears in lower surface of leaf. The spots or the lesions coalesce together causing blight of the plant.

**Management:** Early planting may escape the disease. Removing lower, severely infected leaves, avoiding overhead irrigation and apply irrigation during the late morning hours to facilitate rapid leaf drying, are helpful in reducing downy mildew severity. Malini and Rania are downy mildew tolerant hybrids of cucumber (Budhathoki, 2006). Seed treatment with Metalaxyl containing fungicide and sprays with mancozeb are recommended. Nettle extract in cattle urine (1 kg in 5 L) and diluted with water at the ratio of 1:4 spray reduced downy mildew disease in cucumber (Gautam & Gauli, 2007).

### *2. Powdery Mildew*

Powdery mildew, caused by air-borne fungi *Sphaerotheca fuliginea* (Schlect. ex. Fr.) Poll. and *Erysiphe cichoracearum* D. ex. Merfat, affects almost all cucurbits under field and greenhouse conditions. The disease is favoured by dry weather, moderate temperature and succulent plant growth as well as intensive dew on leaf surfaces. However, excessive moisture on the leaf surface is often detrimental to the development of powdery mildew disease because of washing away of the spores and superficial mycelia.

**Distribution and significance:** Powdery mildew is found in all cucurbit growing areas of Nepal. The disease affects both yield and quality of fruits (Shrestha, 1990). Fruits may get distorted and drop prematurely.

**Sign and symptoms:** Symptoms start from lower leaves and progress as white powdery patches, which coalesce and whole leaf surface is covered (Figure 15.13). Later, the affected parts become yellow and necrotic. In severe infection, leaves get dry prematurely. Sign of powdery symptoms may also appear on stem and fruits. The disease is severe after fruit set in densely planted fields. The infected plant remains stunted and produce malformed and smaller fruits, and give reduced yield.

**Management**: Field sanitation is the most important measure for the control of powdery mildew disease. Planting early maturing variety may escape the disease. Resistant varieties are available, but not commonly available in Nepal. Foliar spray with dinocap 48 EC (e.g. Karathane, formulation dose 0.2%) or wettable sulphur is recommended. Carbendazim is also effective (Timila & Shrestha, 1994). Spray of local preparation of nettle extract (Sisnoo): 1 kg fresh nettle in 5 L water soaked for 5–7 days (or until scum appears) and the extract diluted in 1:4 ratio with water was effective for powdery mildew control in cucumber (Gautam & Gauli, 2007).

## *3. Gummy Stem Blight*

Gummy stem blight, also called leaf blight or black rot, caused by *Didymella bryoniae* (Auersw.) Rehm. (teleomorph), *Stagonosporopsis cucurbitacearum* (Fr.) Aveskamp, Gruyter & Verkley (anamorph) syn. *Phoma cucurbitacearum* (Fr.:Fr.) Sacc.), is a major disease of cucurbits. It is an emerging problem and currently one of the most important diseases of cucurbits in Nepal. The disease is seed-, soil- and air-borne.

**Distribution and significance:** Gummy stem blight is distributed most commonly in humid temperate and sub-tropical areas of Nepal. The disease reduces yields of edible cucurbits by affecting all plant parts vines, leaves and fruits (rotting). Among cucurbits, bottle gourd is more affected by this disease.

**Sign and symptoms:** The early symptoms appear as small, circular, water-soaked gray to greenish or tan spots on leaves, sometimes surrounded by a yellow halo (Figure 15.14a). The spots may start at the margins of leaves or extend to the margins. As leaf spots expand, they coalesce causing blight. Colour and shape of leaf spots vary somewhat with hosts, and old leaf spots may shred or tear-off. Stem infections consist of oblong, water-soaked, brown lesions in the beginning and become brown to tan. Main stem lesions enlarge and may split open to form open wounds or cankers. Characteristic red or brown gummy fluid oozes out of the cankers (Figure 15.14b) and slowly girdle the main stem that result in the wilting of the branch or entire plant beyond the lesion. Pinhead-sized pycnidia may appear on the lesion. The infected fruits become water-soaked greasy green in colour and turn dark brown to black and rotted or may develop irregular lesions. Gummy exudates and black fruiting bodies may develop on the spots or even in gum exudates.

**Management:** Crop rotation at least for two years and field sanitation play a vital role in managing this disease. Removal of infected leaves, branches beyond the lesions and infected fruits and their proper disposal are required. Avoiding overhead irrigation helps

minimize spread of the disease. Seed treatment with thiram or captan (2 g/kg) is highly recommended. Foliar spray with mancozeb or chlorothalonil or carbendazim is recommended. Propiconazole spray is also effective. Since black rot fruits may also occur in storage, avoiding injury to fruit before or during harvest is suggested.




**Figure 15.12.** Downy mildew on cucumber leaves



**Figure 15.13.** Powdery mildew on cucumber leaves.



**a** **b**

**Figure 15.14. (a)** Spot of gummy stem blight on bottle gourd leaf. **(b)** Gum oozing out on blighted stem of bottle gourd.

## Diseases of Onion and Garlic

Onion and garlic are the major bulb crops. Onion is cultivated for bulbs as well as leaves for green vegetable. Garlic is cultivated for bulb as spice and young plants for green vegetable. Various diseases affect both garlic and onion crops. The common diseases are downy mildew, purple blotch, white rot, soft rot, black mold, rust, botrytis bulb rot, southern blight and basal plate rot in garlic, pink root, etc. Few of them are economically important and most of the diseases reported on onion are also common in garlic.

## *1. Purple Blotch*

Purple blotch, caused by *Alternaria porri* (Ellis) Cif. Neergaard, is an economically important major disease of both onion and garlic. The disease is generally found to be associated with another leaf blight pathogen, *Stemphylium vesicarium* (Wallr.) Simmons. In co-infection, *S. vesicarium* is generally dominant over *A. porri*. Garlic is severely attacked in foliar stage; however, bulb is also affected. Under congenial conditions, onion seed crop is badly affected as it attacks seed stalk causing heavy loss in seed production.

**Distribution and significance:** Purple blotch is distributed throughout the hills, high hills and terai region of Nepal, but mostly prevalent in warm and humid areas. Damage is greater during the drier season when heavy dews occur. Severe infections were reported at Rukum and Palpa districts in 2004 (Timila, 2010).

**Sign and symptoms:** Symptom starts from tips of leaves that blacken and hang down, wither and die. Small sunken spots with white centres on the leaves appear first, but expand rapidly into oval, brown to purple blotches of several centimeters long in size (Figure 15.15a). Light and dark rings appear on the blotches. If the blotches grow around the leaves or merge, the parts above the blotch get wilted, collapse and die. Under humid conditions, blackish sporulation of the fungus appears on the blotches. The leaf tips commonly get infected, but leaf sheath in garlic and flower stalks in onion can also be infected. The disease causes premature senescence of the foliage. The bulbs can also be infected at harvest. Infection in bulb is usually at the neck region where a watery yellow to red rot develops. Together with purple blotch pathogen, the plants get infected generally with *Stemphylium* on the same lesions causing leaf blight (Figure 15.15b).

**Management:** Sanitation, crop rotation, surface irrigation to lower leaf wetness period, and avoiding dense planting are the major cultural practices for the managementof the disease. Seed treatment with captan or thiram (2 g/kg of formulation) is recommended to control seed-borne inoculum. Use of chemical fungicides may be necessary as the crop canopy ages. Foliar spray with mancozeb is effective to control purple blotch (Chaurasia et al., 2007, 2010).

## *2. Downy Mildew of Onion*

Downy mildew, caused by *Peronospora destructor* (Berk.) Casp., is a destructive disease of onion (Figure 15.16). Epidemic occurs when cool and wet weather conditions remain for a longer period. This disease can attack at any stage of the crop, including seed stalks of onions grown for seed purpose. The bulbs infected with mycelium are considered to be the primary source of infection.

**Distribution and significance:** Downy mildew of onion is distributed in all onion growing areas of Nepal. Outbreak of the disease in onion was occurred in 1999 and spread in different areas, where cool and wet weather prevailed, and up to 100% crop losses, including seedlings in seed beds were observed (Timila, 2005b). It reduces yield and quality of green foliage.

**Sign and symptoms:** Initially, palegreen, yellowish to brownish blotches of irregular shape and size (oval to cylindrical) appear on leaves. The blotches develop into grayish

to purplish furry growth of the fungus and become pale green. As disease progresses, characteristic dirty growth of the pathogen (sporangial growth) occurs causing dirty blight and pale green appearance, and finally becomes yellow. Later, leaf tips get folded over and leaves are collapsed. Similarly, flowering stalk collapses after it gets infected by the pathogen. The disease disappears as the weather gets dry with relative humidity less than 80% and reappears developing new lesions when the weather turns wet and cool.

**Management:** Crop rotation for 3 years, use of disease-free bulbs, sets and seeds, field sanitation by removing and disposing residues from previous crop, culls and volunteer *Allium* plants, avoiding over use of nitrogen fertilizer, avoiding dense seeding/planting, and minimizing canopy leaf wetness period (avoid overhead irrigation) are general practices to reduce the downy mildew of onion. Removing infected older leaves helps keep minimize the disease inoculum. Late plating may escape the disease. Trichodermas and other biopesticides are reported to reduce the disease. For chemical control, metalaxyl containing fungicide (e.g. Krilaxyl) or mancozeb alone is effective.

## *3. Rust Disease of Garlic*

Rust, caused by *Puccinia porri* G. Wint, synonym *Puccinia allii* Rudolphi, is one of the important diseases of garlic. It also occurs in onion, leeks, shallots and wild species of *Allium*. It causes significant reduction in yield due to premature senescing and drying of foliage. Timila et al. (2005) reported the disease in garlic for the first time from Lumle, western Nepal and found in epidemic form in several districts in subsequent years. The disease occurs under high humid and low rainfall conditions.

**Distribution and significance:** Rust of garlic is distributed in the valleys and the mid hills. Infected plants are susceptible to secondary infections by opportunistic pathogens, and direct bulb yield losses are more likely. Bulbs infected with garlic rust remain small and are of low storage quality.

**Sign and symptoms:** Symptom starts with irregular white or light tan flecks or pustules in older leaves. Those flecks or pustules increase in size and develop with time into bright orange pustules with chlorotic halos (Figure 15.17). Pustules appear in both leaf surfaces and erupt at maturity releasing dusty orange spores, the urediniospores. Later, they develop into dark brown to black pustules releasing two celled teliospores. Severe rust causes foliage yellow, tan and prematurely dry to finally death. Heavily infected plants become stunted, and produce small bulbs and cloves.

**Management:** Planting disease free cloves of garlic is the first important step. Rotation with non-host crops, field sanitation, late planting and intercropping of garlic with non-*Allium* crops help reduce the garlic rust. Proper plant spacing (not dense) also helps to manage the disease. Fungicides, such as mancozeb, propiconazole or tebuconazole, are recommended, if necessary. Local cultivars are less susceptible compared with Chinese cultivars (locally called Bhotelasun or Chinese lasun).



a



b

**Figure 15.15. (a)** Purple blotch lesions on garlic leaf. **(b)** Purple blotch together with Stemphylium blight on garlic



**Figure 15.16.** Downy mildew on onion leaves.



**Figure 15.17.** Rust pustules on garlic leaves.

## Diseases of Leguminous Vegetables

Among leguminous vegetables (Fabaceae), pole bean and bush bean are the important vegetables, cultivated mainly for its green/immature pods. Rust, anthracnose, collar rot, angular leaf blight, some bacterial and viral diseases have been affecting their yield.

### *1. Bean Rust*

Bean rust, caused by *Uromyces appendiculatus* F. Strauss, synonym *U. phaseoli* var. *typica* (Pers.) G. Wint, is one of the economically important common diseases of beans in the country.

**Distribution and significance:** Bean rust is prevalent in all bean cultivating areas of the country where warm and higher humidity prevails. It causes severe damage to foliage with premature defoliation and deterioration of pod quality, thereby lowering the market value. In Nepal, 10–20% yield losses are reported (Shrestha, 1990).

**Sign and symptoms:** Initial symptoms appear as small, raised pale white spots which develop into reddish-brown, raised pustules (uredinia) on both surfaces of the leaves; more on lower surface (Figure 15.18). The pustules may appear in numerous numbers that the whole leaf collapses, turning yellow, drying out and dropping prematurely. Larger pustules are often surrounded by a yellow halo. At maturity, the pustules or the uredia erupt through the leaf epidermis releasing red-brown powdery urediniospores. In severe case, it gives rusty look. The pustules also develop on pods but less abundantly. Later, at the end of the season, black or blackish-brown teliospores are produced in the same uredinia.

**Management:** Effective control measures of bean rust include crop rotation, removal of volunteer plants, deep plowing to remove bean debris from the soil surface, avoidance of excessive nitrogen, and providing adequate potassium fertilizer. Early planting may escape the disease. Planting during the third week of February to the second week of March reduces rust in bean by 33–53% compared to the third week of March and the first week of April (Timila & Shrestha, 1998). The variety, Four Season, is reported to be less attacked by rust (Budhathoki, 2006). Bean varieties resistant to certain races of the rust pathogen are available, but not to all races. So, fungicides are preferred for bean rust management. Effective protectant fungicides include chlorothalonil and mancozeb.

## *2. Anthracnose*

Anthracnose, caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav., is the most important fungal pathogen of beans, affecting yield, seed quality and marketability of the produce. In Nepal, anthracnose in bean was recorded in 1965 for the first time (Khadka & Shah, 1967). The fungus is primarily seed-borne and can survive in crop residues. Cool to moderate temperatures and prolonged periods of high humidity or free water on the foliage and young pods promote anthracnose development. Frequent rainy weather increases disease occurrence and severity. The pathogen has many races.

**Distribution and significance:** Bean anthracnose is widespread in bean growing areas of Nepal. The disease causes greater losses in temperate and sub-tropical zones. Under favourable conditions, yield losses may reach 100% when infected seeds are planted. Considerable losses in green pod production were reported due to the disease in different districts during 1982 (Shrestha, 1990). Production is affected because of poor seed germination, poor seedling vigor, and low yields. Marketing losses are attributed to seed spots and blemishes, which lower their quality.

**Sign and symptoms:** Seedlings grown from infected seeds often have dark brown to black sunken lesions on the cotyledons and stems. Initial symptoms may appear on cotyledonary leaves as small, dark brown to black lesions. Severely infected cotyledonary leaf senesce prematurely, and growth of the plants is stunted. Diseased areas on stems and petioles have brown, sunken, elliptical or circular lesions with dark red brown margin that may girdle the stem and kill the seedling. On leaves, symptoms generally occur on the undersides of the leaves as linear, dark brick-red to black lesions on the leaf veins. As the disease progresses, the discolouration appears on the upper leaf surface. The most striking symptoms develop on the pods. Small, reddish-brown to black blemishes and distinct circular, sunken reddish brown lesions are typical symptoms (Figure 15.19). Mature

lesions are surrounded by a circular, reddish-brown to black border with a grayish-black interior. During moist periods, pink masses of spores appear on the lesion. Severely infected pods may shrivel, and the seeds they carry are usually infected. Infected seeds have brown to black blemishes and sunken lesions.

**Management:** Planting resistant varieties, seed treatment and crop rotation at least for two years are options for the management of bean anthracnose. Because of existence of many pathogenic races, resistant varieties may not work for a longer period. A variety, Contender, is reported to be very effective against anthracnose (Shrestha, 1990). Cultivar mixture, which is practiced in the high hills of Nepal, helps to reduce the disease (Prasad et al., 2016). Avoiding unnecessary movement, especially during wet period in the infected fields, will minimize the spread of the disease. Proper spacing (not dense) also minimizes disease. Seed treatment with mancozeb or thiram, followed by alternate foliar spray with carbendazim or mancozeb is recommended (Shrestha, 1990).

## *3. Floury Leaf Spot of Beans*

This disease, caused by *Mycovellosiella phaseoli* (Drumm.) Deighton, was appeared in Jumla, the high hill of mid-western Nepal for the first time in 2019. The disease was identified at Nepal Plant Disease and Agro Associates (NPDA). It can easily be confused with powdery mildew symptoms in the field. The symptoms appear as white floury growth on lower leaf surface with fungal mats (Figure 15.20). Brownish lesions can be seen on upper leaf surface at later stage.

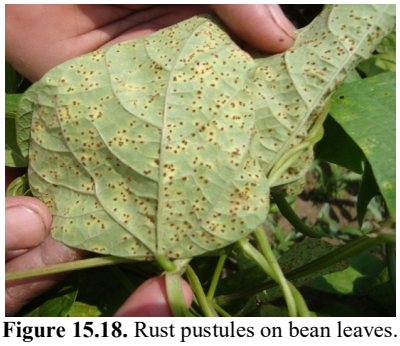


**Figure 15.18.** Rust pustules on bean leaves.



**Figure 15.19.** Anthracnose lesions on pole bean pods.



**Figure 15.20.** Floury leaf spot on abaxial surface of bean leaf.

## Virus Disease Complex

Plant infection by viruses causes physiological disorders and has economic significance in many crops. In recent years, viral disease problem has become a major challenge in cultivation of vegetable crops. Serious problems have been observed mainly in tomato, cucurbits, pepper, broad leaf mustard and okra. New virus-like diseases are also emerging. Research and studies on plant viruses are limited in Nepal.

## Distribution and significance

Virus diseases cause serious threats to crops, causing economic losses by reduction in yield and quality of the plant produce. Depending on severity, stage of crop during infection, location, crop variety, vector population, losses may be high or insignificant. Cucurbit viruses such as *Cucumber mosaic virus* (CMV), *Zucchini yellow mosaic virus* (ZYMV), *Watermelon mosaic virus* 1 and 2 (WMV 1 and WMV 2), *Squash mosaic virus* (SqMV), *Cucumber green mottle mosaic virus* (CGMMV) and *Chayote mosaic virus* (ChMV) in chayote are the major ones and distributed in terai, inner terai and mid hills.

Co-infection by a number of viruses is generally observed in cucumber, squash and pepper (Joshi & Shrestha, 1999; PPD, 2015). Hundred percent incidence of simultaneous infection by more than one virus mentioned above in zucchini squash caused farmers unable to compensate even seed cost (Timila, 2010).

*Cucumber mosaic virus* (CMV), *Tomato yellow leaf curl virus* (TYLCV) and *Tomato mosaic virus* (ToMV) in tomato; and CMV and *Chilli veinal mottle virus* (CVMV) in pepper are the most common viruses in Nepal (Joshi & Shrestha, 2001). Ghimire et al. (2001) reported incidence of TYLCV in most tomato growing pockets and yield losses of 40% or even higher in some areas of western hills of Nepal.

*Bean common mosaic virus* (BCMV) in bean and *Turnip mosaic virus* (TuMV) in broad leaf mustard, radish and turnip are distributed in the mid hills and valleys. Hundred percent incidence of TuMV in turnip and 70% in broad leaf mustard were observed that affected badly in seed production during 1980 (Shrestha, 1990).

*Okra yellow vein mosaic virus* (OYVMV) is distributed in the terai and inner terai in okra. Up to 90% yield loss could be caused by this disease (Kumar et al., 2017). Extent of yield loss is dependent on time of infection during growing stage of the plants. Infection in early stage of plant growth causes higher yield loss.

Viruses in garlic – Several viruses have recently been reported in garlic. They include *Onion yellow dwarf virus* (OYDV), *Garlic common latent virus* (GCLV) (Majumder & Johari, 2014), *Leek yellow stripe virus* (LYSV) (Manandhar et al., 2017), *Garlic latent virus* (GLV) and *Tymovirus* (Neupane, 2020). Of them, LYSV, OYDV and GCLV were commonly detected in both the terai and hills, and GLV and *Tymovirus* were detected in the hills (Neupane, 2020).

## Sign and symptoms

Various types of sign and symptoms are produced in the host plants due to virus infection. Many viruses do not produce symptoms in the host plants causing latent infection.

Symptoms and severity are dependent upon the variety, strain of the virus, age of the host at the time of infection and environmental conditions. Major symptoms of some major viruses on crop plants and their mode of transmission are given briefly below.

***Tomato mosaic virus*:** Typical symptoms include a light and dark green mottling and mosaic of the leaf tissue (Figure 15.21), stunting of the tomato plant and necrotic streaking of stem. Occasionally, the fruit may show uneven ripening to an internal browning of the fruit wall (brown wall) on tomato. This virus is very stable and transmitted by contact and seed.

***Tomato yellow leaf curl virus*:** Stunting of plants, small leaves, interveinal chlorosis, upward curling, crinkling and bronzing of leaves occur on tomato plants (Figure 15.22). The virus is transmitted by whitefly (*Bemisia tabaci*).

***Cucumber mosaic virus*:** Mosaic, mottling, leaf distortion, shoe stringing, and sometimes leaf death and defoliation are the symptoms induced by the virus on tomato (Figure 15.23a), pepper and cucumber (Figure 15.23b). The virus is aphid-transmitted.

***Watermelon mosaic virus (WMV 1 and 2)*:** Strong mosaic, distortion, and deep leaf serration and malformed fruits with knobby overgrowth on various cucurbits are the major symptoms. The virus is transmitted by aphids.

***Zucchini yellow mosaic virus (ZYMV)*:** Symptoms consist of a prominent yellow mosaic, necrosis, distortion and stunting. Fruits remain small, greatly malformed and green mottled. The virus is transmitted by seed and aphids.

***Squash mosaic virus (SqMV)*:** Symptoms include pronounced chlorotic mottle, green vein banding and distortion of leaves of young seedlings. On leaves of matured squash plants, intense dark green mosaic, blistering and hardening appear, and fruits with strong mottling on different cucurbits can be seen. The virus is transmitted by seed and cucumber beetle.

***Cucumber green mottle mosaic virus (CGMMV)*:** Mottling and mosaic symptoms on leaves and different degrees of fruit mottling or distortion are the symptoms produced specially on various cucurbits. This virus is transmitted mechanically and by seed.

The above four viruses (WMV 1 and 2, ZYMV, SqMV and CGMMV) may simultaneously infect cucurbit vegetables, especially zucchini squash. They show the complex symptoms on infected plants (Figure 15.24). However, individual infection is also detected.

***Chilli veinal mosaic virus (CVMV)*:** Leaves develop a mottle or mosaic with dark-green vein banding (Figure 15.25). The virus is transmitted by aphid.

***Bean common mosaic virus (BCMV)*:** Mottling, mosaic, puckering, curling and malformation of leaves, and a stunting of the bean plants are the symptoms (Figure 15.26). The virus is seed-borne and also vectored by aphid. Severe stunting and black root symptoms are produced at 20 °C or higher temperatures.

***Turnip mosaic virus (TuMV)*:** Symptoms include mosaic, puckering with leaf distortion and stunting in turnip, radish and broad leaf mustard (Figure 15.27). The virus is aphid-transmitted.

***Okra yellow vein mosaic virus (OYVMV)*:** A typical vein yellowing and thickening of leaves are the initial symptoms. As disease progresses, a network of veins and veinlets in

the infected leaves appear and the leaves become completely yellow (Figure 15.28). Infected plants are stunted and produce small-sized yellow fruits. The virus is vectored by white fly and okra leaf hopper.

***Garlic viruses*:** Symptoms like mild to severe leaf curling and mosaics with chlorosis appear (Figure 15.29). Most of the symptoms bearing plants had multiple infections by more than one virus, OYDV, GCLV, LYSV, GLV and or *Tymovirus* (Neupane, 2020). All viruses have been found clove-transmitted and vectored by aphids.

## *Management of Virus Diseases*

Curative treatments of virus diseases in the fields are not available yet. They are managed by an integrated approach involving different tactics, such as planting healthy seed, eliminating virus sources, using host resistance, cross protection, crop rotation, avoidance and control of insect vectors. Healthy seeds can be obtained from certified seed sources, i.e. through seed certification, seed health testing, seed treatment, etc. Hot water seed treatment and chemical seed treatment (e.g. trisodium orthophosphate) are recommended to eliminate viruses from seed, but not practiced in Nepal. Sources of virus can be minimized by roguing infected plants in the field, removing weed hosts and volunteer plants, and sanitation. Insect vectors can be avoided by manipulating planting or harvesting time. They can be controlled through pesticides, sticky and pheromone traps, netting, using trap or border crops, or using reflective mulches.

A number of host genotypes or varieties have been identified, recommended or registered as resistant to certain viruses. However, many of them are not available for cultivation or they are not preferred by farmers despite their availability. Some research reports show that tomato genotypes, ATY 3, ATY 5 and ATY 6 were resistant to TYLCV, where as NCL 1, BL410 and Pusa Ruby were tolerant (Malla et al., 2000, 2002). Pepper lines namely, HAD 832, Hybrid Huareua and Toom were identified as resistant to CVMV and P-3, PSP, LV2722, and Tiwari 2 to CMV under screenhouse conditions (Joshi & Shrestha, 2001).

Similarly for the management of OYVMV, early planting and use of resistant varieties, such as Parwani Kranti, Arka Anamika are suggested (Khadka, 2015).

There is no chemical control of plant virus diseases. However, some products as antivirus (Prevental, Bioleafcare, Vircon-H and Victovirus) are being sold. And, Victovirus and some other antivirus products (Anti-VS and Liposome) when tested for the management of cucurbit viruses, they were found to lower the virus severity to some extent (Joshi et al., 2013). Also, farmers do use cow milk as spray against virus diseases.

As many plant viruses are insect-transmitted, growing seedlings and plants under insect-free conditions is the most effective means for the management of viruses. The seedlings raised under muslin cloth had the highest fruit yield and lowest TYLCV incidence in tomato (Malla et al., 2000, 2001). Also, the authors of this chapter had observed reduced co-infection of CMV and ToMV by 59% and increased yield by 50% in tomato grown under insect proof net compared with planting in open field. In our context, growers are suggested to follow the different prophylactic tools (cultural practices, seedling raise under net and vectors control) in integrated way to combat with viral diseases.



**Figure 15.21.** Tomato mosaic virus-infected tomato plant.



**Figure 15.22.** Tomato yellow leaf curl virus-infected tomato plant.



**a**



**b**

**Figure 15.23. (a)** Cucumber mosaic virus-infected tomato plant, and **(b)** Cucumber mosaic virus-infected cucumber plant.



**Figure 15.24.** Zucchini squash plant infected by virus complex.




**Figure 15.25.** Chilli veinal mosaic virus-infected capsicum plant.



**Figure 15.26.** Bean common mosaic virus-infected bean plants.



**Figure 15.27.** Turnip mosaic virus-infected broad leaf mustard plant.



**Figure 15.28.** Okra yellow vein mosaic virus-infected okra plant.



**Figure 15.29.** Leaf curl and chlorosis on garlic plants infected by virus complex.

## Conclusion

Occurrence and outbreak of various diseases are the major constraints of successful vegetable cultivation. Management of diseases, especially viral ones and soil-borne nature, has become a challenge in vegetable production. At the same time, diseases that considered minor earlier are appearing as major problems now. Early detection and application of treatments while the disease is less severe is very essential. Biological control measure is receiving attention in disease management practices as reduced use of chemical pesticides is the priority option. However, the available options are very limited and also it is difficult to achieve a satisfactory level of disease control through biological means only. Thus, for effective management of diseases, integration of management components should be practiced. They include cultural practices, host resistance, biological control and chemical control that are environmentally compatible, economically feasible and socially acceptable.

**Abbreviations:** NARC = Nepal Agricultural Research Council; NPDA = Nepal Plant Disease and Agro Associates.

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# Author's Biography



Dr. Ram Devi Timila, former Senior Scientist at Plant Pathology Division of Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, is the Founder Executive Member of Nepal Plant Disease and Agro Associates (NPDA) based in Kathmandu for research, development and teaching. She has a PhD in plant science with major in plant pathology from the University of Connecticut, Storrs, USA; MSc in botany with specialization in plant pathology from Tribhuvan University (TU); and Diploma in seed pathology from the Danish Government Institute of Seed Pathology, Denmark. She was a Special Skills Research Training Scholar on bacterial wilt of vegetables at AVRDC (now World Vegetable Center). She has contributed in introducing grafting technology in vegetable crops for the management of bacterial wilt and root-knot nematodes**.** She has co-authored two books, authored a number of research and review articles, factsheets and extension articles on agricultural technologies and issues, proceedings and journals, nationally and internationally and also edited research articles. She has received NARC award for her remarkable contribution on vegetable disease management. She has been guiding BSc and MSc students of plant pathology at Institute of Agriculture and Animal Science (IAAS), TU; Agriculture and Forestry University; and HICAST (Purbanchal University). She has been affiliated with the Society of Agricultural Scientists, Plant Protection Society and Women in Science and Technology.



Dr. Hira Kaji Manandhar, former Senior Scientist, Chief of Planning Division, Chief of Plant Pathology Division, and Director for Planning and Coordination at Nepal Agricultural Research Council (NARC), is the Adjunct Professor at Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal; Adjunct Professor at Institute of Agriculture and Animal Science (IAAS), Tribhuvan University (TU), Kirtipur, Kathmandu, Nepal; and Program Leader (Food Crops) at Asian Food and Agriculture Cooperation Initiative (AFACI), sponsored by the Government of South Korea. He has a PhD in plant pathology from the Royal Veterinary and Agricultural University, Copenhagen, Denmark (now University of Copenhagen); Diploma in seed pathology from the Danish Government Institute of Seed Pathology (DGISP); and BSc in agriculture from IAAS, TU. He has authored a number of books, research articles, chapters, reviews, factsheets and broadsheet articles on agricultural technologies and issues and edited books, proceedings and journals, nationally and internationally. He also worked as local consultant for Asian Development Bank and Bioversity International. He along with his colleagues has founded a company, Nepal Plant Disease and Agro Associates (NPDA), in Kathmandu, for research, development and teaching. He has received a number of awards, including His Royal Highness Crown Prince Dipendra Science and Technology Youth Award of RONAST (now NAST). He also served as the president of the Society of Agricultural Scientist, Nepal; member of the Assembly of NAST Academicians; the council member of NARC; and several other organizations.

# Chapter 16

## Mycotoxins: Hazards, Association, Situation in Nepal and Remedies

**Gopal Bahadur K.C.**
*Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal*
* Email: kcgopal2014@gmail.com

*Thousands of mycotoxins exist in nature, of which aflatoxins, fumonisins, ochratoxins, deoxynivalenol, trichothecenes and ergot alkaloids are of more significance. The fungi build up toxins in their hosts when the environment is favourable for their growth, such as high moisture content in the commodities, high temperature, high humidity, damaged grains and poor storage conditions. Gradual intake of sub-acute amounts of toxins via foods and feeds may result in several health problems, like reduced nutrient uptake, gastroenteritis, immune suppression, stunting in children, hepato- and neuro-toxicity, kidney failure, cancer and even death. In Nepal, analyses are done almost exclusively with aflatoxins in major food grains and feeds. Studies carried out during 1980 to 1987 revealed aflatoxins in peanut raw in shell trace to 635 ppb, in peanut butter trace to 282 ppb, in corn trace to 321 ppb, in corn flour trace to 243 ppb, in wheat flour 21 to 91 ppb, in livestock feed trace to 300 ppb and in poultry feed trace to 500 ppb, while based on altitude, Aflatoxin B1 was found 6,334 ppb in terai, 72 ppb in Kathmandu valley and 59 ppb in high hills in maize. During 2009, Aflatoxin B1 and B2 were found in 20% poultry feed samples collected from Chitwan and Kabhre districts. A study carried out during 2017 to 2019 at Nepal Academy of Science and Technology and University of Nebrasca Lincon for Aflatoxin content in foodstuffs of western Nepal, showed tolerable limit (20 ppb) exceeding samples 27% in peanut, 17% in corn, 6% in soybean nuggets and 4% in dry chilli. The study revealed that corn and peanuts were at high risk, soy nuggets and dry chilli at medium risk and rice and baby food at low risk for consumption. Mycotoxins are national issues, and enough drying and proper storage of food grains seem to be very essential to supply safe foods and feeds in future in Nepal.*

**Keywords:** Aflatoxins; carcinogen; drying; proper storage; food safety.

## Introduction

Myctotoxins are toxic, secondary metabolites/chemicals, synthesized in nature by several species of fungi, most commonly belonging to the genera *Aspergillus* and *Fusarium*,

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capable of causing disease and death in vertebrates (Niessen, 2007). Under congenial environment, the fungi grow rapidly into colonies and produce toxins specific to the fungus as a by-product. Problems resulting from mycotoxin consumption may be readily apparent resulting in cancer, neural tube defects in new borns, partial immune system suppression, improper adsorption of essential nutrients, growth stunting in children under age of five years and even death. The best know mycotoxin is aflatoxin. In addition to aflatoxins, ochratoxins, fumonisins, deoxynivalenol, trichothecenes, etc. are also very important. Weather conditions and organic food sources not only affect toxin production, but also characteristics of the toxin produced. Mycotoxins can be produced wherever fungi grow, in grains (for example, maize, barley, wheat, oat, peanut and other crops) during pre-harvest in the field and post-harvest in storage. In either case, damage from insects, mishandling and environmental stresses can enable the fungi to invade the grains and build up the toxins. After production, mycotoxins diffuse into substrates on which the fungi are growing. They break down very slowly and have no or less effect of washing and boiling level heat treatment.

For a sound health of humans, animals and birds, the foodstuffs should be nutritious and safe, basically from toxic compounds. Nutritional security includes food safety (a diet isn't nutritious if it is not safe), and that aflatoxin consumption has been associated with blocked nutrient uptake (so even if you are eating a nutritious diet, if it includes mycotoxins, your body may not get to use any of the nutrients supplied).

## History of Mycotoxin

Mycotoxins were recorded 5,000 years ago in China. In 1861, a suspected mycotoxin affected humans in Russia. In 1891, mouldy rice was found toxic to man in Japan. In 1960, aflatoxins were discovered in England (Sargkant et al., 1963). Between 1960 and 1970, fungal metabolites found cause of disease and death of animals. After 1970, mycotoxins were established as a cause of human disease and death (Pitt, 1987). In Nepal, in 1978, monitoring of mycotoxin in foods was first initiated by FAO/UNEP project (Karki & Sinha, 1992). These days, mycotoxin is taken as a great issue in human foods, animals and birds' feeds throughout the world, especially in developed countries. In Nepal, it is not yet taken as a great matter of concern. However, it seems not to be neglected, but attended seriously to supply safe food and feeds in the market.

## Commodities Affected

Under conducive environment, i.e. high temperature and high humidity, the fungi may attack almost all foods and feeds, such as cereal grains, e.g. rice, paddy, corn, wheat, barley, millets, buckwheat, etc., beans and pulses, peanuts, fresh and dried fruits, flour and breads, other industrial/processed foods/products, cheese, processed meats, animal and poultry feeds, etc. About 25% of the world's agricultural production is estimated to be contaminated with mycotoxins (Boutrif & Canet, 1998).

## Conducive Environment for Mould Growth

Weather conditions somewhat vary from one fungal species to the other for their growth. A temperature range for some important fungal species is -2 to 45 °C (Van Alfen, 2014).

Temperature and humidity requirement for some selected species is presented in Table 16.1.

**Table 16.1.** Temperature and humidity requirement for some important mycotoxin producing fungi.

| Fungi | Temperature °C | | Minimum relative humidity % |
|---|---|---|---|
| | Range | Optimum | |
| *Fusarium graminearum* | 5–35 | 24–26 | 90 |
| *Fusarium verticillioides* | 2–37 | 15–30 | 87 |
| *Fusarium sporotrichioides* | –2–35 | 22.5–27.5 | 88 |
| *Aspergillus parasiticus* | 12–42 | 32 | 78–82 |
| *Aspergillus flavus* | 10–45 | 33 | 78–80 |
| *Aspergillus ochraceus* | 12–37 | 25–28 | 83 |
| *Penicillium verrucosum* | 0–31 | 20 | 81 |

However, a typical optimal environmental condition for most of the toxin producing fungi may be high moisture level (14–30%) in commodities, high temperature (25 to 35 °C), high humidity (80 to 90%), poor ventilation in storage, long time storage, damage of grains by insects, rats and other agents in field and storage, other biotic and abiotic stresses to crops, rough post-harvest handling, etc., where the fungi flourish and may produce profuse mycotoxins.

## Types and Toxicity of Mycotoxins

So far, thousands of mycotoxins have been identified and identification of new mycotoxins is going on. Subtypes of numerous mycotxins have also been appeared. Of the total identified mycotoxins, only a few have been determined to pose a significant threat to the health of humans and animals. Agriculturally and from health hazard aspects more important mycotoxins, known since a long time, are aflatoxins, fumonisins, trichothecenes, zearalenone, ochratoxin and ergot alkaloids. Among them, aflatoxins are most toxic to humans and animals.

Main route of mycotoxin entry into the body is through ingestion of contaminated foods and feeds. However, it may also pass through inhalation and absorption through skin. Although mycotoxins are toxic, each toxin is not harmful to every animal species. But, aflatoxins are dangerous to both humans and animals, while others dangerous to only specific animal species (Neogen Corporation, 2009a). Amount of mycotoxin required to cause disease in humans and animals depends on type of mycotoxin and animal species. It may vary from animal to animal too within one species. However, the intensity of damage caused by a mycotoxin depends on level of contamination in a commodity and its amount ingested by aspecific animal.

General symptoms of toxicity may be of two types. In acute symptoms, there is stomach pain, vomiting and death of animals. Such severe cases happen when a large amount of toxin is ingested at a time via foods or feeds, but such cases are rare. Chronic symptoms appear when a small amount of toxin is consumed continuously for a long time, i.e. several years. Chronic symptoms of the mycotoxins are carcinogenicity (cancer induction), mutagenicity (mutation), teratogenicity (physical abnormalities) and immune suppression (weakening resistance power). Besides, the toxin may cause acute liver damage, tumor induction, kidney failure, intestinal hemorrhage, poor growth, abortion, effect in respiratory system, heart and brain, paralysis and finally death.

Besides toxicity, extensive mold growth on grains may have other obvious negative effects too, such as changes in grains' colour, consistency and smell, which may make the grains undesirable to human food and livestock feed. Mold growth can also rob fat, protein and vitamins from the grains and lead to nutritional deficiencies (Neogen Corporation, 2009a). Viability and germination of maize seeds could be affected by attack of *Aspergillus* and *Penicillium* species. Affected animal species and symptoms of toxicity vary in most of the cases. Main characteristics and symptoms of toxicity of the major mycotoxins are as follows.

## 1. Aflatoxins

Aflatoxins are the most common, the best known and the most toxic among the mycotoxins produced in nature, mostly by *Aspergillus flavus, Aspergillus parasiticus* and *Aspergillus nomius*. The fungi are found virtually throughout the world. They are soil borne, but prefer to grow on high nutrient seeds (Neogen corporation, 2009b). There are four major aflatoxins: B1 ($C_{17}H_{12}O_6$), B2 ($C_{17}H_{14}O_6$), G1 ($C_{17}H_{12}O_7$) and G2 ($C_{17}H_{14}O_7$). B refers to blue and G green fluorescent colours produced by them under UV light on thin layer chromatography (TLC) plates, while 1 and 2 indicate major and minor compounds, respectively. After ingestion of Aflatoxins B1 and B2 by lactating cows, a proportion of about 1.5% is excreted in milk as Aflatoxins M1 ($C_{17}H_{12}O_7$) and M2 ($C_{17}H_{14}O_7$) compounds which are of lower toxicity (10 to 30 times) than parent molecules (Frobish et al., 1986). Aflatoxins are mostly found in corn, peanut, cottonseed and majority of tree nuts.

Aflatoxins are of greater public health concern due to their ability to accumulate in the body, to be present in edible tissues of animals, such as liver and muscles, to be present in animals' food products, such as milk and eggs, and to be found in mothers' breast milk. However, threshold levels are not fixed for eggs and meat.

Aflatoxins are most potent hepatotoxins (cause liver failure) and carcinogens (especially cause liver cancer). They may be also fatal. Lower levels of aflatoxins cause immune suppression (reduced secretion of antibodies and increased susceptibility to HIV, TB, etc.) and decreased appetite, conversion of feed into animal protein, growth, reproductive efficiency and production in livestock. Dairy cattle exposed to aflatoxin contaminated maize (120 ppb) for several months had reduced milk production by 28% (Guthrie & Bedell, 1979). Gradual aflatoxin ingestion also causes reduced growth and egg production in poultry and growth in pigs.

Various agencies and countries have postulated regulatory levels of aflatoxin in their food and feed products to deliver safe food in the markets (Tables 16.2, 16.3 and 16.4). Regulatory levels mean upper limit of a mycotoxin in foods or feeds which is yet consumable by the humans and can be feed to the animals.

**Table 16.2.** Regulatory levels of aflatoxins Food and Drug Administration (FDA), USA for human and animals.

| Species | Aflatoxins | Foodstuffs |
|---|---|---|
| Human | 20 ppb | All except milk |
| All animal species | 20 ppb | All except below |
| Breeding cattle, swine and mature poultry | 100 ppb | Corn |
| Finishing swine (>100 lbs) | 200 ppb | Corn |
| Finishing beef cattle | 300 ppb | Corn |
| Finishing beef cattle, swine & poultry | 300 ppb | Cottonseed meal |

Source: (Neogen Corporation, 2009a)

**Table 16.3.** Regulatory levels of European Union (EU) for aflatoxins in human.

| Foodstuffs | Aflatoxins |
|---|---|
| Spices | 10 ppb |
| Peanuts, nuts, dried fruits, cereals and cereal products | 4.0 ppb |
| Baby foods and cereals intended for infants | 0.1 ppb |

Source: (Neogen Corporation, 2009a)

**Table 16.4.** Regulatory levels of Nepal for aflatoxins.

| Foodstuffs | Maximum | Aflatoxins |
|---|---|---|
| Food (cereals), Pulses/legumes and raw nuts | 20 ppb | Aflatoxin |
| Feed | 50 ppb | Aflatoxin (B1) |

Source: (Nepal Gazette, 2001)

After ingestion of aflatoxins by humans and poisoning of experimental monkeys with aflatoxins, largest amount of aflatoxin was found accumulated in liver after stomach content in autopsy specimens with Reye's syndrome (Table 16.5) (Bourgeois et al., 1971; Shank et al., 1971). It showed that sink of aflatoxin after ingestion was liver.

**Table 16.5.** Aflatoxin B1 in autopsy specimens from Reye's disease and experimental monkeys poisoned with aflatoxin B1.

| Specimen | Aflatoxin B1 | |
|---|---|---|
| | Human | Monkey |
| Brain | 1–4 ppb | 30 ppm |
| Kidney | 1–4 ppb | 87 ppm |
| Bile | 8 ppb | 163 ppm |
| Liver | 93 ppb | 163 ppm |
| Intestinal content | 81 ppb | - |
| Stomach content | 127 ppb | - |
| Stool | 123 ppb | - |

## 2. Fumonisins

Fumonisins are B1, B2 and B3. Fumonisin B1 was first isolated and characterized by (Marasas et al., 1988). They are produced by various species of *Fusarium*, especially in corn and then in rice. In human, it is linked with esophageal cancer and neural tube defects, while in equines, it causes leukoencephalomalacia (inflammation and edema in central nervous system and liquefaction of brain) and liver damage, and in swine, pulmonary edema syndrome and liver and pancreatic lesions (Neogen corporation, 2009a). Horses are extremely sensitive even to low amounts of fumonisins. Various agencies and countries have postulated regulatory levels of fumonisins in their food and feed products to deliver safe food in the markets (Tables 16.6 and 16.7).

**Table 16.6.** Regulatory levels of fumonisins as FDA, USA.

| Species | Foods and feeds | Total fumonisins |
|---|---|---|
| Human | Dry milled corn products | 2 ppm |
| Human | Popcorn | 3 ppm |
| Equids and rabbits | Corn and corn by-products | 5 ppm |
| Swine and catfish | Corn and corn by-products | 20 ppm |
| Breeding ruminants and poultry | Corn and corn by-products | 30 ppm |
| Ruminants ≥3 months raised for slaughter | Corn and corn by-products | 60 ppm |
| Poultry raised for slaughter | Corn and corn by-products | 100 ppm |
| Other species of livestock and pets | Corn and corn by-products | 10 ppm |

Source: (Neogen corporation, 2009a)

**Table 16.7.** Regulations for fumonisins as EU for human.

| Foodstuffs | Fumonisins (B1 + B2) |
|---|---|
| Corn unprocessed | 2.0 ppm |
| Corn flour, grits, germ and oil | 1.0 ppm |
| Corn based foods for direct consumption | 0.4 ppm |
| Corn based baby and infants foods | 0.2 ppm |

Source: (Neogen corporation, 2009a)

## 3. Ochratoxin

Ochratoxin is produced by *Aspergillus ochraceus, Penicillium verrucosum* and *Penicillium nordicum* especially in corn, barley, wheat, cacao, green coffee beans, grapes, nuts and various dried fruits. The toxin is a suspected carcinogen and may be present in conjunction with aflatoxin.

Ochratoxin may cause damage of small blood vessels and nephrons in kidney resulting kidney failure in humans. It is also hepatotoxic in humans. The toxin damages also kidney and liver in animals. In poultry, there is decreased feed conversion resulting in retarded growth and egg production (Neogen corporation, 2009a).

FDA, USA has not set any advisory level. However, many of them agree that levels between 10 to 20 ppb for commodities destined for human and animal consumption may cause health problems (Table 16.8).

**Table 16.8.** EU tolerable limits of ochratoxin for human consumption.

| Foodstuffs | Ochratoxin |
|---|---|
| Dried vine fruits and instant coffee | 10.0 ppb |
| Unprocessed cereals and roasted coffee | 5.0 ppb |
| Processed cereals for direct consumption | 3.0 ppb |
| Wine, wine based drinks and grape juice | 2.0 ppb |
| Baby and infants' cereal foods | 0.5 ppb |

## 4. Trichothecenes

Trichothecenes are produced by several species of *Fusarium*. Other trichothecenes producing fungi are *Trichothecium, Trichoderma, Cephalosporium*, etc. It is a family which includes several members, like Deoxynivalenol (DON), Nivalenol, T-2, HT-2 and Diacetoxyscirpenol (DAS) toxins. Trichothecenes are grouped into class A and class B. The fungal strain producing one class of toxins do not produce toxins of another class. Class A includes T-2, TH-2 and DAS toxins and class B DON and Nivalenol. Class A is more toxic than class B and can be taken up through skin or intestinal mucosa. Trichothecenes are neither mutagenic nor carcinogenic, but inhibit protein synthesis. They are especially toxic to monogastric animals, i.e. human, dogs, equines, rabbits and pigs etc. and are virulence factors in plant diseases. They are most common in grains especially in wheat.

## 5. T-2 and HT-2 Toxins

T-2 toxin is readily metabolized to HT-2 toxin. So both toxins may come together and pose adverse effects. The toxins affect human, cattle, swine, poultry, dogs, cats and horses and cause digestive disorders (feed refusal, diarrhea and vomiting), hemorrhage (especially by T-2), edema, oral lesions, dermatitis and blood disorders. Damage to digestive tract is irreversible. In severe cases, there is death too. In human, T-2 toxin is the principal cause of alimentary toxic aleukia (decrease in disease fighting cells – white blood cells, WBC). In poultry, T-2 intoxication has led to reduction in weight gain, beak

lesions, poor feathering, motor function impairment and increased susceptibility to *Salmonella* spp. (Tables 16.9 and 16.10) (Neogen Corporation, 2009b).

**Table 16.9.** Regulatory levels of EU for total toxins (T-2 and TH-2) in human.

| Foodstuffs | T-2 + TH-2 | Human |
|---|---|---|
| Cereal based food | 0.015 ppm (15 ppb) | Infants and young children |
| Breads and bakery wares, pastries, biscuits, cereal snacks or pasta | 0.025 ppm (25 ppb) | Grown up |
| Breakfast cereals including cereal flakes | 0.075 ppm (75 ppb) | Grown up |
| Cereal milling products | 0.05 ppm (50 ppb) | Grown up |
| Cereal bran except oat and maize milling products | 0.1 ppm (100 ppb) | Grown up |
| Oat bran and flaked oats | 0.2 ppm (200 ppb) | Grown up |

**Table 16.10.** Regulatory levels of EU for total toxins (T-2 and TH-2) in livestock.

| Feedstuffs | T-2 + TH-2 |
|---|---|
| Unprocessed wheat, rye and other cereals | 0.10 ppm (100 ppb) |
| Unprocessed barley and maize | 0.20 ppm (200 ppb) |
| Compound feed | 0.25 ppm (250 ppb) |
| Oat husk | 2.00 ppm (2,000 ppb) |

## 6. Deoxynivalenol

Deoxynivalenol (DON) is also called as vomitoxin because of vomiting its major toxic symptom. It is most commonly produced by the pink mold *Fusarium graminearum* and also by *Fusarium culmorum* that frequently infect cereals, like wheat, corn, barley, etc. In addition to vomiting, it causes feed refusal, gastroenteritis, diarrhea, immune-suppression and blood disorders. Pigs are highly sensitive to DON (Tables 16.11 and 16.12) (Neogen Corporation, 2009b).

**Table 16.11.** Advisory levels of FDA, USA for human and livestock.

| Species | Deoxynivalenol | Foodstuffs |
|---|---|---|
| Humans | 1 ppm | Wheat flour, bran and germ |
| Swine | 1 ppm | All grains and grain by-products |
| Cattle and chickens | 5 ppm | All grains and grain by-products |
| All other animals | 2 ppm | All grains and grain by-products |

**Table 16.12.** Regulation of EU for human.

| Foodstuffs | Deoxynivalenol |
|---|---|
| Unprocessed durum wheat and oats | 1750 ppb |
| Unprocessed cereals other than durum wheat, oats and maize | 1250 ppb |
| Cereal flour, including maize flour, maize grits and maize meal | 750 ppb |
| Cereal products, e.g. biscuits, breads, etc. | 500 ppb |
| Processed cereal-based foods for infants, babies and young children | 200 ppb |

## 7. Zearalenone

Zearalenone is primarily produced by *F. graminearum* and *F. culmorum*, which also commonly produce Deoxynivalenol. Hence, if zearalenone is detected in any food or feedstuff, there is possibility of presence of other fusarial mycotoxins too. Zearalenone is also classified as an estrogenic mycotoxin, because it oftenly causes estrogenic responses in animals.

In livestock, it may cause a wide variety of reproductive problems. In swine, it causes vulvovaginitis (inflammation or infection of vulva and vagina), low birth weights, fetal re-absorption, abortion, reduced litter sizes, abnormal estrus and feminization of immature males. FDA advisory level for zearalenone is <500 ppb for livestock (Table 16.13) (Neogen corporation, 2009a).

**Table 16.13.** Regulatory levels of EU for zearalenone in human.

| Foodstuffs | Zearalenone |
|---|---|
| Unprocessed corn | 200 ppb |
| Other unprocessed cereals | 100 ppb |
| Processed cereals, e.g. bread, pastries, etc. | 50 ppb |
| Baby and infants cereal foods | 20 ppb |

## 8. Ergot Alkaloids



**Figure 16.1.** Ergot in cereal.

Ergots (also known as sclerotia) are abnormally produced structures from flowers of rye, wheat, barley, sorghum, pearl millet, oats, etc. due to infection in ovary by *Claviceps purpurea*, *Claviceps fusiformis*, *Claviceps africana*, *Claviceps sorghi*, *Claviceps paspali*, etc. The modified grains, the ergots (derived from the French word "argot", meaning spur) (Figure 16.1), contain ergot alkaloids (ergot toxin) which are also known as mycotoxins (Haschek & Voss, 2013). Ergot alkaloids are often divided into (1) amine alkaloids, e.g. lysergic acid, ergonovine (ergometrine), methylergonovine, methysergide, lergotrile, and (2) amino acid alkaloids, e.g., ergotamine, bromocriptine, etc (Hodgson, 2012). The toxins affect cattle, swine, sheep, human and birds. Ergot poisoning in humans and domestic animals is known as ergotism. Ergotamine especially stimulates central nervous system and ergometrine causes vascular stasis.

Ergot alkaloids can be fatal. Early symptoms of poisoning in human include nausea, vomiting, muscle pain and weakness, numbness (lost, reduced or altered sensation), itching, and rapid or slow heartbeat. Ergot poisoning can progress to gangrene (localized death and decomposition of body tissue), vision problems, confusion, spasms, convulsions, unconsciousness and death. Today, ergot alkaloids are being exploited for medicinal purposes including the treatment of migraines, induction of child birth and control of post-partum bleeding (Schmale III & Munkvold, 2009).

In general, the symptoms are categorized into hallucinations (mental problem), neuropathy (damage of nerves causing sensation loss and pain of some body parts) and gangrene. In cattle and sheep, there is lameness of hind limbs first and then forelimbs, high fever, high pulse rate, high respiratory rate, swelling and tenderness of joints, loss of sensation of affected areas, dry gangrene at the distal part, sloughing (shed a layer of dead skin) of the distal part and death. Sheep have also mouth ulceration. Swine show lower feed intake, lower weight gain, lack of udder development, weak and undersized newborn piglets and low survival rate of the piglets. The problem of ergot alkaloids can be solved by sorting ergot bodies before processing or consumption of the grains.

## Regulation

Toxicity of ergot toxins is not regulated in USA for food and feed. In the EU, the provisional maximum tolerable levels of ergot alkaloids in feedstuff are as below shown in Table 16.14 (Jakubczyk et al., 2014).

**Table 16.14.** Regulatory level of EU on rye ergot alkaloids.

| Undesirable substance | Products intended for animal feed | Maximum content in mg/kg (ppm) relative to a feed with a moisture content of 12% |
|---|---|---|
| Rye ergot (*Claviceps purpurea*) | Compound feed for cattle (except dairy cattle and calves), sheep (except dairy sheep and lambs), goats (except dairy goats and kids), pigs (except piglets) and poultry (except young animals) | 0.02 (20 ppb) |
| | Feed materials and compound feed containing unground cereals | 1.00 (1,000 ppb) |

For a quick overview, a summary of major mycotoxins is presented below in Table 16.15.

**Table 16.15.** Some mycotoxins, their sources and potential toxicity.

| S. No. | Mycotoxins | Producing fungi | Major foods involved | Major toxicities |
|---|---|---|---|---|
| 1 | Aflatoxins B1, B2, G1 and G2 | *Aspergillus flavus*, *A. parasiticus* | Corn, peanut, cotton seed, dried fruits, majority of tree nuts, spices. | Hepatocarcinogen and fatty liver. |
| 2 | Aflatoxins M1 and M2 | Metabolites of aflatoxins B1 and B2 | Milk and dairy products | Hepatotoxin |
| 3 | Fumonisins B1, B2 and B3 | *Fusarium verticillioides*, *F. proliferatum*, *F. moniliforme* | Maize, rice, etc. | Esophageal cancer |
| 4 | Trichothecenes | *Fusarium sporotrichioides*, *F. poae*, *F. graminearum*, *F. culmorum*, etc. | Wheat, maize and other cereals | Cytotoxicity |

| | | | | |
|---|---|---|---|---|
| 5 | Deoxynivalenol (DON) | *F. graminearum*, *F. culmorum* | Corn, wheat, barley, etc. | Vomiting |
| 6 | Nivalenol | *F. graminearum*, *F. crookwellense* | Cereals and their products | Feed refusal, vomiting, erythropenia, leukopenia. |
| 7 | Zearalenone (estrogenic mycotoxin) | *F. graminearum*, *F. culmorum*, *F. crookwellense* | Maize, wheat, other cereals, cereal flour, etc. | Hyper-estrogenic effect |
| 8 | Ochratoxins | *A. ochraceus*, *P. verrucosum*, *P. nordicum* | Cereals, pulses, spices, green coffee beans and dried fruits | Hepatotoxin, nephrotoxin |
| 9 | Ergot alkaloids | *Claviceps purpurea*, *C. fusiformis*, *C. africana*, *C. sorghi*, etc. | Rye, sorghum, barley, pearl millet, oats and wheat | Numbness (loss of sensation) and gangrene (death of tissue) |
| 10 | Citreoviridin | *Penicillium viridicatum* | Rice | Cardiac beri-beri |
| 11 | Citrinin | *P. viridicatum*, *P. citrinum* | Rice, wheat, oats, rye, corn, barley, etc. | Nephrotoxin, Nephrotoxin |
| 12 | Cyclochlorotine | *Pyrobaculum islandicum* | Rice | Hepatotoxin |
| 13 | Cytochalasin E | *Aspergillus clavatus* | Rice, barley | Cytotoxicity |
| 14 | Maltoryzine | *Aspergillus oryzae* | Rice | Cytotoxicity, |
| 15 | Patulin | *Penicillium expansum*, *P. patulum* | Apple juice and apple related products | Brain and lung hemorrhage |
| 16 | PR toxin | *Penicillium requeforti* | Tobacco leaves | Carcinogenicity |
| 17 | Rubratoxin | *Penicillium rubrum* | Corn, soybean | Liver haemorrhage and fatty infiltration |
| 18 | Rugulosin | *Penicillium islandicum*, *P. rugulosum*, *P. tardum* | Rice | Nephrosis and liver damage |
| 19 | Sterigmatocystin | *Aspergillus flavus,* *A. versicolor* | Cheese, wheat, maize, animal feed, green coffee beans, etc. | Hepatocarcinogen |
| 20 | Tremorgens | *Penicillium* and *Aspergillus* | Corn, silage, etc. | Paralysis, respiratory arrest |

Table 16.16, derived from the above Table 16.15, consists of major foods which may be contaminated with the respective mycotoxins. As mentioned earlier, aflatoxins, fumonisins, trichothecenes, zearalenone, ochratoxin and ergot alkaloids are the most toxic and commonly found mycotoxins in food and feed commodities in Nepal and worldwide.

**Table 16.16.** Food and feed commodities and mycotoxins associated with them.

| Food and feed commodities | Mycotoxins found in them |
|---|---|
| Groundnut (Peanut) | Aflatoxins |
| Maize (Corn) | Aflatoxins, fumonisins, trichothecenes, DON, zearalenone, ochratoxin, citrinin, rubratoxin and sterigmatocystin |
| Wheat | Trichothecenes, DON, zearalenone, ochratoxin, citrinin and sterigmatocystin |
| Rice | Fumonisins, ochratoxin, citreoviridin, citrinin, cyclochlorotine, cytochalasmin, maltoryzine and rugulosin |
| Barley | DON, ochratoxin, ergot alkaloids, citrinin and cytochalasmin. |
| Oat and rye | Ergot alkaloids and citrinin |
| Sorghum and pearl millet | Ergot alkaloids |
| Cereals and their products | Nivalenol |
| Cereal flour | Zearalenone |
| Pulses | Ochratoxin |
| Soybean | Rubratoxin |
| Green coffee beans | Ochratoxin and sterigmatocystin |
| Spices, cotton seed, dried fruits and tree nuts | Aflatoxins |
| Apple juice and apple products | Patulin |
| Milk and dairy products | Aflatoxins M1 and M2 |
| Cheese and animal feed | Sterigmatocystin |
| Silage | Tremorgens |
| Tobacco leaf | PR-proteins |

In the final products, such as animal feed, corn flour, etc., not only the given or respective mycotoxins but also the toxins found or prevailing in the raw materials e.g. wheat grains, corn grains, etc. are also carried over or produced.

## Aflatoxin Situation in Nepal

Mycotoxin study in Nepal seems not to be regular. Hence the foods and feeds available in the market have no mycotoxin information at all. Findings of some of the studies carried out several years earlier are cited below.

A total of 100 livestock and poultry feeds and feed ingredients, 1 kg each from 100 kg lot, were collected from Feed Millers from Kathmandu (79 samples), Chitwan (13 samples) and Biratnagar (8 samples) during summer of 1998 (Khadka et al., 2000). Aflatoxins B1 and B2 were analysed by TLC for qualitative assay and spectrophotometrically for quantitative estimation.

Aflatoxins B1 and B2 showed strong, blue fluorescence, whereas Aflatoxins G1 and G2 revealed green fluorescence under ultra-violet light. Out of 100 samples, 75 samples (75%) were contaminated with Aflatoxin B1 and/or B2 (Khadka et al., 2000). Aflatoxin B1 was found in all positive samples (i.e. 75) either alone or incombination with B2, while B2 appeared only in 11 samples (Table 16.17). There was non-significant difference in contamination of aflatoxin among various feeds and feed ingredients.

**Table 16.17.** Aflatoxin contamination in livestock and poultry feeds and feed ingredients of Nepal.

| Sample type | Sample number | Samples contaminated with Aflatoxin B1 and/or B2 | Sample number with | | Concentration of aflatoxin |
|---|---|---|---|---|---|
| | | | B1 | B1 & B2 | |
| Livestock feed | 25 | 20 (80%) | 17 | | Trace to 300 ppb |
| Poultry feed | 50 | 37 (74%) | 32 | 5 | Trace to 500 ppb |
| Feed ingredients | 25 | 18 (72%) | 15 | 3 | Trace to 300 ppb |
| Total | 100 | 75 (75%) | 64 (85%) | 11 (15%) | Trace to 500 ppb |

Aryal and Karki (2009) carried out Aflatoxins B1 and B2 analysis in 65 poultry feed samples collected from Chitwan and Kabhrepalanchok districts. They found that 49 samples (75.38%) were contaminated with aflatoxin ranging from trace to 366 ppb. Out of 49, 42 samples had both Aflatoxins B1 and B2, five had only B1 and two had B2 alone. Thirteen samples out of 65 (20.0%) crossed the European Economic Community (EEC) tolerable limit of 50 ppb with a contribution of 18.46% (12 samples) by Aflatoxin B1 alone.

Seasonal comparison of aflatoxin prevalence was also carried out in poultry feeds (Aryal & Karki, 2009). Number of positive samples was slightly higher during summer (76.9%) than winter (69.2%) (Table 16.18). Among the two aflatoxins, B1 was more prevalent in both the seasons crossing 50 ppb by 19.2% and 15.4% samples during summer and winter seasons, respectively.

**Table 16.18.** Seasonal occurrence of Aflatoxins B1 and B2 in poultry feeds from Chitwan and Kabhre districts.

| Season | Total samples | Positive samples | Aflatoxin type | Samples above 50 ppb[¶] |
|---|---|---|---|---|
| Summer (Jul-Oct) | 52 | 40 (76.9%) | B1 | 10 (19.2%) |
| | | | B2 | 1 (1.9%) |
| Winter (Nov-Feb) | 23 | 9 (69.2%) | B1 | 2 (15.4%) |
| | | | B2 | 0 (0%) |

[¶]Permissible limit suggested by EEC.

Occurrence of Aflatoxin B1 in various products of peanut, corn, rice and wheat was studied by Karmacharya (1988) during 1980 to 1987. Highest percentage of contaminated samples were found in peanut butter (36.53%), peanut shelled kernels (31.32%) and corn flour (28.57%), while high level of contamination appeared in raw peanut in shell (634.6 ppb), corn (321 ppb) and peanut butter (282 ppb) (Table 16.19). Highest percentage of samples exceeding the tolerable limit of 30 ppb occurred in corn flour (14.28%). The study revealed that parboiled rice (trace) was very safe for food and also the roasted peanuts (trace to 10 ppb) have very low level of Aflatoxin B1.

**Table 16.19.** Occurrence of Aflatoxin B1 in food commodities of Nepal.

| Commodities | Total samples | Contaminated sample no (%) | Level of contamination | % of samples (containing <30 ppb)¶ |
|---|---|---|---|---|
| Raw peanut in shell | 83 | 13 (15.66) | Trace to 634.6 ppb | 7.03 |
| Corn | 134 | 26 (19.40) | Trace to 321.0 ppb | 5.97 |
| Peanut butter | 52 | 19 (36.53) | Trace to 282.0 ppb | 1.90 |
| Corn flour | 63 | 18 (28.57) | Trace to 242.7 ppb | 14.28 |
| Peanut shelled | 83 | 26 (31.32) | Trace to 141.0 ppb | 9.63 |
| Peanut roasted in shell | 29 | 7 (24.10) | Trace to 10.0 ppb | 0 |
| Parboiled rice | 98 | 7 (7.14) | Trace | 0 |
| Wheat flour | 40 | 3 (7.50) | 21.1 to 91.0 ppb | 5.00 |

Trace = less than 5 ppb. ¶Persimmible limit for Aflatoxin B1 as FAO.

Karki et al. (1988) carried out a study to find out the geographical variations of aflatoxins and fungi associated in corn grown at different altitudes of Nepal. Terai/inner terai region appeared most prone to Aflatoxins B1 and B2 contamination with the highest value of 6334 ppb and 976 ppb, respectively, produced by the strain A06 of *A. flavus* (Table 16.20). Production of Aflatoxins B1 and B2 reduced gradually in Kathmandu valley and hills/mountains. Aflatoxins G1 and G2 were produced only by the strains A12 and A13 isolated from Kathmandu valley. Among four types of aflatoxins, Aflatoxin B1 appeared predominant, followed by Aflatoxin B2. Higher susceptibility of corn to aflatoxins collected from terai/inner terai would be due to high temperature and high humidity than other two regions throughout the year.

**Table 16.20.** Variation in production of aflatoxins by *A. flavus* strains isolated from corn grown at different altitudes in Nepal.

| Location | Strains | Production of aflatoxin (ppb) by *A. flavus* | | | |
|---|---|---|---|---|---|
| | | B1 | B2 | G1 | G2 |
| Terai/inner terai (Elevation: 72–474 m) | A01 | - | - | - | - |
| | A02 | 6,134 | 936 | - | - |
| | A03 | 6,042 | 560 | - | - |
| | A04 | 6,235 | 906 | - | - |
| | A06 | 6,334 | 976 | - | - |
| | A07 | 120 | 20 | - | - |
| | A08 | 305 | 63 | - | - |
| | A09 | 3,255 | 303 | - | - |
| Kathmandu valley (Elevation: 1330–1350 m ) | A10 | 48 | - | - | - |
| | A12 | 48 | 5 | 20 | 5 |
| | A13 | 48 | 5 | 24 | 5 |
| | A14 | 72 | 10 | - | - |
| | A15 | 32 | 0 | - | - |
| Hills/mountains (Elevation: 1517–2300 m) | A16 | 29 | 0 | - | - |
| | A17 | 59 | 10 | - | - |
| | A18 | 24 | 0 | - | - |

Most frequently observed fungal flora were *Fusarium* spp. (40.62%) and *A. flavus* (10.0%) from the mountain, hill and Kathmandu valley, and *A. flavus* (10.62%) and *Fusarium* spp. (8.75%) from the terai/inner terai (Table 16.21).

**Table 16.21.** Predominant mould flora in corn as altitude.

| Mountain/hill/Kathmandu valley | Terai |
|---|---|
| *Fusarium* spp. (40.62%) | *Fusarium* spp. (8.75%) |
| *A. flavus* (10.0%) | *A. flavus* (10.62%) |
| *A. fumigatus* (3.12%) | *A. fumigatus* (3.12%) |
| *A. niger* (3.12%) | *A. niger* (2.5%) |
| *Penicillium* spp. (8.12%) | *Penicillium* spp. (3.75%) |
| *Rhizopus* spp. (2.5%) | *Rhizopus* spp. (1.87%) |

As *Fusarium* spp. were found dominant in hills/mountains and Kathmandu valley, and *A. flavus* in terai, *Fusarium* toxins may prevail in hills and valley and aflatoxins in terai.

Department of Food Technology and Quality Control (DFTQC) had carried out aflatoxin analysis in 21 maize and 14 feed samples, one kg each, collected from Shankhuwashava, Ilam, Tanahun (hilly), Makawanpur, Chitwan and Morang (terai) districts during 2016 (2072 BS). Out of 21 maize samples, 4 (19.0%) samples had total aflatoxins above 20 ppb (with 739 ppb utmost) and 17 (81.0%) samples less than 20 ppb (Table 16.22) (Shrestha et al., 2019). Out of total aflatoxins, Aflatoxin B1 had contributed 92% alone. Out of 14 feed samples, 4 (28.6%) samples had total aflatoxin more than 50 ppb (with 123 ppb utmost) and remaining 10 samples had less than 20 ppb. In the feed also, Aflatoxin B1 had the highest (71%) contribution. The study revealed that the most toxic Aflatoxin B1 was predominant in both types of the samples.

**Table 16.22.** Level of aflatoxin in corn and feed samples from 6 districts.

| Sample | Total No. | Sample with aflatoxin | Aflatoxin | Contribution of B1 |
|---|---|---|---|---|
| Maize | 21 | 4 (19.0%) | >20 ppb | 92% |
| | | 17 (81.0%) | <20 ppb | |
| Feed | 14 | 4 (28.6%) | >50 ppb | 71% |
| | | 10 (71.4%) | <20 ppb | |

All maize samples collected from Shankhuwashava, Ilam and Tanahun districts, where temperature and humidity are relatively low, did not contain any aflatoxin even in maize with high mould growth. Maize samples collected from Makawanpur, Chitwan and Morang districts, where temperature and humidity are relatively higher, were found to contain aflatoxins even in maize with no visible mould growth. The result indicated that

maize samples with high mould growth may not contain aflatoxin and vice-versa with respect to weather.

To find out the carcinogenicity of aflatoxin, van Rensburg (1976) collected data from different parts of some countries (Table 16.23). He/she obtained higher the aflatoxin intake higher the cases of liver cancer. As aflatoxin 3.5 mg/kg body weight per day was ingested, 0.7 persons had liver cancer out of 100,000 persons per year. As amount of aflatoxin was raised to 10 mg/kg body weight per day, liver cancer cases were also increased to 4.2 persons per year in the same population.

**Table 16.23.** Relationship of aflatoxin intake with liver cancer in Africa and Asia.

| Region and altitude | Aflatoxin intake (mg/kg body weight/day) | Incidence of liver cancer (Number per 100,000 people per annum) |
|---|---|---|
| Kenya: highlands | 3.5 | 0.7 |
| Thailand: Songkhal | 5.0 | 2.0 |
| Swaziland: highlands | 5.1 | 2.2 |
| Kenya: medium altitude | 5.8 | 2.9 |
| Swaziland: medium altitude | 8.9 | 4.0 |
| Kenya: lowlands | 10.0 | 4.2 |
| Thailand: Ratburi | 45.0 | 6.0 |
| Swaziland: lowlands | 43.1 | 9.7 |
| Mozambique: Inhambane | 222.4 | 13 |

## Mycotoxin Assessment by Post-harvest Loss Innovation Lab Project at NAST

Mycotoxins are not an unknown problem in Nepal. Only the regular studies are lacking. The USAID Feed the Future Nutrition Innovation Lab (NIL) has worked with pregnant women for a number of years and identified high levels of exposure to aflatoxins in several areas based on blood tests. To expand the NIL findings, the US embassy at Nepal brought the USAID-Sponsored Feed the Future Post-Harvest Loss Innovation Lab (PHLIL) based at Kansas State University (KSU), USA to assess the most likely sources of mycotoxin contamination in Nepalese food chains. PHLIL included a partnership between KSU and the University of Nebraska-Lincoln (UNL), USA. In Nepal, this partnership was expanded to include the Nepal Academy of Science and Technology (NAST), Nepal Development Research Institute (NDRI), Helen Keller International (HKI), and Tribhuvan University (TU) as major partners and numerous other entities as implementing partners. Similarly, the partnership also elaborated with the Italian National Research Council (CNR) and Institute for the Science of Food Production (ISPA), Italy.

The overall plan was to conduct two surveys. One was a large in-depth survey throughout USAID designated Zone of Interest/Influence (ZOI) in western Nepal. Peanuts and maize are the usual suspects as sources of mycotoxin contamination in diets. Yet the NIL results indicated that ~95% of the women evaluated had been exposed to aflatoxins, and certainly all of the population is not eating miaze and peanuts all the time. Thus, there

must be other significant sources of aflatoxins in the diet, but what were they? To help address this question, a preliminary pilot "snapshot" survey was conducted to identify food commodities other than maize and peanuts that should be included in the large scale second survey.

## Pilot Snapshot Market Survey

A multi-mycotoxin, multi-commodity pilot snapshot market survey was conducted to identify food commodities in addition to maize and peanuts for inclusion in the large-scale market and household surveys. Samples for the pilot survey were collected/purchased from a subset of readily accessible markets in the Zone of Influence (ZOI) districts, to facilitate the assembly and analysis of the collected materials as quickly as possible.

Commodities collected were selected based on knowledge of the PHLIL technical team, including visual observations on site visits, and on knowledge of frequently consumed foods in Nepalese diets. Collected samples were transported to Italy and analyzed at ISPA for toxin(s) presence, and in selected samples for *Aspergillus* spp. Maize and groundnuts were excluded from the pilot snapshot survey as they were already to be included in the large survey since aflatoxin contamination is a common problem in these crops globally.

Various food commodities (Table 16.24) were screened for deoxynivalenol, T-2/HT-2 toxins, zearalenone, Aflatoxin B1, fumonisins, Ochratoxin A, 3- and 15-acetyl-deoxynivalenol, Enniatins (A, A1, B, B1) and Beauvericin at the CNR-ISPA, Bari, Italy. Among these analyzed foods, soybean cake (59%) and chilies (green 36% and dry 23%) had the highest proportion of samples that were positive for Aflatoxin B1(Table 16.24). Thus, the initial pilot snapshot survey succeeded in identifying chilies and soybean cake as important additional commodities to include with maize and groundnuts in the major survey conducted by the project. Among rice and the spices tested, all had little or no aflatoxin contamination.

**Table 16.24.** Contamination of foodstuffs by Aflatoxin B1 in pilot snapshot study.

| Commodity | Number of samples | % Aflatoxin positive samples |
|---|---|---|
| Soybean cake | 27 | 59 |
| Chili – green | 25 | 36 |
| Chili – dry | 26 | 23 |
| Cardamom – small | 25 | 4 |
| Cumin | 26 | 4 |
| Rice | 27 | 0 |
| Coriander | 28 | 0 |
| Cardamom – large | 27 | 0 |

In those aflatoxin positive samples, fungi from *Aspergillus* section *flavi*, most commonly *A. flavus*, were found as well. Aflatoxin B1 contamination levels in positive samples generally ranged from 0.3 to 6.1 µg/kg (the EU maximum permitted level in

spices is 5 µg/kg). Three samples were contaminated at higher levels: one from cumin (99 µg/kg), one from dried chilies (26 µg/kg) and one from small cardamom (17.2 µg/kg). Other than aflatoxins, Ochratoxin A was detected in two dry chili samples and one small cardamom sample. Fumonisins were unexpectedly detected in 64% of the small cardamom samples. The high frequency of fumonisin contamination in the small cardamom samples are worthy of follow-up study that was not in the scope of the larger survey conducted for this project. The remaining toxins that were screened for were not detected at any significant level. A mycological analysis also was conducted to determine if potential mycotoxin-producing fungi were present. In general, chilies had a large number of fungal species colonizing them and a high number of colony-forming units (cfus) than other spices. Fungi from *Aspergillus* section *Flavi* (commonly associated with aflatoxins) and *Aspergillus* section *Nigri* (commonly associated with Ochratoxin A) were encountered most frequently, but strains of *Alternaria*, *Penicillium* and *Fusarium* also were isolated from chilies. Green chilies were particularly difficult to work with as they begin to degrade due to bacterial infection rather quickly after sampling, so only dried chilies were evaluated in the large-scale survey. The other commodities were colonized by strains belonging to *Aspergillus* section *Flavi*, *Aspergillus* section *Nigri*, *Penicillium* and *Alternaria* (only on coriander and soybean cake), but not *Fusarium*. *Fusarium* was detected on small cardamom.

## Large-scale Mycotoxin Assessment Survey

### *Background*

An intensive, large-scale mycotoxin assessment of various foodstuffs and animal feed was conducted by PHLIL under the leadership of Jagger Harvey with the assistance of John Leslie (KSU) and Andreia Bianchini (UNL), in collaboration with NAST and NDRI, Nepal, from June 2017 to June 2019 (see Table 16.25). Samples were collected by NDRI in cooperation with HKI and NIL, and processed at NAST and the UNL. These samples were collected from 20 districts in a USAID defined ZOI in the terai (Kapilbastu, Dang, Banke, Bardia, Kailali and Kanchanpur) and mid-hills (Palpa, Gulmi, Arghakhanchi, Pyuthan, Rolpa, Rukum, Salyan, Jajarkiot, Surkhet, Dailekh, Achham, Doti, Dadeldhura and Baitadi) of western Nepal. Samples originated from farmers' houses, groceries and open markets with major collections made in March-April and October-November, 2018. The project was very ambitious and the results obtained by the project team are significantly larger than commonly obtained by projects of this type, with more than three thousand samples processed across multiple commodities. Among these samples, all peanut samples were analyzed at NAST while others at UNL for aflatoxin.

### *Human Resource Development*

Five technical research personnel from three Nepalese institutions were trained at UNL on mycotoxin analyses by Andreia Bianchini and her staff from 13-22 November 2017. These individuals were from NAST: Jaishree Sijapati and Rosa Ranjit; from the Institute of Agriculture and Animal Science (IAAS), TU: Gopal Bahadur K.C. and Ram Kumar Shrestha; and from Department of Agriculture (DoA), Ministry of Agriculture and

Livestock Development (MoALD): Prakash Ghimire. Prior to training at UNL, none of the trainees had more than basic knowledge of mycotoxins and no experience in the analysis of mycotoxins. The personalized training covered theoretical and practical aspects of mycotoxins, their hazards to humans and domesticated animals, the identification of major mycotoxin-producing fungi and the crops and crop products with which they commonly are associated, mitigation strategies and detection techniques for aflatoxins and fumonisins in corn flour, raisins, chilies and other foodstuffs by enzyme-linked immunosorbent assay (ELISA), fluorometer, high performance liquid chromatography (HPLC) and polymerase chain reaction (PCR). Techniques for culture, isolation and identification of mycotoxin-producing fungi associated with various foods also were taught. The NAST scientists Jaishree Sijapati and Rosa Ranjit and Ravindra Shrestha from NDRI also received training from 3-7 June, 2018 at a commercial Mars, Inc. testing laboratory in Hyderabad, India, on processing peanuts and maize for aflatoxin analyses in peanuts and maize in ELISA micro-wells. Ram Kumar Shrestha was seconded to the UNL mycotoxin lab from July 2018 to February 2019 to analyse samples collected during the large survey for aflatoxin. All of the trained staff now have in-depth knowledge of mycotoxin hazards and mitigation strategies. They also are proficient in the analytical skills required for aflatoxin and fumonisin analyses by ELISA and fluorometer. These staff can run an independent lab, if other labs are established outside NAST, and have already begun training others to conduct credible analyses and manage independent labs as well.

### *Mycotoxin Lab Establishment*

The mycotoxin lab established by the PHLIL project resulted from an investment of more than 10 million Nepalese rupees at NAST, Khumaltar, Lalitpur, and included a technical partnership with the Mars Global Food Safety Center (Beijing, China) as well. The NAST lab can efficiently analyse aflatoxins in peanuts and maize. Jaya Kumar Gurung and his team at NDRI led planning and oversight of the lab's timely establishment and initiated project operations, after which lab management was transferred completely to NAST. Great cooperation also was provided by the Vice-Chancellor of NAST, Dr. Sunil Babu Shrestha, Secretary Dr. Mahesh Kumar Adhikari, Faculty Chiefs and staff of the Faculty of Science, members of project management committee, and heads and staff of account and administration sections at NAST. Without their unwavering support for the lab establishment and the completion of the project, the results of the project would not have been as successful as they were.

The new lab at NAST can analyse aflatoxins in peanuts and maize, and fumonisins in maize. The lab includes the following major equipment: grain drier, hand held moisture meters, computer hardware and software to generated bar-coded labels used for tracking and identifying samples, kitchen grinders, food processors and blenders, laboratory scale, Romer mill, humidity-temperature meters, chemical fume hood, coffee pulper (for peanut), –20 °C freezers, refrigerator, Romer ELISA analysis equipment, fluorometer, digital balances (1 mg to 2 kg range), reverse osmosis water purifier, orbital shaker, air conditioners, chemical safety cabinets, Dell computers and printers, micropipettes (20 µL, 200 µL and 1000 µL), multi-channel pipettes, pH meters, timers, vacuum cleaners,

vortex, lab trolleys and glassware. The NAST lab will serve as a central lab for the country with satellite labs being established at other locations throughout the country.

## Mycotoxin Assessment

There are 3 major steps in mycotoxin assessment: sample collection, sample processing and mycotoxin analysis. Errors in the results depend largely on sample collection (88%), with sub-sampling (10%) and analysis (2%) making much smaller contributions to the overall error. In the PHLIL project, aflatoxin assessments were carried out as below.

### *Sample Collection*

A total of 3,214 samples (groundnut, maize, soybean nuggets, chili, animal feed, rice and complementary food) were collected in two phases from arbitrarily selected farmers' houses, groceries and open markets in 20 districts of western Nepal. Three members of the technical staff (Gopal Bahadur K.C., Ram Kumar Shrestha and Prakash Ghimire) worked with staff from NDRI and HKI for the sample collections from the field. Small samples and those with incomplete background information were discarded. Target sample sizes collected were 200 g for dried chilies, 1000 g for unshelled peanuts and 500 g for other each item. In some cases smaller amounts of dried chilies and unshelled peanuts were also collected, since these items were less widely available than some of the other commodities sampled. Small subsets of each sample were taken from different strata of each selected sack or pile, mixed well, and weighed to obtain the target amount for each sample. Samples were placed in single zip lock plastic bags and delivered to NAST, Khumaltar as soon as possible. Upon arrival at NAST, sample bags were stored at –20 °C until processed.

### *Sample Processing*

Rice, maize, soy nuggets and peanut samples were processed at NAST. Some dried chili samples were milled at NAST, but most of them were sent as intact chilies to UNL for processing and analysis. Complementary food and animal feed samples also were sent to UNL for analysis. Before processing the samples at NAST, the frozen samples were thawed to ambient temperature (20–24 °C). Processing and toxin analysis were done using personal protective equipment. All trained personnel participated in processing the rice, maize, groundnut, soy nugget and dry chili samples (partly), the aflatoxin analysis of peanuts and fumonisin analyses in maize.

In brief, the processing steps were:

1. Samples of rice and maize were mixed well and three moisture measurements were taken. Samples with a mean moisture level ≤14.5% were used for further processing without any additional drying.
2. Samples with >14.5% moisture were dried for 2–6 hr at 70–80 °C until the moisture level was equal to or less than 14.5%.
3. Once dry, samples were separated into a 300 g lot and a 50–100 g lot (based on available quantity of samples). The 50–100 g lot from each sample was milled in a

Romer mill to clean the mill to avoid the contamination of any residue from the previous sample. The milled material was discarded.

4. The ~500 g lot was milled and divided into three sub-samples. Among them one sub-sample (100 g) was refrigerated and shipped to UNL for analysis as soon as possible after milling. The other two sub-samples (one 200 g and the other remaining) were retained at NAST and stored at –20 °C as quickly as possible.
5. For soy nuggets, the intact sample balls (which were too big for Romer mill) were broken into smaller pieces by using either a food processor or kitchen grinder before being milled in the Romer mill and divided into three sub-samples similar to those obtained for the grains.
6. Peanut samples were shelled with a coffee pulper and the peanut kernels were cleaned from shell debris by winnowing. Three-hundred grams of peanut kernels from a sample were blended in food processor for ~15 sec and then mixed with 450 mL of distilled water, i.e. in a 1:1.5 sample:water ratio. The water/peanut mixture was blended/homogenized for 5 min at high speed to obtain slurry. Chunks were scraped from the walls once or twice during the grinding as needed. Blended samples were collected in double zip lock plastic bags and stored at –20 °C until analysed for aflatoxins.

### *Aflatoxin Analysis of Peanuts*

*By an Agravision Strip Reader:* Three hundred and ninety-one peanut slurries were analysed by ELISA Reader (Agra Vision) using Watex kits from Romer Labs. Peanut slurries were thawed to room temperature (20–24 °C) before analysis. All analytical steps were conducted at room temperature following the instructions provided by the manufacturer of the kit. For accurate results, strips must be read within 5 min of the completion of the test. Results will appear on the Agra vision reader screen and can be printed with the Agra vision printer. Five ppb is the limit of quantification (i.e. 5–500 ppb). For the final ppb calculation, if the value obtained from the reader is >5 but <500 ppb, then the value is multiplied by 2.5, to adjust the sample dilution during the preparation of slurry, to obtain the final result. If the reader value is >500 ppb, then the samples were tested by fluorometer.

*By Fluorometry:* Samples exceeding 500 ppb aflatoxin by Agra Vision strip reader were analysed with a Vicam AflaTest® fluorometry test kit following the manufacturer's instructions. The fluorometer was calibrated at least weekly with the calibration standards supplied with the kit. The range of quantitation for the fluorometer is 1–50 ppb, and samples with values outside this range must be diluted and then rerun. Once an acceptable reading (1–50 ppb) is obtained, then the reader values is multiplied by 2.5, to account for dilutions that are part of the analytical process, and by whatever additional dilutions which were required to obtain a result in the 1–50 ppb range. Note that the accuracy of these results will be no more than two or three significant digits.

All samples were processed at the mycotoxin lab, NAST up to the final chemical analyses. Final chemical analyses of the maize, dried chilies, rice, animal feed, complementary food and soybean nuggets were conducted at UNL (Table 16.25). Final chemical analyses of aflatoxins in groundnuts were carried out at NAST using ELISA

Reader and fluorometry, as necessary, by using Romer and Vicam test kits, respectively (Table 16.25).

**Table 16.25.** Aflatoxin in foodstuffs and feed samples collected from 20 districts of western Nepal.

| Commodity | Total number of samples | % of Samples (≤LOD)[1] | % of Samples (>LOD and <Regulatory Limit)[2] | % of Samples (>Regulatory Limit) | Aflatoxin range (Samples >Regulatory Limit) | Aflatoxin mean (Samples >Regulatory Limit) |
|---|---|---|---|---|---|---|
| Peanut[3] | 391 | 59 | 10 | 27 | 21–5,400 ppb | 440 ppb |
| Maize | 986 | 73 | 10 | 17 | 22–7,200 ppb | 370 ppb |
| Soybean nugget | 238 | 79 | 15 | 6 | 21–44 ppb | 28 ppb |
| Chili | 1028 | 81 | 15 | 4 | 21–130 ppb | 38 ppb |
| Animal feed | 262 | 70 | 27 | 3 | 58–650 ppb | 240 ppb |
| Rice | 165 | 93 | 5 | 2 | 22–25 ppb | 24 ppb |
| Complementary food | 123 | 87 | 12 | 1 | 39–39 ppb | 39 ppb |

[1]LOD (limit of detection): 0.06 ppb to 3.3 ppb.

[2]Regulatory limit: 20 ppb for aflatoxin in human food and 50 ppb for aflatoxin in animal feed.

[3]Includes 13 samples with values >500 ppb. Peanut data were generated at NAST. All other data were generated/calculated at UNL

## Diagnosis of Mycotoxins

Detection of mycotoxins in human body can be done by testing various samples. In most cases, it is done through urine samples. Testing can also be done on nasal secretions, sputum or tissue biopsy. Mycotoxin content in breast milk and blood samples is also tested in rather complex ways. Results are expressed in ppb or ppm.

Estimation of mycotoxins in various foods and feedstuffs can be done in different ways. Various testing kits are available from different manufacturers, such as Vicam, Romer, Alibaba, etc. Mycotoxin tests can be done by ELISA, TLC, HPLC, high performance thin layer cromatography (HPTLC), fluorometer, UV or fluorescence detection (FD), enzyme immunoassays (EIAs), gas chromatograph-mass spectrometry (GC-MS), liquid chromatography-mass spectrometry (LC-MS), etc.

## Remedies to Manage Mycotoxins

Mycotoxin control is a big task in our context. When every preventive measure is carried out normally from the beginning, it may not be a big issue too. Mycotoxins are stable to washing, high heat and freezing. These have also been shown to be resistant to breakdown in the animal's digestive system. That means they can be passed to meat and dairy products too (Neogen corporation, 2009a).

Main causes of toxin formation are growth of fungi: (1) in field (standing crops) i.e. pre-harvest, (2) during post-harvest handling, (3) in storage, and (4) in processed/ industrial products in warehouses and groceries.

Factors involved in enhancing formation of mycotoxins are: (1) plant susceptibility to fungi, (2) suitability of fungal substrate, e.g. corn, peanut are more susceptible to aflatoxins, (3) high environmental temperature, (4) high moisture in products, (5) high humidity, and (6) physical damage of crops and grains by insects, pests, environment (e.g. hailstone) and mishandling, and environmental stresses.

According to the site of infestation, toxigenic fungi can be divided into three groups:

1. *Field fungi:* They are strong or weak plant pathogenic fungi which attack crops in the field, such as *Fusarium moniliforme*, *F. roseus*, *F. graminearum*, *F. tricinctum*, *F. nivale*, *Alternaria* spp., etc.
2. *Storage fungi:* These are saprophytic fungi which attack grains in the storage, e.g. *A. flavus, A. parasiticus* and *Penicillium* spp.
3. *Advanced deterioration fungi:* These are also saprophytic fungi which attack further deteriorated or damaged grains at high moisture content, e.g. *Aspergillus clavatus*, *A. fumigatus*, *Rhizopus*, *Mucor*, *Chaetomium*, *Scopulariopsis* and *Absidia*.

Based on sites of infection, congenial environments for growth of fungi and infection stages, mycotoxin management measures can be adopted as below:

### *Pre-infection Management*

For avoiding fungal infection and formation of mycotoxins, following measures should be followed.

1. Use of fungal resistant varieties for cultivation of certain crops. Use proper pesticides to avoid fungal and other infections and other damages in field.
2. Make suitable pre-harvest, harvest and post-harvest schedules. Harvest crops at proper maturity in sunny days, and also carry out post-harvest practices safely avoiding rain.
3. *Drying:* strictly lower the moisture content of grains at post-harvest period before storage by sun or mechanical drying, e.g. bring peanut cornel at 9% moisture level, corn and other cereals below13.5% moisture level, etc.
4. Avoid damage of grains/crops during harvest and post-harvest handlings and from various stresses to crops. Stressed plants from insects, diseases, heat, drought, high yield, weather conditions, etc. have more fungal infections and high toxin build up.
5. *Proper storage:* store well dried commodities at low temperature and well ventilated (dry) conditions. Poor ventilation may lead to temperature, moisture and humidity rise in the rooms. Store grains as short as possible. Longer the storage duration higher the chances of fungal contamination and vice versa.
6. Karki and Sinha (1992) found no aflatoxin in corn stored as a *Thangro* (outdoor open storage system around a pole or between 2 poles). They found 1.5 ppb Aflatoxin B1 in Bhakari (bamboo bins), 40 ppb in Ghyampo (clay jar) and 125 ppb in metal bin. It showed that proper drying and storage of grains in Bhakari might be a good way to maintain aflatoxins below the tolerable limit. It would be due to proper aeration into the Bhakari which did not allow temperature and moisture rise in the Bhakari/room.

7. Store grains in hermetic bags (air and water proof plastic bags). It is not only safe from fungus but also from insects and bad weather conditions.
8. Develop diversified food habit which reduces risk of toxin. Quantity ingested is important than level of contamination. So eat less from suspicious food and more from others so that toxin is diluted or ingestion is less. The risks posed by mycotoxins decrease as variety in diets increases. Higher quality diets with more vegetables, fruits, meat and dairy products pose a lower risk since these products are less likely to be contaminated with mycotoxins and since smaller quantities of commonly contaminated cereals are likely to be part of the diet.

### *Post-infection Management*

After infection of crops or grains with fungus, following measures should be followed to control fungus and reduce mycotoxin level.

1. Control infection and attack of crops and grains by fungal and other diseases, insect-pests, rats, birds and other pests by using proper pesticides and good management practices at pre- and post-harvest stages and in storage.
2. Stop growth of infested fungi in storage by proper re-drying of the grains.
3. Sort out the contaminated/deformed grains, e.g. ergots from rye and other cereal grains.
4. Remove rotten fruits or trim infected/rotten parts from fruits and vegetables wherever applicable. If a small portion of a fruit or vegetable is contaminated or rotten, remove it properly with some healthy parts before use for consumption.
5. Pressure cooking destroys 70% aflatoxin in rice while normal cooking only 50%.
6. Dry and oil roasting can reduce about 50–70% of Aflatoxin B1 (Suttajit, 1989).
7. Roasting peanut upto 100 °C, reduced only 10% Aflatoxin B1. Aflatoxin resists upto 260 °C (Suttajit, 1989).
8. If the commodities surpass the tolerable limits for human, it may be fed to the animals. Various animal species might have variation in sensitivity to certain mycotoxin. That means safe level for one group of animals may not be safe for all other groups. So the feedstuffs or feed ingredients containing a specific mycotoxin can be diverted from more sensitive to less sensitive animal species. For example, corn products known to contain harmful levels of fumonisin can be diverted from horses and rabbits (found to be more sensitive to fumonisins) to other animal species.
9. Fermenting reduces aflatoxins in vitro. If the products can be used after fermentation, they should be used for fermentation than direct consumption.
10. Gamma-irradiation of products stops growth of microbes and insect-pests. One and 5 M-rad gamma irradiation also reduced 30% of total 600 ppb Aflatoxin B1 in contaminated peanut.
11. Chemical treatments for detoxification or destruction of aflatoxins/mycotoxins from contaminated commodities by alkalinization, ammoniation and absorption in big plants, e.g. peanut oil, vegetable oil refining, etc. These are high-tech and costly measures.

## Conclusion

Mycotoxins, especially aflatoxins, are very toxic to humans, animals and birds, which may cause various, serious health problems including cancer and even death. Major toxigenic fungi are various species of *Aspergillus* and *Fusarium* (most common and important genera), which are commonly associated with corn, peanut, wheat, barley and other grains, beans, chilli, soy-nuggets and many industrial food- and feed products and synthesize various toxins under conducive environment. The fungi attack only when the grains or products have high moisture content, grains are damaged by pests or broken, improper storage (high temperature and high humidity), long storage duration, etc. Avoiding those conditions may escape from fungal attack and mycotoxin formation. Proper drying of the grains and other commodities with mechanical driers or under sun before fungal infection and during storage as needed is the best way of reducing mycotoxins contamination in food- and feedstuffs. Right time harvesting, careful post-harvest handlings and saving grains from damage will provide additional advantages to save from fungal infections.

Amongst the foodstuffs and feed samples tested at NAST and UNL, groundnuts (27%) had the highest proportion of samples contaminated with aflatoxin, followed by maize (17%) amongst the samples exceeding 20 ppb. Individual maximum levels for a sample were 5400 ppb for groundnuts and 7200 ppb for maize with mean values of 440 ppb and 370 ppb, respectively. Hence, these two commodities pose a high risk for the ingestion of large quantities of aflatoxins from human food or animal feed in Nepal. Soy nuggets (6%), chilies (4%), and animal feed (3%) all had medium levels of contamination and pose a medium risk of aflatoxin hazard, while rice and complementary food were both low risks for aflatoxin contamination as found in UNL.

Chronic exposure to sub-acute levels of aflatoxins and fumonisins are now associated with significant health problems in both domesticated animals and humans. In this context, any sustained consumption of toxin contaminated materials is likely to have detrimental health consequences. Thus, true risks in Nepal are posed by any samples with detectable levels of contamination. In particular, for peanut – 37% of samples, maize – 27%, soybean nuggets – 21%, dried chilies – 19%, animal feed – 30%, rice – 7%, and complementary food – 7%.

*Fusarium proliferatum* and *F. verticillioides* were common producers of fumonisins in samples analysed at UNL. In this study, household flour, animal feed, and maize were all found to be contaminated with these fungi. Thus, these commodities in the Nepalese markets may be contaminated with fumonisins, and further studies of fumonisin contamination of these commodities are needed. For maize, as the altitude of the market increased, the number of samples with detectable aflatoxin decreased. Thus, communities living at higher altitudes may be at lower risk of consuming aflatoxin-contaminated food. The samples of rice, coriander and large cardamom are contaminated with *Aspergillus*, but little or no aflatoxin was detected. The reason(s) for this, lack of toxin contamination needs to be determined so that it can be used as the basis for control of toxin contamination in other plant products. Some potential differences are: (i) differences in the microbiomes present on these crops from crops on which aflatoxins commonly are synthesized, (ii) differences in plant metabolism that may limit or prevent mycotoxin

biosynthesis, and (iii) differences in cultural conditions that reduce the opportunity for mycotoxin biosynthesis.

Poor storage conditions were associated with higher levels and more rapid accumulation of aflatoxin. Under poor storage conditions, aflatoxin contamination can exceed the regulatory limits in a matter of days. Thus, good storage conditions are essential to the availability of food and feed with minimal aflatoxin levels. Nepalese farmers from survey areas (PHLIL Project field survey in 20 districts of western Nepal from 2017 to 2019) are not using improved drying technologies for their produce. Most of them (99.8%), use sun drying, with grain usually spread out on the ground. Most farmers (57.8%) dry maize cobs directly on the ground where many mycotoxin-producing fungi reside, which provides another opportunity for these fungi to colonize in the food/feedstuff. Drying directly on the ground also increases exposure to other food safety hazards, e.g. animal and bird feces, sand, chemical contaminant, etc. Improved drying and storage technologies that reduce/prevent post-harvest losses, including aflatoxin contamination, are effectively non-existent in Nepalese farming communities. Introduction of existing, effective low-cost technologies in drying and storage of grains, Nepalese farmers could improve the quantity, quality and safety of the overall Nepalese food supply.

***Policy suggestions for increasing the future provision of safe food to the Nepalese people:***

1. Mycotoxin issues should be incorporated in Nepal government policy, so that they are recognized as an important issue by the people and are included in the mainstream of regular programming.
2. Legislative bodies should regulate national policy of food safety and declare maximum tolerance limits for major mycotoxins in major grains and food- and feedstuffs.
3. A mycotoxin testing lab should be established in each province. These labs would be managed by local provincial governments, can focus on toxins of local importance, and collectively provide first line coverage for the national domestic food supply. Mycotoxin tests should be conducted regularly on major products and suspected commodities regularly.
4. Education on food safety issues posed by mycotoxins should be incorporated into secondary school and university curricula.
5. Research institutions should carry out researches in mycotoxin detection, identification, hazards and remedial measures regularly.
6. Agricultural technicians, farmers, consumers, millers, agri-industires and agricultural traders should be trained to provide awareness about mycotoxin hazards and mitigation.
7. The government should provide a subsidy for recommended/improved drying and storage structures to enable adoption by farmers and/or farmers' cooperatives.
8. International cooperation for mycotoxin regulation in trading products and commodities of maximum/regular consumption, e.g. mycotoxin assessment in low

cost, tolerance limit determination, mitigation, etc. should be sought and provided as well by the government.

9. Conferences, workshops, trainings, seminars, webinars, etc. should be organized regularly at national and international levels to update current information on mycotoxins to the stakeholders by the universities, research centers and other institutions.
10. Importers and exporters should be made aware of existing mycotoxin regulations and asked to help enforce them to insure the safety of food being imported into Nepal.

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**Abbreviations:** CNR = Consiglio Nazionale delle Richerche; DFTQC = Department of Food Technology and Quality Control; DoA = Department of Agriculture; EEC = European Economic Community; EIAs = enzyme immunoassays; ELISA = enzyme-linked immunosorbent assay; EU = European Union; FAO = Food and Agriculture Organization; FDA = Food and Drug Administration; GC-MS = gas chromatograph-mass spectrometry; LC-MS = liquid chromatography-mass spectrometry; GoN = Government of Nepal; HKI = Helen Keller International; HPLC = high performance liquid chromatography; HPTLC = high performance thin layer chromatography; IAAS = Institute of Agriculture and Animal Science; ISPA = Institute for the Science of Food Production, Italy; KSU = Kansas State University, Kansas, USA; MoALD = Ministry of Agriculture and Livestock Development; NAST = Nepal Academy of Science and Technology; NDRI = Nepal Development Research Institute; PCR = polymerase chain reaction; PHLIL = Post-Harvest Loss Innovation Lab; ppb = part per billion; ppm = part per million; TLC = thin layer chromatography; TU = Tribhuvan University; UNEP = United Nations Environment Programme; UNL = University of Nebraska-Lincoln, Nebraska, USA; USAID = United States Agency for International Development.

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# Author's Biography



Dr. Gopal Bahadur K.C., born in December 27, 1957 (2014.09.12 BS) in Sundarbazar, Lamjung from the parents Dan Bahadur K.C. and Sita Kumari K.C., resides at present in Tokha, Kathmandu, Nepal. He has completed SLC examination in 2029 BS from Shree Bir Bhakti High School, Tarkughat, Lamjung; IScAg in 2037 BS in distinction and BScAg in 2042 BS as a "Gold Medalist" from the Institute of Agriculture and Animal Science (IAAS), TU. MScAg and PhD degrees in Plant Pathology were accomplished from Georg-August University, Goettingen, Germany during 1997 (2054 BS) and 1999 (2056 BS), respectively, under advisorship of Dr. Klaus Rudolph. He served over 33 years as an Asst. Lecturer to Professor in the Department of Plant Pathology at IAAS, TU and is serving now as a Professor (Ad.) at Dean's Office, IAAS, TU, Kirtipur. He got opportunities to serve as a Farm Manager, Hostel Warden, Department Head, Subject Matter Committee Head and so on at various institutes; Campus Chief at IAAS, Lamjung; and Asst. Dean at IAAS, Dean' Office, Kirtipur. Dr. K.C. has expertise in plant disease diagnosis, integrated disease management, mycotoxins and their assessments, and good knowledge in scientific proposal and article writing and evaluation. He has received a lot of trainings and experiences in many aspects of agriculture. He has published *Laboratory Manual of Horticulture*, 7 research articles as a main author, 22 research articles as a co-author, and 8 agriculture related reports and writings. Dr. K.C. has served as a chairman of advisory committee of 30 MScAg students and is chairing now 2 students, while 4 students of PhD are served as a member advisor, and 4 others' member-advisorship is running.

Dr. K.C. was a senator of Pokhara University from 2065 to 2068 BS in the capacity of an Academician. He is a life member of Nepal Development Research Institute (NDRI). Dr. K.C. is an Academician at NAST since 2069 BS as an agriculture expert and is cooperating NAST in policy making, research and other scientific areas. He has visited India, Germany, France, England, Scotland, Netherland, USA, Taiwan, China, Japan, Thailand and South Korea, and is fluent in written and spoken English, and good in Hindi and German languages. Dr. K.C. believes in truth and impartiality for human welfare and national development.

# Chapter 17

## Postharvest Handling and Storage of Vegetables

**Durga Mani Gautam**
*Agriculture and Forestry University, Rampur, Chitwan, Nepal*
Email: durgagautam2013@gmail.com

*Postharvest loss of vegetables during handling is very high in Nepal. Losses can be physical, physiological and pathological. These losses are mainly due to faulty harvesting and inappropriate handling practices. Most of the farmers sell their products to the middlemen from the field directly. Pre-cooling and grading are not practiced, and packaging and transportation are inappropriate. A lot of inedible portions are also transported to the markets thereby increasing transportation cost and ultimately price of the product. Vegetables are fresh produce and highly perishable and cannot be stored and transported to a long distance market. Assembling, pre-cooling and storage are necessary to make bulk for transportation and regulate supply. Cold storage is the widely adapted technology for vegetable storage. This chapter aims to discuss briefly about postharvest handling and storage practices of vegetables in order to sharing of knowledge with the farmers and agricultural business partners.*

**Keywords:** Agriculture; food quality; food safetly; marketing; postharvest handling practices.

## Introduction

Nepal produces different types of vegetables in different agro-ecological zones throughout the year. Despite its hidden potentiality to produce a huge amount of agricultural products that could fulfil national demand, Nepal has been importing large quantities of vegetables from India (Gautam, 2013; SINA, 2016). Most of the winter season vegetables grown in terai, across the border area of northen India and Bangladesh, can be successfully produced during summer in hills and mountains of Nepal. Hills and mountains have comparative advantages to produce off-season vegetables. In the year 2017-18, the share of vegetables to the total AGDP was about 21 percent (Thapa et al., 2019). There is a great potentiality to increase production of vegetables, but poor transportation facilities, inadequate coordination with the market, lack of knowledge – about improved post production technology; appropriate harvesting, handling, and packaging, poor transportation and lack of storage facilities are the constraints for the promotion of commercial production of fruits and vegetables.

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Vegetables even after their harvest are living materials and thus continue physiological activities like respiration and transpiration. The rate of physiological activities depends on the type and nature of the commodity and external factors (Gautam & Bhattarai, 2018). Higher the rate of physiological activities, higher would be the postharvest loss. Postharvest loss can be minimized by proper handling and storage techniques. The handling activities carried out after harvesting of vegetables are called packhouse operations that include washing, trimming, curing, sorting, grading, pre-cooling and packaging (Gautam et al., 2019). Some of the operations can be done by the producers themselves, while some need collective approach. Small farmers in Nepal lack resources and are unable to implement suitable storage technique. Cold storage is widely adopted technology to store vegetables and is beyond the reach of small farmers in Nepal. Postharvest losses are also largely the result of poor organization. For commercial production, a large quantity of vegetables should be produced in a particular area. It is not possible to consolidate land for the production, but it is possible to have combined marketing. Development of packhouse along with cold storage facility in production pockets can promote efficient marketing of vegetables to distance markets (Gautam, 2020). Packhouse with pre-cooling and cold storage facility in production area facilitates assembling and transaction of vegetables in large quantities. Huge amount of postharvest loss occurs in vegetables. Postharvest loss of vegetable is very high in developing countries and it often reaches up to 40% (AVRDC, 2015). A study conducted by the Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Kathmandu, Nepal shows 7-33% postharvest losses of vegetables at different points from farmers' level to the retailers in Nepal (ANSAB, 2015). There are various causes for postharvest loss that can be minimized by appropriate harvesting, handling and storage.

## Causes of Postharvest Loss

***Physical:*** Almost all the fresh vegetables are delicate and perishable in nature. Mechanical damages and injuries occur during harvesting, handling and transportation. Injuries occur due to faulty harvesting method. Harvesting by hands forcefully may cause damage to the vegetables at the detached point. Injuries may occur during handling in the field, in packhouse and transportation. Packaging containers having rough surface and sharp edges cause damage to the vegetables. Sometimes, vegetables are kept in large piles in the fields and stores. Keeping large quantities of vegetables in piles causes compression at lower parts causing much damage. Similar case may occur while packaging as well. Using large container for packaging causes damage to the contents at lower and middle portions due to compression. If vegetables are not packed properly, vibrational damage occurs during transportation which results in bruising and abrasion. Any kinds of physical damages enhance respiration, ethylene emission and transpiration, and create avenue for the entry of pathogens.

***Physiological:*** Even after harvesting, fresh vegetables being living materials continue all the physiological processes. Respiration, transpiration and ethylene production are the vital processes which reduce shelf-life and lead to deterioration. Storage components of vegetables (carbohydrates, proteins and lipids) are utilized in respiration to produce carbon dioxide, water and energy that results in weight loss and senescence of vegetables.

Similarly, transpiration is continuous in harvested organ resulting in loss of water and causing desiccation, weight loss and drying. All most all vegetables produce ethylene. Production of ethylene is higher in damaged and senescing organs. Any kind of damage during harvesting, handling, transportation and storage cause increase in ethylene production. Ethylene enhances ripening, senescence and rotting, and shortens shelf-life of vegetables.

***Pathological:*** It is inevitable to harvest vegetables without wounds. Wounds, bruises and scratches are the avenue for the entry of pathogens. The growth of pathogen and development of disease are favored by high temperature and high relative humidity. Moreover, faulty and improper handling practices cause damage to the commodities leading to infection. Inoculums are present everywhere in the field, transportation containers, carriers and storage.

***Others:*** Some of the problems are specific to certain commodities. For example, greening is problem in potato, whereas sprouting is problem in potato, onion and garlic. Continuous growth and maturity, fiber development, loss of freshness and nutritive value are common in many vegetables.

## Factors Affecting Storage

***Temperature:*** The rate of most of the physiological processes in the plant materials approximately doubles with every 5.6 °C (10 °F) increment (Gautam & Bhattarai, 2018). In general, higher the rate of physiological activities, faster would be the loss of storage components of vegetables and shortening of their shelf-life. Principally, shelf-life of vegetables can be doubled with every 5.6 °C drop in temperature while storing within a range of 35 to 0 °C. However, appropriate storage temperature varies for different vegetables. Most of the tropical vegetables like beans, cucumber, watermelon, eggplant, lady's finger, peppers, etc. cannot tolerate lower temperature and should be stored above 8-13 °C. Low temperature causes a kind of physiological damage to the above vegetables and known as chilling injury. Temperate vegetables can be stored even at 0 °C or just above the freezing point for several days. Tolerance to low temperature depends on variety and growing conditions.

***Relative humidity:*** Relative humidity is the amount of water vapour present in atmosphere as compared to its maximum holding capacity. With the same amount of water vapour present in the atmosphere, the percentage of relative humidity increases with decrease of temperature and vice versa. Most of the vegetables contain 80-90% water. The loss of water from vegetables depends on surrounding relative humidity. Vegetables stored at low humidity lose more water and desiccate. Loss of water from vegetables causes both quantitative and qualitative loss in vegetables.

***Others:*** Besides temperature and relative humidity there are several factors that influence shelf-life and storage of vegetables. Shelf-life and storability of vegetables varies with the nature of the commodity and type of organ. Vegetables can be a growing plant, leaf, stem, flower, fruit, root, tuber, bulb, rhizome, etc. Physiologically, flowers are more active

followed by leaves, fruits, stems, tubers, rhizomes and bulbs. Leaves have thin epidermal layer and large number of stomata thus have a higher rate of transpiration and water loss. Similarly, young growing shoots have higher rate of respiration as they are physiologically very active. Well-developed tubers and bulbs have minimal rate of physiological activities and relatively have a greater shelf-life and storability. Moreover, harvest stage, harvesting time, methods of harvesting, handling and transportation influence the shelf-life of harvested commodities. Vegetables harvested at pre-mature stage have higher rate of respiration and transpiration thus have short shelf-lives. Similarly, over mature vegetables are senescing and deteriorating, and has short shelf-life and poor storability. Vegetables harvested at proper maturity stage have better shelf-life and long storability. Harvesting time of the day also influences shelf-life and storability. Vegetables should be harvested during the coolest part of the day, preferably during late afternoon and evening. Harvesting of vegetables early in the morning causes damage to the plants and products as they are more turgid and easily damaged during harvesting.

## Approaches to Reduce Postharvest Loss, Increase Shelf-life and Storability

***Harvest maturity:*** Vegetables are harvested at various stages of physiological maturity. Appropriate maturity stage for marketing is known as commercial maturity or horticultural maturity. Asparagus sprouts are harvested at early growing stage, cauliflowers are harvested at tight curd stage before flowering, tomatoes are harvested at mature stage before full colour development, and onion and potatoes are harvested at matured stage. Radishes, turnips and carrots are harvested before the emergence of floral sprouts. Over mature radish loss crispiness associated with the development of pithiness and loss of quality. Bitter gourds, sponge gourds, bottle gourds and cucumbers should be harvested while their seeds are soft and no fiber development in flesh. Beans should be harvested when they reach about full size, plump and easily snap. Lady's finger should be harvested while they are tender and still growing. Young developing vegetables continue to grow even after harvesting, thus for storage or transportation to a long distance, they should be harvested 1-2 days in prior of reaching the local markets.

***Harvesting method:*** In conventional methods, vegetables are harvested by pinching, twisting and pulling. Faulty harvesting practice causes damage to the harvested products. Any kind of damage is the avenue for the entry of pathogens. Fruit vegetables like brinjal, capsicum, pumpkin, squash, gourds and tomatoes should be harvested along with pedicel. Fruits attached with its pedicel can be stored for a long period. It is advised to use sharp knives, scissors or secateurs to harvest the vegetables.

***Trimming:*** Trimming is the process of removing undesirable portion. Trimming is necessary in radishes and carrots to remove top leaves and small roots. Carrots, radishes and turnips are usually marketed for their roots. Unnecessary foliage portion utilizes reserve material of root for respiration, enhances water loss, and reduces shelf-life and quality. By trimming, unnecessary portion transportation cost is reduced, and shelf-life and storability of roots are increased. Similar case is with cabbages and cauliflowers. Cauliflowers and cabbages in Nepal are often transported together with unnecessary leaves. A study revealed that 30% extra materials transported with cauliflowers contribute

about 30% raise in cost of the vegetable (Gautam et al., 2015). The cost of transporting unnecessary materials certainly increases the price of transported commodities.

***Sorting and grading:*** Sorting is a practice to remove off size, diseased, damaged and undesirable vegetables from the mass, where as grading is a practice to categorize vegetables in different groups based on size, shape, colour, maturity stage, defect and other uniformity. If grading is done on the basis of size, it is called sizing. Different grades can be defined for different vegetables based on market demands. For example, potatoes and onions can be graded to large, medium and small. Fresh vegetables can be graded as Grade 1, Grade 2 and ungraded, etc.

***Curing:*** Curing is a natural process of thickening of periderm layer, healing of wounds (as in the cases of potatoes and sweet potatoes), and tightening of bulbs and neck (as in onions and garlics). In potatoes, curing process starts during maturity and continues after harvesting as well. In immature potatoes, tuber peel is thin and delicate while it is tough, hard and leathery in matured potatoes. Immature potatoes harvested early in the season fetch a higher price in the market but they are delicate and cannot be stored for a longer period. Tubers which are harvested late in the season and upon natural drying of haulms will have a thick skin, partially cured in the field and will have a better shelf-life. Curing process continues in the harvested potatoes at ambient temperature. If potatoes are to be stored in cold storage they should be properly cured before storage, otherwise serious rotting may occur later upon removal from the storage. It is advised to spread potatoes for about 15-20 days for curing. Onions and garlics are partially cured in the field by bending their neck (top fall) a week before harvesting. It is practiced by using a long bamboo pole or stick. After harvesting, onion bulbs are exposed in sunlight for a day. Upper portion, about 2-2.5 cm above the bulb, is removed by a scissors. Long roots can be trimmed to 1-2 cm. Curing should be done by spreading on the floor for 7-10 days. Cured onions have hard brittle outer skin and tight neck.

***Packaging:*** Packaging plays crucial role in marketing of vegetables. Different vegetables are packed in different ways. Plastic crates are the most suitable containers for packing of tomatoes. Potatoes are packed in jute sacks and onions are packed in netted nylon sacs. Potatoes should always be packed in an opaque container to avoid light exposure. Potato tubers if exposed to light develop green colour (greening). Greening of tuber is due to the formation of solanine and it is harmful to human health. Most of the fresh vegetables are metabolically very active and need holes in package for exchange of gases. Anaerobic condition inside the package causes fermentation and rotting. Packing container should be strong enough to protect the vegetables and should be easy for handling. Depending on the nature of commodity, different sized containers are used. For highly perishable commodities, small package should be used. Crates of about 20 kg capacity are the most useful size for most of the vegetables. For big sized commodities like cauliflowers and cabbage, crates of 40 kg capacity may be appropriate. Plastic lined perforated corrugated fiber board (CFB) boxes are best packaging materials for transportation of fresh fruits and vegetables for a long distance market. For retail market, 0.5 to 1 kg packets of vegetables are appropriate.

***Pre-cooling:*** Pre-cooling is a process of cooling of products before transportation/ shipment or storage. It is necessary to remove field heat and lower down the temperature. Vegetables at harvesting time have a higher temperature nearly close to the ambient condition. If such vegetables are transported or stored without pre-cooling, temperature rises inside the heap causing faster deterioration of the product. As mentioned earlier, quick pre-cooling of the harvested products close to the storage temperature prolongs the shelf-life of the products significantly. Various methods of cooling can be used to lower down the temperature. In the hills and mountains, just keeping of vegetables in an open space in shade lowers the temperature. It is slow and it takes a long time. This method can be practiced for transportation of vegetables for the local markets. Mechanized pre-cooling chambers should be used to cool vegetables before storage and refrigerated vegetables should be transported to the markets at long distances. Pre-cooling can be done by hydro cooling, vacuum cooling, forced air cooling, icing, etc. Rapid cooling is necessary for highly perishable vegetables.

***Pack house:*** Pack house is a place where different operations are carried out before storage and transportation of harvested vegetable products (Acedo et al., 2016). Commonly used pack house operations are washing, cleaning, trimming, sorting, grading, chemical treatment, pre-cooling, etc. Different kinds of vegetables require different pack house operations. Some vegetables may require washing and sanitization treatments. A pack house is necessary for assembling the products and their efficient marketing, and it should coordinate with production farm and markets. A pack house should consist of washing and cleaning area, sorting and grading area, packing table, pre-cooling chamber, and cold storage. For local short distance domestic markets, pre-cooling and cold storage may not be important but for export the products to long distant markets, these are necessary components. For commercial production of vegetables, pack house and cold storage facilities are very important to assemble and regulate effective marketing.

***Cold chain:*** Cold chain is an approach to handle harvested vegetables at lower temperature. At lower temperatures, all physiological activities are at lower rate and vegetable remains safe. After harvesting, vegetables should be cooled, stored, transported and stored in a cold condition (Gautam, 2020). At present, it does not exist in Nepal but it is needed for the near future for vegetable marketing.

***Transportation:*** In conventional practices, vegetables are transported loosely, in trucks and small vehicles. For short distances, vegetables can be transported in an ordinary vehicle. Losses due to pressure and vibration are very high in this system. In modern practice, vegetable should be transported by proper staking in side carriers. Proper staking prevents the commodities from pressure damage. Hard containers like plastic crates can be placed one after another without staking. Staking is necessary if the containers are delicate and could not sustain the above pressure. For long distance transportation, vegetables should be pre-cooled and properly stalked in carriers. Refrigerated vehicles are the most appropriate carriers for transporting fresh vegetables. Losses can be minimized and shelf-life is prolonged as a result of a low temperature. This is the most appropriate method for long distance transportation of the vegetables.

## Storage

Storage of vegetable is important to regulate market supply and refrigerated transport. Long-term storage of fresh vegetables in Nepal is not necessary as they can be produced throughout the year within the country. Short-term storage is necessary for refrigerated transport and market supply. Vegetables are perishable commodities and cannot be stored for long duration at an ambient condition. Storages should be utilized to assemble vegetables in large quantities to make bulk transportation. Cold storage is the most common method for vegetable storage. Different types of vegetables require different temperature range for storage. Temperature requirement of some important vegetables and possible storage duration is given in Table 17.1 (Gautam & Burlakoti, 2017).

**Table 17.1.** Storage temperature and storage duration of some important vegetables

| Vegetables | Temperature ($^{o}$C) | Relative Humidity (%) | Length of storage |
|---|---|---|---|
| Asparagus | 0-2 | 95-98 | 2-3 weeks |
| Beans (snap) | 4-7 | 95 | 7-10 days |
| Beets | 0 | 98-100 | 3-5 months |
| Bitter gourd | 12-13 | 85-90 | 2 weeks |
| Bottle gourd | 12-13 | 85-90 | 2 weeks |
| Broccoli | 0 | 95-98 | 10-14 days |
| Brussels (sprout) | 0 | 95-98 | 3-5 weeks |
| Cabbage | 0 | 98-100 | 3-6 weeks |
| Cauliflower | 0 | 95-98 | 2-4 weeks |
| Capsicum | 7-10 | 95 | 2-3 weeks |
| Chili (dry) | 7-10 | 60-65 | 6 months |
| Carrot (late) | 0 | 95-100 | 3-4 months |
| Carrot (immature) | 0 | 95-100 | 4-5 months |
| Colacasia | 7-10 | 85-90 | 3-5 months |
| Cucumber | 10-13 | 95 | 10-14 days |
| Eggplant | 12-15 | 90 | 1 week |
| Garlic | 0 | 65-70 | 6-7 months |
| Ginger | 13 | 60-65 | 5-6 months |
| Ladies finger | 7-10 | 90-95 | 2-3 weeks |
| Leeks (green) | 0 | 95-98 | 4-6 months |
| Lettuce | 0 | 95-98 | 2-3 months |
| Onion | 0 | 65-70 | 6-7 months |
| Peas (green) | 0-1 | 95 | 1-3 weeks |
| Potato (early) | 4 | 90 | 1-3 weeks |
| Potato (late) | 4 | 90 | 4-9 months |
| Pumpkin | 5-10 | 70-75 | 2-3 months |
| Radish (spring) | 0 | 95 | 3-4 weeks |
| Radish (winter) | 0 | 95 | 2-4 months |
| Spinach | 0 | 95-98 | 10-14 days |
| Sponge gourd | 12-13 | 85-90 | 2 weeks |
| Watermelon | 10-15 | 80-95 | 2-3 weeks |
| Tomato | 10-13 | 90 | 1-3 weeks |
| Turmeric | 13 | 60-65 | 5-6 months |
| Yam | 16 | 70-80 | 2-6 months |

Small producers and retailers can use coolBot storage or zero energy storage (evaporative cooling structure) to store small quantities of vegetables for a short duration. CoolBot storage is a recent technology that can be used to store small quantity of vegetables (1-2 tons). CoolBot is a small device that is connected with air conditioner to lower down the temperature. Air conditioners are usually designed to adjust temperature within 16 to 32 $^{o}$C. Connection of coolBot device to air conditioner reduces temperature up to 4 $^{o}$C. Zero energy storage, which is also known as evaporative cooling storage, requires no electricity. A simple structure about 1.5-2.5 m (length) × 1-1.5 m (breadth) × 1-1.25 m (height) is made which is surrounded by double layers of bricks joined with soil. Between the two brick walls, sand and gravel are placed. Sand and gravel are regularly moistened by dripping water in it. Temperature inside the chamber reduces as a result of evaporative cooling of water from the wall. Vegetables are placed inside chamber and covered with thatch roof or moistened gunny sacks. Small producers can harvest their vegetables during evening and keep in zero energy storage waiting for transportation and marketing. Evaporative cooling storage is effective during hot and dry conditions. It is not effective during humid and rainy conditions as evaporative cooling is less and vegetables may damage due to high moisture in storage. Studies conducted at National Agriculture Research Council (NARC) and Agriculture and Forestry University have found coolBot and zero energy storage are effective to prolong shelf-life of vegetables (Gautam et al., 2020). Modified atmosphere packages can be used further to prolong shelf-life in storage, transportation and marketing. In modified atmosphere (MA), storage vegetables are kept in perforated polyethylene bags. A slight increase in carbon dioxide and decrease in oxygen levels as a result of respiration increase shelf-life of packed commodities. Modified atmosphere packaging can be applied for packaging vegetables during transportation and marketing. Its principle is based on controlled atmosphere (CA) storage. CA storage is a sophisticated technology which is used to prolong shelf-life of expensive fruits, vegetable and cut flowers. In CA storage temperature, oxygen and carbon dioxide are controlled. At present situation, CA storage is beyond the expectation to the Nepalese farmers to store vegetables.

## Conclusion

Nepal has tremendous scope to increase vegetables production, substitute import and possibility to export. Lack of proper handling and storage technologies could not make possible to market the vegetables produced in remote areas. If handling, transportation and storage techniques are improved and applied, effective marketing is possible. Improvement in handling, transportation and storage facility, establishment of pack house, cold storage and cold chain facility will certainly reduce postharvest loss, increase marketing and ultimately boost commercial vegetable production in large areas.

**Abbreviations:** AGDP = Agricultural Gross Domestic Product; ANSAB = Asia Network for Sustainable Agriculture and Bioresources; AVRDC = Asian Vegetable Research and Development Center; CA = controlled atmosphere; NARC = National Agriculture Research Council.

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# Author's Biography



Born at Amarpur, Gulmi, Durga Mani Gautam obtained his B.Sc. Ag and AH from G.B. Pant University of Agriculture and Technology in 1979, MS in postharvest horticulture from UPLB Philippines in 1984 under USAID scholarship program and Ph. D. in 1996 from Bangladesh Agriculture University under SAARC fellowship program. He has obtained higher trainings from Israel, United Kingdom, Bangladesh and Philippines. Dr. Gautam served as a faculty in the Institute of Agriculture and Animal Science, Tribhuvan University from 1979 to 2012. During the period, he also possessed different positions and responsibilities like farm manager, extra-curricular activities chief, hostel warden, chairman of horticulture department, and campus chief at Lamjung and Paklihawa campuses. He was the founder chairman of Agriculture and Forestry University Service Commission. He has also served as a short term consultant and resource person in postharvest horticulture in different government and non-government organizations viz. KISAN, CARE Nepal, GIZ, CYMET, CEAPRED, etc. Dr. Gautam has been honored with Mahendra Bidya Bhusan-Ka, Gorkha Dakshin Bahu-Chautha, Dirgha Sewa Padak and an Intenational award on Outstanding Research Leader and Scientist in Quality and Postharvest Horticulture by International Society of Horticultural Science (ISHS) and Royal University of Cambodia. He has more than 100 publications including 15 books.

# Chapter 18

## Processing Losses of Common Nepalese Vegetables during Preparation and Cooking

**Pravin Ojha[1]* and Ganga P. Kharel[2]**
[1]*National Food Research Centre, Nepal Agricultural Research Council*
*Khumaltar, Lalitpur, Nepal;*
[2]*Central Department of Biotechnology, Tribhuvan University*
*Kirtipur, Kathmandu, Nepal*
* Email: projha84@gmail.com

*Dal, bhat, tarkari and pickle are the major segments of Nepalese meal. Food preparation, however, varies depending upon the individual to traditional practices of a community. The choice of vegetables also depends on the season and taste. They are major sources of vitamins, minerals and dietary fiber. While preparing vegetables, due to increased awareness of food safety, excess peeling and overcooking have been practiced. This might result in an excessive loss in nutrients. Therefore, researches should be carried out to estimate the actual losses occuured because of our cooking practices. Certain modifications like minimum peeling, maximizing the cut size, less degree of cooking and cooking in or with less water, etc. can preserve more nutrients in the vegetables.*

**Keywords:** Cooking; cutting; fiber; minerals, peeling; phytochemicals.

## Introduction

Vegetable has always been considered as an important item of the Nepalese cuisine. Nepalese people generally prefer *dal*, *bhaat* and *tarkari* (green leafy vegetables and other vegetables), with a green salad and pickles. Most commonly consume vegetables can be classified into flowers (cauliflower, broccoli, etc.), pods and peas (beans, okra, etc.), leaves (cabbage, lettuce, etc.), fruits (tomato, eggplant, bell pepper, etc.), roots (radish, carrot, etc.), bulbs (onion, garlic, etc.), tubers (sweet potato, cassava, etc.) and stems (asparagus, edible fern, etc.) (Dhaliwal 2017). A decade ago, the choice of vegetables mainly depends on the season; however, with progress in agriculture, most vegetables are available round the year. With modernization, the preparation methodology is also changing in urban areas. However, the basic processing of vegetables includes washing, peeling, cutting and cooking. Vegetable cooking manly includes pressure cooking, currying, stirring and deep frying and roasting, and now-a-days, microwave cooking is also coming up as a result of constant electricity supply. This paper aims to highlight the

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Sajan Lal Shyaula, Gan B. Bajracharya, Gopal K.C., Shanta Man Shakya and Dilip Subba (Editors)
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available micronutrients in common Nepalese vegetables and the effect of Nepalese preparation practices in those micronutrients.

## Micro-nutrient in Vegetables

Vegetables are a good source of minerals such as magnesium, manganese, iron, copper, zinc, molybdenum, selenium, sodium, potassium, calcium and nickel. Vegetables are also a good source of dietary fiber, vitamins, phytochemicals and phenolic compounds. Phenolic compounds, which generally contribute to the bitter and astringent taste, are more concentrated in the peel than in the pulp. Phenols are classified into different sub-groups namely phenolic acids, flavonoids, tannins and others. The major contribution of phenolic acid is its antioxidant activity, which mainly depends upon the number of hydroxyl groups present on it (Dias 2012; Vincente et al. 2014).

Lycopene is present in tomato and has been linked to anticarcinogenic activity. Carotenoids give colour (red, yellow and orange) to the vegetables. Carotenoids namely lutein, β-carotene, lycopene and zeaxanthin are found in fruits and vegetables. Carotenoids contribute to human health by increasing low-density lipoproteins (LDL) oxidation resistance (preventing cardiovascular disease), lowering DNA damage and improving the immune system. Dark green and leafy vegetables are good sources of lutein and zerxanthene. Carrot, squash, sweet potato and spinach are good sources of β-carotene. vitamin C (ascorbic acid), an essential vitamin, is also supplemented by fruits and vegetables (Dias 2012; Vincente et al. 2014).

The nutrient, and mineral and vitamin compositions of some common vegetables as published by Nepal Government (DFTQC 2012) are shown in Tables 18.1 and 18.2, respectively.

**Table 18.1.** Nutrient composition per 100 g of some common vegetables in Nepal

| Common Vegetable | Edible portion (g) | Moisture (g) | Protein (g) | Fat (g) | Carbohydrate (g) | Minerals (g) | Fiber (g) |
|---|---|---|---|---|---|---|---|
| Cauliflower | 70 | 90.8 | 2.6 | – | 4 | 1 | 1.2 |
| Broccoli | 80 | 85.61 | 4.99 | 0.2 | 7.1 | 1.12 | 0.94 |
| Bitter gourd | 97 | 92.4 | 1.6 | 0.2 | 4.2 | 0.8 | 0.8 |
| Broad bean | 88 | 85.4 | 4.5 | 0.1 | 7.2 | 0.8 | 2 |
| Okra | 84 | 89.6 | 1.9 | 0.2 | 6.4 | 0.7 | 1.2 |
| Cabbage | 88 | 91.9 | 1.8 | 0.1 | 4.6 | 0.6 | 1 |
| Lettuce | 66 | 93.4 | 3.3 | 0.1 | 2.7 | 0.6 | 0.8 |
| Pumpkin | 79 | 92.6 | 1.4 | 0.1 | 4.6 | 0.6 | 0.7 |
| Tomato | 100 | 93.5 | 1.3 | 0.1 | 3.9 | 0.7 | 0.5 |
| Eggplant | 91 | 92.7 | 1.4 | 0.3 | 4 | 0.3 | 1.3 |
| Capsicum green | 97 | 93 | 0.9 | 0.11 | 25 | 0.52 | 0.7 |
| Radish | 99 | 94.4 | 0.7 | 0.1 | 22.7 | 0.6 | 9.6 |
| Carrot | 95 | 86 | 0.9 | 0.2 | 10.6 | 1.1 | 1.2 |
| Cucumber | 83 | 96.3 | 0.4 | 0.1 | 2.5 | 0.3 | 0.4 |
| Chayote* | – | 91% | 0.87 | 0.03-0.3 | 4.51 | 0.39-3.65 | 5.31 |
| Onion | 95 | 86.6 | 1.2 | 0.1 | 10.4 | 0.4 | 1.3 |
| Sweet Potato | 97 | 68.5 | 1.2 | 0.3 | 28.3 | 1 | 0.7 |
| Asparagus | 86.8 | 92.5 | 3.3 | 0.1 | 2.7 | 0.6 | 0.8 |
| Cassava | – | 62.5 | 1.2 | 0.3 | 34.7 | 2.41 | 0.43 |

*(Vieira et al. 2019)

**Table 18.2.** Vitamin and mineral composition per 100 g of some common vegetables in Nepal

| Common vegetables | Calcium (mg) | Phosphorous (mg) | Iron (mg) | Carotene (µg) | Vitamin C (mg) | Thiamine (mg) | Riboflavin (mg) | Niacin (mg) |
|---|---|---|---|---|---|---|---|---|
| Cauliflower | 33 | 57 | 1.23 | 30 | 56 | 0.04 | 0.1 | 1 |
| Broccoli | 44.86 | 108.9 | 1.52 | 630 | – | – | – | – |
| Bottle gourd | 20 | 70 | 0.61 | 126 | 88 | 0.07 | 0.09 | 0.5 |
| Broad bean | 50 | 64 | 1.4 | 9 | 12 | 0.08 | – | 0.8 |
| Okra | 66 | 56 | 0.35 | 52 | 13 | 0.07 | 0.1 | 0.6 |
| Cabbage | 39 | 44 | 0.8 | 120 | 124 | 0.06 | 0.09 | 0.4 |
| Lettuce | 50 | 28 | 2.4 | 990 | 10 | 0.09 | 0.13 | 0.5 |
| Pumpkin | 10 | 30 | 0.44 | 50 | 2 | – | – | – |
| Tomato | 15 | 27 | 0.7 | 424 | 23 | – | – | – |
| Eggplant | 18 | 47 | 0.37 | 74 | 12 | 0.04 | 0.11 | 0.9 |
| Capsicum green | 25.1 | 32.65 | – | – | 48.03 | – | – | – |
| Radish | 24.7 | – | 0.4 | 3 | 15 | 0.06 | 0.02 | 0.5 |
| Carrot | 80 | 530 | 1.03 | 4275 | 3 | 0.04 | 0.02 | 0.6 |
| Cucumber | 10 | 25 | 0.6 | 0 | 7 | 0.03 | 0 | 0.2 |
| Chayote* | 17.9 | 18 | 3.4 | – | 7.7 | 0.3 | 0.3 | 0.47 |
| Onion | 47 | 50 | 0.6 | 0 | 11 | 0.08 | 0.01 | 0.4 |
| Sweet Potato | 46 | 50 | 0.21 | 6 | 24 | 0.08 | 0.04 | 0.7 |
| Asparagus | 30.6 | 45.5 | 1.3 | – | 12.8 | – | – | – |
| Cassava | 33 | – | 0.7 | – | – | – | – | – |

*(Vieira et al. 2019)

## Common Processing Methods in Household

The common processing methods practiced in the Nepalese kitchen involved sorting, washing, peeling, cutting and then cooking. Normally vegetables like cucumber, radish and carrot are served fresh after peeling and cutting as a green salad, while some vegetables are served as pickles after seasoning with fenugreek, cumin and turmeric fried in mustard oil.

## Nutrient Loss during Preparation and Cooking

**(a) Washing:** All the vegetables are washed after receiving them in the kitchen. Washing is done to remove dirt and other unwanted adhered particles from a vegetable. Plain washing is practiced by passing running water through the vegetable put in the net (plastic or metal mesh) or a container with water. Washing of vegetables does not affect the nutrient of vegetables; however, if leafy vegetables are washed after cutting, significant loss occurs in water soluble vitamins.

**(b) Peeling:** Normally all the vegetables are peeled except green leafy vegetables. Vegetables like cucumber, radish and carrot may or may not be peeled before consumption. But now-a-days, due to the increased awareness about the use of chemical pesticides, these are peeled. Peeling is practiced by *chulesi* (cutting utensils with stand) or by the special kitchen peeling knife. Peeling is carried out to remove the outer skin or peel of the vegetables. Vegetables are peeled to make more digestible; however, results in fairly heavy loss of fiber, minerals and vitamins. The percentage loss of nutrients due to peeling is shown in Table 18.3 (Alvi et al. 2003).

**Table 18.3.** Effect of peeling on the nutrient loss of vegetable

| Nutrients | Eggplant | | Bitter gourd | | Colocasia | | Tomato | |
|---|---|---|---|---|---|---|---|---|
| | Raw unpeeled | % Loss after peeling | Raw unpeeled | % Loss after peeling | Raw unpeeled | % Loss after peeling | Raw unpeeled | % Loss after peeling |
| Protein (g/100 g) | 1.18 | 11.02 | 0.7 | 12.85 | 0.2 | 10 | 1.1 | 18.18 |
| Crude fiber (g/100 g) | 1 | 13.33 | 1 | 20 | 3.1 | 31.89 | 0.6 | 18.33 |
| Ash (g/100 g) | 0.58 | 18.96 | 0.9 | 36.36 | 2.12 | 13.2 | 0.5 | 20 |
| Calcium (mg/100 g) | 17.3 | 8.1 | 19 | 13.16 | 33.08 | 13.09 | 10.75 | 25.36 |
| Magnesium (mg/100 g) | 19 | 5.68 | 22.05 | 4.76 | 27 | 11.59 | 11.95 | 32.63 |
| Phosphorous (mg/100 g) | 35.5 | 8.78 | 30.25 | 9.26 | 65 | 2.38 | 30 | 6.4 |
| Potassium (mg/100 g) | 221 | 4.07 | 270 | 8.88 | 445 | 0.45 | 235 | 2.9 |
| Ascorbic acid (mg/100 g) | 4.8 | 25.83 | 18.25 | 13.26 | 6.25 | 8.33 | 22.52 | 28.86 |
| Folic acid (μg/100 g) | 4.6 | 15.21 | 2.85 | 13.13 | 10.8 | 4.62 | 4.5 | 17.17 |

Though peeling is an essential household practice in reference to food safety, peeling should be done as thin as possible to minimize the nutrient and fiber losses. The presence of polyphenols in peel is 10 times higher than in flesh, and peel constitutes 50% of dietary fiber (Al-Weshahy & Rao 2012). Potato should not be peeled to derive the maximum benefits of dietary fiber. Also, in many vegetables like tomatoes, phenolics, lycopene, ascorbic acid and antioxidants are more concentrated in the skin than in pulp (Sharma & Le Maguer 1996). As reviewed by Ahmad et al. (2019), the root part of carrot consist of the peel (periderm), a pulpy outer cortex (phloem), and an ineer core (xylem) (Figure 18.1). Though peel accounts only 11% of fresh weigh of carrot, it contributes more than 50% of polyphenol. The phenolics are more located in periderm, and goes on decreasing while moving to central in the carrot. Carrots have higher concentrations of carotenoids in the phloem than in the xylem. Silicon, an important mineral for human health, is located more in exocarp of cucumber compared to the fleshy part (Figure 18.2) (Tripathi et al. 2017).

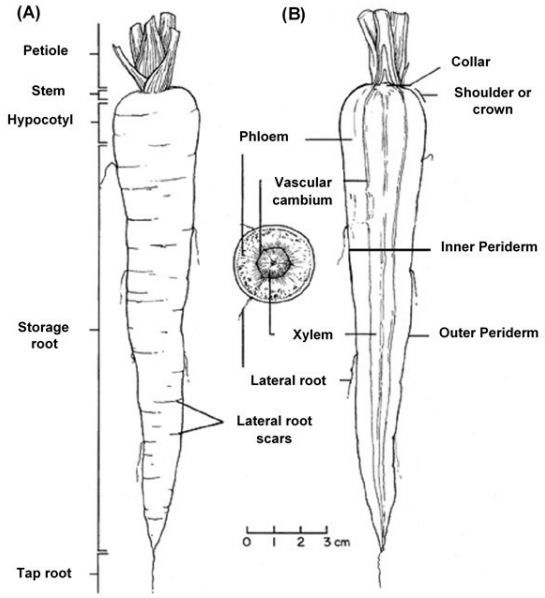



**Figure 18.1.** Anatomy of carrot: **(A)** Longitudinal view; (B) Cross-section view.

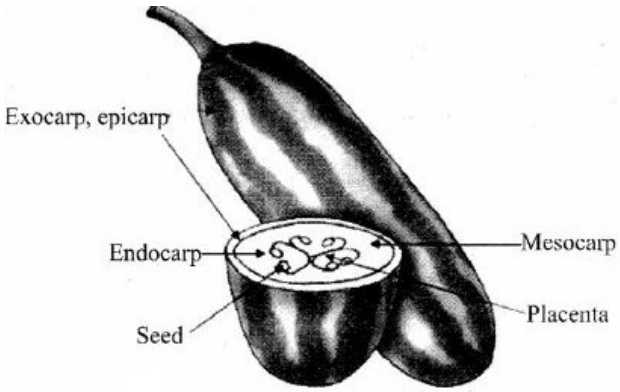



**Figure 18.2.** Anatomy of cucumber (Source: https://www.rbsesolutions.com).

**(c) Cutting:** Cutting is practiced in all vegetables after or before peeling. Cutting to appropriate size not only makes vegetable appearance nice but also easy to consume (due to modification of texture). Cutting can be classified into three types, namely, cutting (to cut across perpendicular to the food), chopping (cutting into small pieces) and dicing (cutting into cubes) (Fabbri & Crosby 2016). Cutting and mincing activate various enzymes, for example, myrosinase in broccoli, and this enzyme converts the glucosinolates to isothiocyanates, which are responsible for flavours (Johnson 2002). The allinase enzyme released after cutting onion gets contacted with sulphur

compounds and elevates the pungency of onion (Russo et al. 2013). The surface area of vegetables is increased by cutting, and the nutrient loss is due to oxidation of fatty acid and carotenes. Vitamin C can be lost by 78% in sliced cucumber (Fellows 2009). Loss of vitamin C and thiamine is significant in chopped vegetables. Mineral loss is also substantial, if soaked after cutting. Nutrient loss can be minimized, if vegetables need to be served raw is prepared just before serving, and served in closed utensils. Besides that, chopping to small size will expose the vegetable to the atmosphere, degrade more and nutrients prone to undergo oxidation. Cutting the vegetable just before cooking and to a maximum possible size will minimize the nutrient loss.

**(d) Cooking:** Cooking enhance the bioavailability of nutrient after cooking. Cooking methods are changing with time, but the following are the common practices practiced in the Nepalese kitchen.

*(i) Pressure cooking:* Pressure cooking is common in the Nepalese kitchen, and applied to green leafy vegetables and other vegetables, depending on the taste. Root vegetables like potato and cassava are steam cooked before other processing like frying, pickling, etc. It is a simple cooking of food with water using a utensil with a sealed lid (called pressure cooker) and the food is cooked under pressure.

*(ii) Frying:* Frying is generally of two types, namely, pan-fried or deep-fried. Vegetable snacks are normally deeply fried, whereas vegetables served during lunch and dinner are pan-fried. Vegetables like potato, ladyfinger, eggplant, etc. are fried in oil, and seasoned with turmeric, fenugreek, cumin and other spices. Chopped tomatoes, garlic and ginger are also added to enhance the taste. However, green leafy vegetables are fried in oil with no or little spices.

*(iii) Currying:* Currying is similar to frying, but water is added and cooked further. This is served to replace *dal*. Sometimes, little water is added to make the gravy-like consistency.

*(iv) Microwave cooking:* Microwave heating is carried to re-heat the food, but limited to restaurants and selected households.

*(v) Roasting:* Roasting is occasionally practiced in the Nepalese kitchen. Roasting is practiced by cooking food in a pan layered with oil, which is similar to sauté. However, in rural areas, fire roasting of vegetables (e.g. potato) is a common practice. The electric roasting provides cleanliness and easy heat control, but smoke flavour is preferred by Nepali people.

These cooking practices and recipes may differ based on community, geographical location and other social factors. Nutritional loss while cooking depends on the food we cooked, the methodology we used, and the cooking practices (Kharel 2018). Haphazard use of pesticides is making headlines in the newspaper, which has elevated the level of awareness of the consumers. People are also concerned about food safety issues. This has increased the cooking time to minimize the impact. Stea et al. (2007) revealed that boiling reduces 59% of folate in potato compared to 63% reduction by oven baking. Lombard et al. (2005) reported that oven baking and sauté increase the flavonoid (quercetin) in contrast to boiling, which reduces the flavonoid. As reported by Miglio et al. (2008),

cooking in water preserves the antioxidant activity, carotenoids in carrot and broccoli, and more vitamin C retention in carrot compared to frying. In another study conducted by Lee et al. (2018), microwave cooking retains more vitamin C in vegetables compared to boiling and steaming.

Yuan et al. (2009) reported steaming results in less degradation of soluble protein, soluble sugar, chlorophyll, vitamin C and total glucosinolates, compared to stir-frying and stir-frying followed by boiling. Ikanone and Oyekan (2014) reported 72% and 60% losses of vitamin C in sweet potato by boiling and frying, respectively. Chukwu et al. (2012) reported losses of vitamin A, vitamin C and vitamin E in sweet potato while frying and cooking, and reveal that the loss depends upon cooking time. The reduction of more than 50% vitamin C was observed in broccoli, spinach and lettuce processed through boiling (Yuan et al. 2009; Zeng 2013). Microwave heating retains more phenolic compounds in mushroom and preserves more antioxidant activity compared to boiling, frying, steaming and pressure-cooking (Sun et al. 2014).

Desobry et al. (1998) reported that β-carotene provides 80% of vitamin A when expressed as retinol equivalent (1 retinol equivalent = 1 μg of retinol = 6 μg of β-carotene = 12 μg of other pro-vitamins A such as carotenoids). Since carotenoids are highly unsaturated, their degradation is influenced by heat, light and oxygen (Britton 1996). Zhang and Hamauzu (2004) reported that carotenoid loss in broccoli was high when cooked for more time. Padmavati (1992) also reported that loss of β-carotene was low when vegetables were heated low. They have also reported that shallow frying causes double retention compared to deep-frying. As reported by Gayathri et al. (2004), the addition of acidulants and spices retains β-carotene more during cooking.

Vitamin E content increases in vegetables fried in vegetable oil (Holland et al. 1991); however, Carlson and Tabacchi (1986) reported no significant increase in vitamin E of French fries. The loss of vitamin E in French fries is balanced by oil uptake. Vitamin C of the vegetables is reduce during cooking and it depends on the intensity of heating, the surface area exposed, pH, presence of other pro-oxidants, leaching loss in cooking water, etc (Eitenmiller & Laden 1999). Domestic cooking results in thermal destruction along with enzymatic destruction. It is also observed that vitamin C retention was found to be higher in cooking with less water (Burg & Fraile 1995). McKillop et al. (2002) have reported that folate retention was high in vegetables like spinach and broccoli when cooked in less water. As reviewed by Lešková et al. (2006), folate degrades during heat processing and leaches out in cooking water. The loss of carotenoids in vegetables by heating is mainly due to oxidation, degradation and isomerization (Zepka et al. 2009). As reviewed by Patras et al. (2010), anthocyanins in vegetables undergo heat degradation and oxidation, which are influenced by high temperature, long exposure to heat and high pH. A high mineral loss is also associated with leaching loss while cooking, and as reviewed by Tian et al. (2016), frying of potato retains more minerals compared to boiling. Some researchers have reported increament of polyphenolics content while cooking, while others revealed the detrimental effect of heat on polyphenols. The increase of polyphenols might be due to the inactivation of the enzyme polyphenol oxidase and also increase of the extractability of phenolic compounds bound by dietary fiber (Ruiz-Rodriguez et al. 2008). The detrimental effect is due to leaching loss and degradation of polyphenols by heating (Kita et al. 2013).

As documented by Jiménez-Monreal et al. (2009), microwave cooking and baking are comparatively better than steaming, boiling or pressure cooking regarding a nutritional loss. Alvi et al. (2003) have found that nutrient loss is high in peeled vegetables compared to unpeeled vegetables when subjected to cooking, and data published by the authors are tabulated in Table 18.4 and 18.5. The report reveals that nutrient loss will be minimum if the vegetables are cooked unpeeled. The major reasons for minimum nutrient loss in unpeeled vegetables while cooking are due to less exposure to direct heat, minimum leaching loss, less area exposed to atmospheric oxygen, etc. Cooking vegetables in less water and for a minimum possible time will maintain the nutrient profile high in the vegetables. Storing of cooked vegetables for a longer time also reduces the nutrients amounts.

**Table 18.4.** Effect of peeling on nutrient loss during cooking of eggplant and bitter gourd

| Nutrients parameters | Eggplant (per 100 g) | | | Bitter gourd (per 100 g) | | |
|---|---|---|---|---|---|---|
| | Raw | % Loss in cooking (unpeeled) | % Loss in cooking (peeled) | Raw | % Loss in cooking (unpeeled) | % Loss in cooking (peeled) |
| Protein (g) | 1.18 | 15.25 | 27.97 | 0.7 | 14.28 | 22.85 |
| Crude fiber (g) | 1 | 16 | 22.22 | 1 | 28 | 32 |
| Ash (g) | 0.58 | 34.48 | 50 | 0.9 | 36.36 | 60 |
| Calcium (mg) | 17.3 | 14.56 | 25.02 | 19 | 24.37 | 32.16 |
| Magnesium (mg) | 19 | 12.89 | 17.05 | 22.05 | 11.56 | 14.97 |
| Phosphorous (mg) | 35.5 | 19 | 46.42 | 30.25 | 17.35 | 31.3 |
| Potassium (mg) | 221 | 9.04 | 25.34 | 270 | 22.22 | 27.47 |
| Ascorbic acid (mg) | 4.8 | 61.45 | 97.3 | 18.25 | 53.42 | 89.75 |
| Folic acid (μg) | 4.6 | 41.3 | 78.47 | 2.85 | 30.52 | 63.15 |

**Table 18.5.** Effect of peeling on nutrient loss during cooking of colocasia and tomato

| Nutrients parameters | Colocasia (per 100 g) | | | Tomato (per 100 g) | | |
|---|---|---|---|---|---|---|
| | Raw | % Loss in cooking (unpeeled) | % Loss in cooking (peeled) | Raw | % Loss in cooking (unpeeled) | % Loss in cooking (peeled) |
| Protein (g) | 0.2 | 14.5 | 16 | 1.1 | 31.82 | 54.54 |
| Crude fiber (g) | 3.1 | 32.58 | 36.87 | 0.6 | 33.33 | 40 |
| Ash (g) | 2.12 | 22.17 | 32.55 | 0.5 | 32 | 40 |
| Calcium (mg) | 33.08 | 20.83 | 27.17 | 10.75 | 36.28 | 50.88 |
| Magnesium (mg) | 27 | 18.52 | 31.41 | 11.95 | 45.86 | 74.14 |
| Phosphorous (mg) | 65 | 6.92 | 15.89 | 30 | 33.33 | 49.96 |
| Potassium (mg) | 445 | 15.5 | 19.32 | 235 | 19.57 | 25.96 |
| Ascorbic acid (mg) | 6.25 | 49.92 | 68.32 | 22.52 | 89.12 | 97.7 |
| Folic acid (μg) | 10.8 | 25.74 | 58.33 | 4.5 | 68.88 | 100 |

## Recommendations to Minimize Nutrient Loss while Preparing and Cooking of Vegetables

- ✓ Wash leafy vegetables without chopping.
- ✓ Soak vegetables without peeling in water to avoid leaching loss.
- ✓ Peeling should be done as thin as possible to minimize the nutrient and fiber losses.
- ✓ Wherever possible (especially in a salad), try to consume unpeeled vegetables.
- ✓ Cooked vegetables should be kept in a closed container.
- ✓ Cooked vegetables should not be stored for a long time.
- ✓ Vegetables should be cut to maximum possible size while preparing for cooking.
- ✓ Cooking vegetables in less water is preferable for minimizing nutrient loss.
- ✓ Practices such as cooking vegetables at high temperature and for a long time should be avoided.
- ✓ Nutrient retention will be better in cooked unpeeled vegetables compared to cooked peeled vegetables.

## Conclusion

Vegetable is the important segment of the Nepalese meal. Vegetable preparation and cooking methodologies depend upon the preferred taste, community and social factors. Vegetable preparation practice has a significant effect on nutritional quality, especially peeling and cutting. However, peeling has been also related to food safety practices. Though cooking results in significant nutrient loss, it is essential to increase the digestibility of vegetables. However, cooking practices in Nepal is different from the other parts of the globe, research can be carried out to assess the actual loss of nutrients due to the cooking methodology applied in Nepalese kitchen.

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# Author's Biography



Pravin Ojha is currently working as Scientist (S-1) in National Food Research Centre, Nepal Agricultural Research Council. He has completed his postgraduate education in Food Technology from Tribhuvan University. He has more than 13 years of working experiences in projects, industry, academia and research. He has more than two dozens publications including journal articles, conference papers and a book chapter.



Ganga Prasad Kharel is currently Professor of Food Technology in the Department of Biotechnology, Tribhuvan University. He has completed his Doctorate in Agriculture Science (Food Technology) from Kagoshima University, Japan. He has more than 35 years of experience in the field of food science. He has more than three dozens publications including journal articles, conference papers, books, book chapters and informative articles in daily national newspaper.

# Chapter 19

## Home Garden for Health and Happiness

**Indra Raj Pandey**
*Khumaltar, Lalitpur Metropolitan Ward No. 15, Lalitpur, Nepal*
* Email: pandeyindraraj1947@gmail.com

*Home garden is the miniature of agriculture system. From well managed home garden, nutrition rich fruits, vegetables, cereals, small animals, birds and fish can be harvested. Almost all types of climates of the world are available in Nepal. Nepal can grow almost all types of foods, flowers and ornamental plants using these climatic boons and geo-physical settings for health and happiness. However, food insecurity persists sporadically and nutrition insecurity is rampant all over Nepal. Nepal Living Standard Survey 2011 and Nepal Public Health Survey 2016 both have depicted the alarming situation of malnutrition among children, adolescent girl and woman of reproductive age group in Nepal. Stunting, wastage, marasmus and underweight among children, anemia and underweight among women, and overweight among some men and women are prevalent.Malnutrition is the result of many underlying causes and improvement also needs multifarious approach. For immediate relief, vaccine and capsule may be administered; however, for lifelong nutrition security and sustainability, food based invention with fresh and healthy balanced diet, sanitation and family affection are required. To combat the alarming situation of food and nutrition insecurity, establishing and improving home-gardens for year round production of fruits and vegetables for regular supply of nutritious food throughout life-cycle is the basic necessity. Sustainable food based change from food production, consumption and preservation needs change in food attitude and behaviour. Establishment of multipurpose resource nurseries to supply planting materials to home gardeners, training individual home gardeners for nutritious food production, preparation for consumption and preservation for lean season are prerequisite. Home gardening in 100–200 $m^2$ land or if land is not available, rooftop andverandah may be used for vegetable production.*

**Keywords:** Agro-biodiversity; agro-climatic zones; ecological belts; home garden; multipurpose resource nursery; surplus production.

## Introduction

The home garden is the miniature of the whole agriculture system. It is the traditional component of the rural ecosystem that has been practiced for a long time by farmers.

*Comprehensive Insights in Vegetables of Nepal*
Sajan Lal Shyaula, Gan B. Bajracharya, Gopal K.C., Shanta Man Shakya and Dilip Subba (Editors)
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Home garden is often overlooked as an important source of food and nutrition at national level (Sthapit et al., 2004). A home garden refers to a piece of land near or around the home including rooftop and even *veranda.* Home garden regularly provides the nutrients required to the family year round and give aesthetic environment. It also serves as bio-diversity center where vegetables, fruits, medicinal and ornamental plants are produced utilizing household resource and water (FNSP, 2012). A home garden is the store of family nutrition, source of income and the base of entertainment. Well maintained home gardens not only serve as family nutrition center but also increase the prestige and pride of home dwellers. Home garden is known by different connotations such as home garden, backyard garden, homestead garden, etc. The practice of growing fruits, vegetables and ornamentals around house started along with the human civilization. When human threw hard seeds of fruits and vegetables around their residents, later they found that the seeds grew up bearing edible fruits, and then they started domestication of useful plants. During medieval age, it developed to aristocratic garden during Mughal and English rule in India, and that emitted during Rana regime in Nepal. The aristocratic gardens of those eras served as biodiversity centers and pride of aristocrats.

At present, the concept of home garden has taken a new dimension. Home garden is for the safe fruits and vegetables production for family nutrition. The modern home gardens are for growing fruits, vegetables, flowers, ornamental plants, medicinal herbs and even to keep small animals, birds and kitchen fish pond as the climate and resource permits. Different designs of home gardens; such as natural permaculture design, semi-developed and completely developed and well designed home gardens are in practice. These designs depend on the availability of land and space. Based on the ground reality of town dwellers, completely developed and well designed biodiversity home gardens, perhaps is possible only with some well to do families having sufficient land. However, growing vegetables, fruits and ornamentals in the available land, rooftop and veranda, wherever possible and whatever could be grown, has been the reality of home garden for the family nutrition, home beautification and environment protection. Present home gardens are aimed at improving nutrition to fight with malnutrition and fulfill the aesthetics.

## The Role of Home Garden to Reduce Malnutrition in Nepal

According to Nepal Living Standard Survey (NLSS, 2011), 31% of the children (below 5 years) are underweight and 42% are stunted. Poverty increases with increased number of children. Seasonal poverty is the lowest during October-January (main harvesting season) and the highest during April-July (dry and no agricultural activities in most rain fed areas). Caste identity has some relation with poverty in Nepal. About 42% of the Dalits are poor compared to only 23% among the non-Dalits. Households headed by agricultural wage workers are the poorest. Poverty rates are different in different regions and are rampant in mountain areas followed by rural hills of the mid and far west (Figure 19.1). Under-nutrition is the main underlying cause of death among children less than 5 years.

Similarly, Nepal Demographic and Health Survey (NDHS, 2017) reported that 36% children below 5 years were stunted. This stunting was 40% in rural areas compared to 32% in urban areas. Province wise it was 29% in Bagmati and Gandaki and 55% in Karnali province. On an average, 53% children between 6–59 months were anemic and it

was 56% in rural areas. Almost 42% of children in Bagmati province were anemic where as province 2 had 59%, the highest in Nepal. In 2011, anaemic children were 36% which rose to 46% in 2016. In 2006, 36% women between 15–49 year ages had anemia, which rose to 41% in 2016.

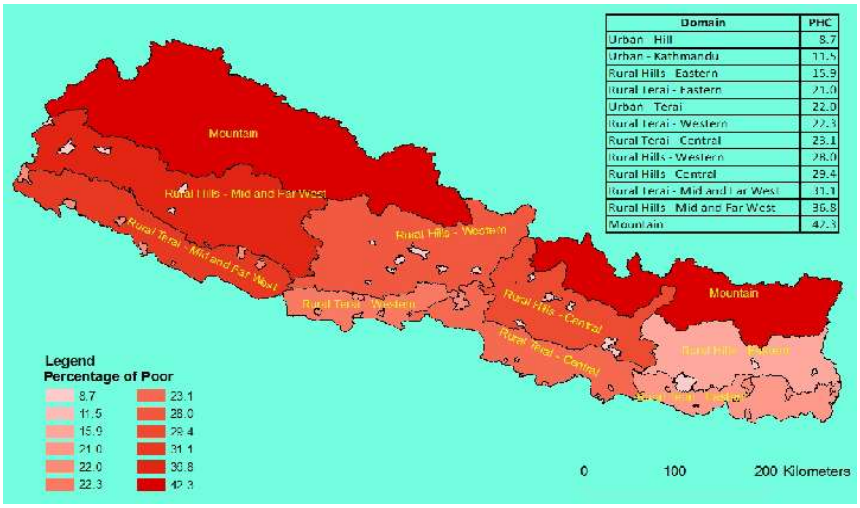



**Figure 19.1.**Percentage of the poor in different domains of Nepal.

According to Nepal Demographic and Health Survey 2016 (NDHS, 2017), 17% women between 15–49 years were lean and thin with Body Mass Index(BMI)<18.5 and22% had over weight with BMI >25.0. During 2009, 9% women had overweight (BMI>25.0) which rose to 22% in 2016,whereas, 35% rich women of Bagmati province had BMI >25.0. Among men of between 30–39 years of age, 17% were lean and thin with BMI <18.5 while 32% well to do rich men had overweight with BMI >25.0. Thus, in Nepal, nutrition and malnutrition varies among poor and rich persons. Both underweight and overweight is the sign of malnutrition. Thus, the health surveys of 2011 and 2016 revealed that malnutrition is prevalent sporadically in the country and community. This imbalance includes both inadequate and excessive energy intake; the former leading to malnutrition in the form of wasting, stunting and underweight, and the latter resulting in overweight and obesity. Malnutrition exists as vicious cycle among all aged people.

## The Vicious Cycle of Malnutrition

The vicious cycle of malnutrition seems from children to adults and senior citizens and from one generation to the next generation. The reasons of malnutrition among people are the consequence of a range of factors that are often related to poor food quality, insufficient food intake, and severe and repeated infectious diseases, or frequently some combinations of the three. These conditions, in turn, are closely linked to the overall standard of living and basic education. Under nutrition is the vicious cycle from childhood to old age and from one generation to another (Figure 19.2).

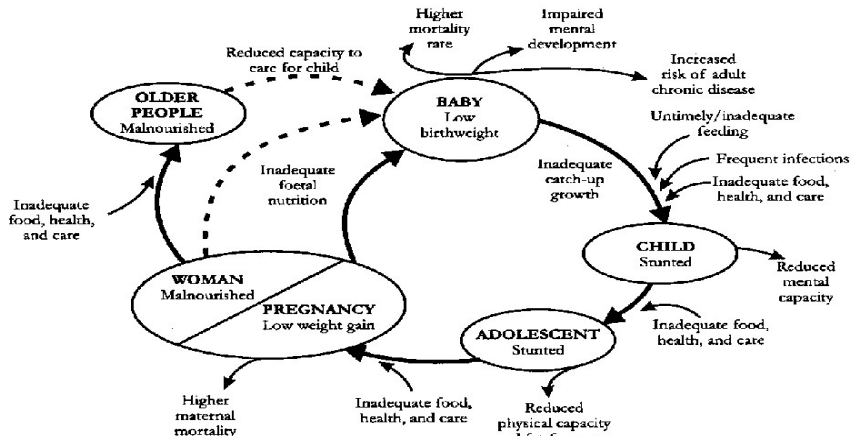



**Figure 19.2.**The vicious cycle of under nutrition (NLSS, 2011).

This vicious cycle is associated with poverty and poor nutritious food availability. To address the under-nutrition effectively throughout life cycle, food based dietary intervention with appropriate technology and guidance of production, preservation, food preparation and consumption is the need of the day.

In Nepal, lack of balance diet, especially in the rural areas, and more consumption of fatty food and junk foods, especially in the urban areas, are the causes of malnutrition. Both underweight and overweight are the result of malnutrition. In rural Nepal, where poverty is rampant, the malnutrition starts from pregnancy itself. Pregnant mothers seldom get nutritious food. The new born is underweight. Though breast feeding is there, the mother's milk is not sufficient. The poor family children are stunted and underweight. Balanced diet is dream even in adolescence. After some basic education, they cannot go for higher education. Soon they meet the legal age or sometimes even under legal age they are married. In Nepalese society, it is the responsibility of parents to organize marriage of their children. After marriage, in some orthodox family, parents do not take food in married in-laws house till daughter gives birth to a child. This inspires new couple to produce child earlier. Thus, poor nutrition in childhood, poor education, early marriage, early pregnancy, low income and again malnutrition even in next generation continues the vicious cycle of malnutrition from one generation another.

## Home Garden to Break This Vicious Cycle

Malnutrition is frequently a part of the vicious cycle that includes poverty and disease. These three factors are interlinked in such a way that each contributes to the presence and permanence of the others. Socioeconomic change and political commitment can improve health and nutrition that break the cycle by implementing home garden production of fruits and vegetables, specific nutrition education and health interventions. The WHO Global Database on Child Growth and Malnutrition seeks to contribute to the

transformation of this cycle of poverty, malnutrition and disease into a virtuous one of wealth, growth and health through the improvement in food intake as defined in food security and nutrition security (WHO, 1986).

## Food and Nutrition Security

### *Food Security*

Food security is a state when when all people at all times have both physical and economic access to sufficient safe food to meet their dietary needs for a productive and healthy life. This statement describes three conditions: (a) food availability,(b) food affordability, and (c) food consumption. Any hungry person needs food security first and then goes for nutrition security (ESA, 1996).

### *Nutrition Security*

Nutrition security is a state when all people have access to safe food stuffs with sufficient quantities of carbohydrates, proteins, minerals, fats and vitamins regularly throughout the life cycle for healthy living (ESA, 1996). Proper nutrition requires ingestion and absorption of fibers, vitamins, minerals, and food energy in the form of carbohydrates, proteins, vegetable oils and fats. Dietary habits and choices play a significant role in quality of life, health and longevity, and can define cultures and play a role in religion (USDA, 2010). The constitution of Nepal, BS 2072 recognizes "Food sovereignty and right to food" as one of the fundamental rights of the people(GoN, 2015).

### *Attainment of Food and Nutrition Security*

'Food and Nutrition Security' definitions dictate to increase the availability, affordability and consumption of balanced food with sufficient quantities of carbohydrates, proteins, minerals, fats and vitamins regularly throughout the life cycle for healthy living. Nutrient deficiency is the main cause of stunting, wasting and marasmus in children. It occurs in those children who don't ingest enough protein, calories, carbohydrates, and other important nutrients. This is usually due to poverty and scarcity of food. To break this vicious cycle, people must be inspired to increase production and productivity from home gardening including rooftop and veranda gardening. Together with production technology nutrition education with focus on proper cooking, consuming and preserving the foods for lean season must be combined. Change in food habit and attitude towards food is necessary. People grow up and behave as per the food they eat (Baiddhya, 1991). With the consumption of balanced diet or food, this vicious cycle of malnutrition can be broken. Fruits and vegetables help to combat the alarming situation of food and nutrition insecurity.

For both food and nutrition security, fruits and vegetables are rich source of dietary fiber, vitamins, minerals, especially electrolytes; and more recently phyto-chemicals especially antioxidants. Various reviews have shown low intake of fruits and vegetables as the underlying causes of malnutrition among children. Among adolescent and adults, low body mass, chronic diseases such as cardiovascular diseases, blood pressure, hypercholesterolemia, osteoporosis, many cancers, chronic obstructive pulmonary diseases,

respiratory problems as well as mental health are the common problems due to poor nutrition. Despite the increasing focus on the health benefits of fruits and vegetables, their consumption in most of the developing countries is below the recommended intake average 300g/day (280–375g/day/person (Acharya & KC, 2017). Fruits and vegetables play a significant role in human nutrition, especially as sources of vitamins (A, C, E, B6, thiamine, niacin, etc.), minerals and dietary fiber. Other important nutrients supplied by fruits and vegetables include folacin, riboflavin, zinc, calcium, potassium, and phosphorus. United States Department of Agriculture (USDA) Dietary Guidelines has encouraged consumers to enjoy five servings a day, i.e. eat at least 2 servings of fruits and at least 3 servings of vegetables(USDA, 2000). While serving each day, it is suggested to choose a variety of colours and kinds, dark green leafy vegetables, dry beans and peas, and different colored fruits and vegetables.

## *Components of a Balanced Diet*

A balanced diet consists of safe food stuffs with sufficient quantities of carbohydrates, proteins, minerals, fat and vitamins. For this, each meal should be based on different vegetables. Cereals should constitute only half of the meal. For protein legume supplement is compulsory. Fruits such as papaya, pineapple, straw berry, mango, guava, banana, temperate fruits or fruit vegetables must be included in the meal. Foods of animal origin should be nearly equal to 15% of the total meal and should always be eaten with vegetables. Variety of foods is best because one kind of food does not fulfill all the required nutrients. Fiber is called the body's broom because the insoluble fiber binds with water to usher/escort waste out of the body. Normally acid-alkali ratio in blood should be 20:80. Maintenance of this ratio is essential to keep the body healthy. All toxic substances in the body are in the form of acid and to prevent the accumulation of acid in the body, people must take food that is mainly alkali-genic. Vegetables like spinach, leafy salad (lettuce),cucumber, turnip, sweet potato, radish, cabbage, cauliflower, onion, etc. are alkali-genic. All these contain alkali-genic effect ranging from 3 to 28%. The alkali-genic vegetables are an efficient eliminating and cleansing agency (FNSP, 2012).There are three major kinds of foods to be eaten:

1. ***Energy food*** is required to stay alive, be active, move and work. Energy food includes rice, maize, wheat, millet, buck wheat, oat, etc. that are rich in carbohydrates, and fats like ghee and oils that provide energy.
2. ***Growth and developmentfood*** is required to build new cells and tissues for growth and development. Such body building food includes meat, fish, egg, and legumes that are rich in protein.
3. ***Health protective food***is required to stay healthy and to repair and maintain the body's cells, and to prevent and fight infections. Such food includes vegetables and fruits, which are rich in minerals, vitamins and amino acids.

The food items which provide all above functions are called balanced diet. An average adult person needs different food components per day (24 hr food cycle) as presented in Table 19.1.

**Table 19.1.** Quantity of different food components per day (24 hr food cycle)

| S. No. | Daily food component | Quantity |
|---|---|---|
| 1 | Carbohydrates (Depending on work type) | 500–1,000 g |
| 2 | Protein | 50–55 g |
| 3 | Different minerals | 400–500 mg |
| 4 | Vitamin A | 3,000–4,000 µg |
| 5 | Vitamin B | 20–30 mg |
| 6 | Vitamin C | 50–60 mg |
| 7 | Fats (Depending on body condition) | 20–50 g |

Source: (DFTQC, 1994)

To meet the requirements of protein, minerals and vitamins, the required quantities of different fruits and vegetables as refined is presented in Table 19.2.

**Table 19.2.** Requirements of vegetables and fruits per day (24 hr food cycle) for an adult person

| S. No. | Daily vegetable and fruit component | Quantity |
|---|---|---|
| 1 | Green leafy vegetables (rayo, spinach, cress, etc.) | 100–125 g |
| 2 | Root and tuber vegetables (radish, turnip, carrot, etc.) | 100–125 g |
| 3 | Legume vegetables (peas, French beans, faba bean, etc.) | 50–75 g |
| 4 | Fruit vegetables (tomato, eggplant, cucurbit fruits, etc.) | 30–50 g |
| | **Total vegetable** | **280–375** g |
| 5 | Different fruits (apple, mango, orange, banana, etc.) | 100 g |

Source: (Acharya & KC, 2017)

The recommended daily consumption quantity of vegetables is 280–375 g and 100 g fresh fruits to remain healthy. These recommended quantities are on an average. This amount varies from the age and sex of person and kinds of work he or she performs. The details of nutrients required for the persons of different age and sex are presented in Annex 19.1,edible percentage of different vegetables and fruits in Annex 19.2,and quantity of foods to avail the amount of nutrients as mentioned in Annex 19.1is presented inAnnex 19.3(DFTQC, 2017)**.**

## *How to Manage Balanced Diet*

The required nutrients to balance the diet may be availed from plant sources like vegetables and fruits. To avail and consume all required fruits and vegetables by all people across the life cycle and to meet the nutrient requirement, there may be three possible options: (1) buying all required quantities of fruits and vegetables from the market, (2) growing all fruits and vegetables year round from home and rooftop garden, and (3) growing whatever is possible in home and rooftop garden and buying what is not possible to grow.

Among three possible options, rich people, especially city and apartment dwellers, may go for the first option; rural and semi-urban people may go for the second option, and urban people with limited land may go for the third option. To manage balanced diet from option two and three, the physical settings and climatology of Nepal is highly favourable. The physiographic settings and opportunities must be understood and explore the production of suitable fruits and vegetables in the locality where people reside.

## Physical Settings of Nepal

### *Physiographic Settings and Opportunities*

Nepal is situated in the lap of Himalaya as trapezoidal shape in northern hemisphere from 26°22' to 30°27' North latitude and 80°04' to 88°12' East longitude. The expansion is 880 km in length from east to west and 150–250 km range width from north to south. Its total area is 1,47,516km$^2$. The altitude ranges from about 60 mamsl in the eastern terai to 8,848 m amsl, the Mount Everest, the highest summit of the world. Almost all types of world climate and a wide range of agro-biodiversity exist in Nepal.

The physiographic map of Nepal (Figure 19.3) describes five ecological belts; high Himalaya (2,500–8,848 m), high mountain (2,000–2,500 m), middle mountain (700–2,000 m), Siwalik (300–700 m) and terai (<300 m). Four distinct seasons (spring, rainy, autumn and winter), four aspects of hills and mountain (south, north, east and west) makes many micro-climatic zones and have provided agro-climatic wealth to Nepal. Almost all types of world climate and a wide range of agro-biodiversity exist in Nepal (HMG, 1983).

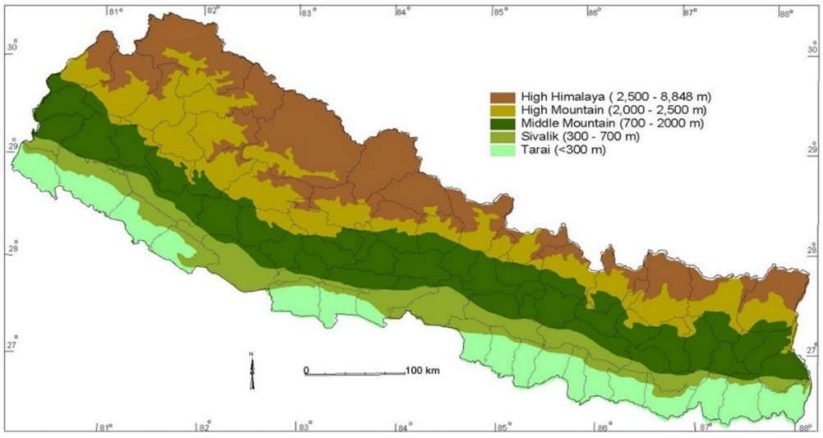



**Figure 19.3.**Physiographic map of Nepal(Source: Topographic Survey Branch, Department of Survey, His Majesty's Government, Nepal, 1983. This is an old map, as new map is readily not available).

Nepal receives monsoon rain during summer from Arabian Sea and Bay of Bengal. Winter rain is received from Mediterranean Sea. From the agricultural production practices, there are three main production seasons like dry season (mid February to mid June), rainy season (mid June to mid October) and winter season (mid October to mid

February). The combinations of ecological belts, four aspects (facings) of the hills and three production seasons provide many micro-climatic production pockets. These micro-climatic pockets favour for many kinds of horticultural crops production and provide comparative advantages. Though, there are three distinct production seasons; however,most vegetables overlap from one season to another. Some vegetables planted during winter season is harvested during dry season, while others planted during dry season continue to grow and can be harvested up to rainy season, and rainy season planted crops go up to winter. Fruits being long term permanent plantation crops, they are specific to agro-ecological zones/climatic regions.

## *Production Opportunities at Different Agro-climatic Regions*

The micro-climates and specific favourable pockets provide vast opportunities for the production of fruits and vegetables to combat food and nutrition insecurity and get rid of malnutrition. Specific commodities can be produced in specific climatic pockets during different production seasons. The production of one production pocket can also be supplied to other areas as off-season production for consumption and to earn income for producing pockets. Nepal's horticultural bio-diversity includes around 45 species of fruits and 200 species of vegetables (Regmi, 1982). Among 200 vegetables species, 127 are in use with 57 leafy, 14 stem, 36 fruit, 11 legumes, and 15 root and tubers type of crops (Pandey et al., 2018). The major climatic regions and production opportunities of different fruits and vegetables are described under different micro-climatic regions as elucidated (Shrestha, 1989; VDD, 1993).

## *Trans Himalayan Region*

High Himalaya is classified above 2,500 m to Mount Everest which is mostly covered with snow and has limited agricultural potentials. However, Trans-Himalayan region ranging from 2,500 to 4,000 m resembles with Tibetan plateau with dry and cool valleys (Manang, Mustang, Dolpa, etc.). The average daily temperature during winter (December/January) fluctuates from –9–10°C. During summer, from April onward till September, average temperature remains between 10–21°C. This specific region has production opportunities for specific perennial fruit crops like apple, apricot. etc. and vegetable crops such as cole crops, root crops and leafy vegetables, and local beans for home and local consumption, and also as off-season marketing to lower altitude areas during dry season through rainy season.

## *High Hills*

The high hills between 2,000–2,500 m are mostly the top of the Mahabharata range. The summer average temperature is between 10–15°C and maximum temperature is around 25 °C. The average temperature during summer varies from 10–25°C, and in winter, it goes below –0°Celsius. The Mahabharata high hills often receive snow falls and snow cover is common during winter and it is chilly. During spring, through rainy season, high hills favour for production of fruits and vegetables during different seasons as presented in Table 19.3.

**Table 19.3.** Vegetables and fruits to grow during different seasons at high hills

| Dry season (mid February to mid June) | Rainy season (mid June to mid October) | Winter season (mid October to mid February) |
|---|---|---|
| Tomato, eggplant, chili, sweet pepper | Tomato, eggplant, chili, sweet pepper, | Garlic, onion |
| Squash, cucumber, bitter gourd, bottle gourd | Cucumber, bitter gourd, bottle gourd, pumpkin | Peas, faba bean |
| Radish (Tokinasi),turnip, carrot | Radish (40 days, Mino Early), carrot | Carrot,turnip |
| Early cauliflower, cabbage, knol-khol | Cauliflowers, cabbage, knol-khol, broccoli | Cauliflower, cabbage, broccoli, knol-khol |
| Broad leaf mustard, cress, spinach, coriander, fenugreek | Broad leaf mustard, coriander, lettuce | Broad leaf mustard, coriander, lettuce |
| Bean, asparagus bean, taro, yams | Okra, taro, yams, bean, soybean | |
| Fruits: apple, apricot, plum, peach, pear, walnut, pica nut, sea buckthorn, kiwi, strawberry, etc. | | |

Source: (Pandey et al., 1999;Pandey, 2000)

## *Mid Hills*

Mid hills extend from east to west with the varied elevation and aspect from 700 to 2,000 m. Summer temperature varies from 20–35°C during summer months. Mild warm temperate climate is experienced during winter with an average temperature of 10–15 °C, which favours all types of vegetables during spring, rainy and winter seasons. Mid hills have the vast opportunities of growing various fruits and vegetables. Mid hills can further be classified as lower mid hills (700–1,500 m) and higher mid hills (1,500–2,000 m). Almost all types of vegetables are produced in these areas during different seasons of the year. Major fruits like mandarin, sweet orange, lime, lemon, and other fruits such as pummel,peach, plum, kiwi, papaya, guava, avocado, dragon fruits etc. are grown in mid hills (Table 19.4).

**Table 19.4.** Vegetables and fruits to grow during different seasons at mid hills

| Dry season (mid February to mid June) | Rainy season (mid June to mid October) | Winter season (mid October to mid February) |
|---|---|---|
| Tomato, eggplant, chili, sweet pepper | Tomato, eggplant, chili, sweet pepper | Cauliflower, cabbage, knol-khol,broccoli |
| Cucumber, bitter gourd, bottle gourd, sponge gourd, squash | Cucumber, bitter gourd, bottle gourd, sponge gourd, pumpkin | Carrot, radish, turnip |
| Radish (Tokinasi), turnip (red) | Radish 40-days | Garlic, onion, cress, spinach |
| Swiss chard, amaranth, buckwheat, sweet potato, | Bean, soybean, asparagus bean, okra | Swiss chard, coriander, fenugreek, broad leaf mustard, lettuce |
| Bean, asparagus bean, asparagus | Taro, yams,sweet potato | Peas, faba bean |
| Cabbage, knol-khol | Early cauliflower | |
| Fruits: mandarin, sweet orange, lime, lemon, pummel, peach, plum, kiwi, papaya, guava, avocado, dragon fruits, etc. | | |

Source:(Pandey et al., 1999; Pandey, 2000)

### *Terai, Inner Terai, Siwalik and River-Basins*

These areas consist of terai plain, inner terai, Churia hills, lower foothills of Mahabharata range with Tars, deeply cut river basins having elevation up to 700 meter above mean sea level (mamsl). The summer temperature in these areas varies from 30–38°C (sometimes goes up to 42°C. The average winter temperature varies from 15–20 °C with minimum temperature around 5 °C. Cold wave and foggy days make trembling cold sometimes during winter in terai. These areas have warm temperate climate during winter, sub-tropical to tropical during spring and rainy season. Almost all kinds of vegetables can be grown adjusting the sowing time in different seasons. During winter, vegetables such as tomato, eggplant and sweet pepper together with temperate vegetables can be grown in the terai plain. Vegetables grown in terai and inner terai during winter are the off-season products for markets and cities of the hills and high hill. Among fruits mango, litchi, banana, pineapple, papaya, jackfruit, pomegranate, guava, low chilling peach, etc. can be grown (Table 19.5).

**Table 19.5.** Vegetables and fruits to grow during different seasons at terai, Siwalik and basins

| Dry season (mid February to mid June) | Rainy season (mid June to mid October) | Winter season (mid October to mid February) |
|---|---|---|
| Swiss chard, amaranth, Patuwa, Poi sag, sweet potato, Karmi sag | Poi sag, sweet potato, Karmi sag | Cauliflower, cabbage,knol-khol, broccoli, tomato, eggplant, chili, sweet pepper |
| Cucumber, pumpkin, sponge gourd, bottle gourd, bitter gourd, squash | Cucumber, pumpkin, sponge gourd, bottle gourd, bitter gourd, snake gourd | Radish, turnip, carrot, garlic, onion, peas, beans, faba bean |
| Bean, asparagus bean, sweet potato, okra, taro, yams | Bean, asparagus bean, soybean, okra, taro, yams | Broad leaf mustard, cress, lettuce,spinach, coriander, fenugreek |
| Fruits: mango, banana, papaya, pineapple, litchi, pomegranate, chiku, sapota, jackfruit, guava, etc. | | |

Source:(Pandey et al., 1999; Pandey, 2000)

## Home Garden

Food and nutrition security dictates to increase production and productivity of home garden including rooftop and veranda garden. Together with production technology, nutrition education for cooking, consuming and preserving the produce for lean season must be combined. Change in food habit and attitude towards food is also necessary. This is possible through improved home gardening and nutrition education.

A home garden refers to a piece of land near or around the home including rooftop and veranda where vegetables, fruits, ornamentals, medicinal plants, bee keeping, fish farming, poultry keeping, small livestock, etc. (whichever possible) are produced utilizing household waste water, homemade compost and using family labour for year round production and consumption of nutritious foods and surplus sale in the local market. To improve nutrition from home gardening, it requires basic production skills,

production inputs, and food preparation and consumption techniques. Based on the dietary research, 280–375 g of vegetables, including dark green leafy vegetable, legumes, fruit vegetables, root vegetables and 100 g fruits are required per day per average adult person (Acharya & KC, 2017).

## *Objectives of Home Garden*

The general objectives of home garden are to produce fresh vegetable, fruits and ornamental plants; maintain small animals and birds/fish; provide nutrition to family members regularly; and also to earn some income through the surplus sale in the local market. The hidden objectivesare to enjoy aesthetic value, improve house hold surroundings and enjoy natural beauty at home. Specifically, home garden must fulfill the following five objectives:

1. Produce and increase consumption of fresh and healthy fruits and vegetables for family.
2. Beautify home by growing seasonal flowers, ornamentals and medicinal herbs.
3. Depending on local resource and climate, keep small animals, birds and fish for nutrition.
4. To balance the family diet with veggie and animal proteins regularly.
5. Improve home environment through greenery and enjoy aesthetic amusement.

## *Benefits from Home Garden*

Home garden is the miniature form of all agricultural system. Home garden gives the following benefits to the family members.

1. Healthy and safe fruits and vegetables would be available regularly.
2. Self inspired physical works and exercises give mental peace and improve health.
3. Family members understand the relation among plants, nutrition and environment.
4. Increases availability of fresh, clean and vitamin and mineral rich fruits and vegetables.
5. House hold garbage and waste water used for composting and home garden irrigation.
6. The environment around house would be clean and pleasant due to gardening.
7. Saves time and money for vegetables purchasing from the market.

## *Family Consent and Commitment to Start Home Gardening*

Home gardening should run with the common understanding and efforts of all family members. The use of family labour, garbage, household resources and use of used water are the committed conditions to achieve the objectives of home gardening. The aim of home garden is to produce year round fresh vegetables, fruits, flowers, ornamentals and where possible to include small animals, birds and fish in the complex home gardening system. Fence and interrelationship between plants and animals in the home gardening is a big challenge. To maintain regular supply of fresh fruits and vegetables to kitchen, maintain pleasant environment around home and sale surplus produces, there is a need of consciousness among all the family members with specific responsibilities of compost making, waste water use, home garden designing with specific places to specific functions. Home gardening planning approved by the family members and acceptance of specific jobs

by each member of the family are the key to success. Sharing the responsibility among family members for composting, planting, placing the pots at appropriate places in rooftop gardening, watering and weeding are of prime importance. Home garden planning, layout, planting material management, planting calendar, care and maintenance of each species of plants, their harvesting, etc. need practical knowledge and skill. It is easy to produce one or two crop varieties for commercial cultivation; however, in home garden, several crop plants are to be dealt with and needs wide range of information. All family members must be active, and keenly interested. There are three major aspects of home gardening.

1. Establishment of home garden in specific land area, verandah and rooftop with fence.
2. Adoption of organic or safe production techniques and system.
3. Year round production plan of various crops to meet the family nutrition needs.

## *Estimation of Annual Need of Vegetables and Fruits*

As per the analysis of Table 19.2, an adult person needs 280 to 375 g of cleaned and ready to cook vegetables and 100 g fruits to meet the protein, vitamins and mineral needs for a day (24 hr cycle). As fruit is a long term crop, it will be dealt separately. First, let us consider for the vegetable. If there are 5 people in a family, the family needs 1,875 g (375 ×5=1,875) i.e. roughly 1,800 g. Freshly harvested vegetables from garden or bought from the market give 90% edible parts of vegetable (Annex 19.3). Thus daily need is 2 kg fresh vegetable for a family of five and yearly need comes to be 760 kg. Festivals and guests may increase this quantity to 900 kg per year.

## *Area Required for Producing Estimated Quantities of Vegetables*

It is important to decide how much land should be allocated to plant vegetables to maintain the supply of vegetables all the year around to fulfill the need. Generally, depending upon soil fertility, crop intensity and geographic region, 100–150 $m^2$ land is sufficient. As per the estimation of 900 kg vegetables required annually for the family of five, we can calculate exact land based on some assumption. This amount is to make balanced diet to fight with malnutrition. The allocation of land for a home garden depends on soil fertility, number of family members, geographic location, cropping system and the grower's knowledge, skills and experience to produce the required quantity of vegetables. Now, let us discuss about the required area of home garden to produce the required quantity. In general, soil fertility, cropping intensity and production skill of owner decide the land requirement. From intensive home gardening, it has been proved that on an average 3 kg fresh vegetable can be produced from 1 $m^2$ land in a crop season and three crops can be grown in a particular piece of land in a year. Thus, 9 kg vegetables can be harvested from 1 $m^2$ land in a year with 300% cropping intensity. Therefore, for 900 kg production, we need 100 $m^2$ net land (900÷9=100). Ditch, ridge, walk path, compost pit and water pond needs additional 25 $m^2$ and another 25 $m^2$ for fruits, seasonal flowers, small animals and birds/fish. Thus, total ideal land for perfect home gardening needs 150 $m^2$. This 150 $m^2$ is very ideal one which may be possible for some rich people in the cities and urban areas. However, it is not possible for semi-urban and rural households easily. City dwellers can start their home garden with the land they have and as a complement to home garden, rooftop and verandah garden can compensate for the purpose. Few pots, old utensils, wear and tear tires and fish box can help to start the rooftop garden.

## *Planning and Designing a Home Garden*

Since the start of planned agriculture development, Department of Agriculture (DoA) designed and demonstrated planned home garden through its extension system. UNICEF distributed home garden seed packets in collaboration with DoA and Agriculture Development Bank (ADB). Helen Keller International (HKI) has demonstrated three types of home garden e.g. traditional, semi-developed and developed based on layout, line sowing and design. Center for Environmental, Agricultural Policy Research, Extension and Development (CEAPRED) and Local Initiation for Bio-diversity Research and Development (Li-BIRD) have defined home garden as per the local situation. There are several names, opinions and explanation about home garden by different botanists and horticulturists. Whatever the definition and explanation may be, at present, home garden is an art and science both. From lazy permaculture design to scientifically designed modern model of home gardens are in practice. Planning and well designed outline of home garden is necessary to meet the increasing demand of healthy and fresh fruits and vegetables through limited land and home premises available.

The planning and design of home gardening depends on the availability of land around the home, verandah, rooftop and parapet. Wherever the place is available, it is better to start planting vegetable, fruits, flowers, medicinal herbs and ornamentals including bonsai. The main purpose of home garden is to supply nutritious food and provide aesthetic value with beautiful natural environment. If someone has 100-200 $m^2$ rectangular land, she/he is lucky enough. However, this is not available to most persons. Therefore, one should start home garden with positive attitude with whatever the land and space they have. An example of a complete home garden design with 125 $m^2$ rectangular plot with path, channel, compost pit, water pond, nursery plot and sowing beds for different vegetables is shownin Figure19.4(Pandey et al., 1999).

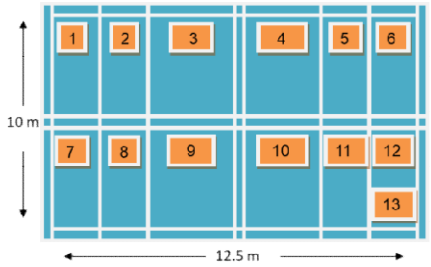



**Figure 19.4.**Home garden design adopted from Pandey et al. (1999) related to Tables19.3, 19.4 and 19.5.

While designing the garden, different plots of 5–10 $m^2$ sizes are made and numbered to facilitate the planting of the fruits and vegetables as described in Tables19.3 to 19.5 and expanded annual cropping pattern as presented in Annexes19.4, 19.5 and 19.6 for different agro-ecological regions (CEAPRED, 2012; Pandey et al., 1999).

The developed home garden must have three important components such as layout, line sowing and live fence (Pandey et al., 1999). Developed home gardens have outline of paths, drainage and irrigation channel, compost pit, water pond, nursery plots and planting plots of 5 or 10 $m^2$ sizes. This helps to maintain regular production of vegetable crops

throughout the year. To facilitate the planting of fruits and vegetables as described in Tables19.3, 19.4 and 19.5, and expanded annual cropping pattern as presented in Annexes 19.4, 19.5 and 19.6for different agro-ecological regions, the layout of a home garden should consider the following points:

1. The layout should have maximum utilization of land for cultivation and minimum for paths and channels.
2. The design may be made with length 12.5 m east-west and 10 m north-south with 50 cm wide walk path at the center, 25 cm wide and 25 cm ridges or trench all-around the plot.
3. Raised beds for monsoon season and sunken beds for winter and dry seasons with 1 or 2 m width.
4. There should be 30 cm wide channel or ditch between two plots (beds).
5. While making beds, if possible, make north-south facing beds to favour sunshine in all the parts of plants during morning or evening
6. Water pond, compost pit, nursery plots and irrigation channels should be made at appropriate places as indicated in plot numbers 12 and 13.
7. Mixed fencing should be built around the home garden using live fences or bamboo.
8. The plots should be mapped on paper and given numbers (1, 2, 3, 4,…..13). This helps maintaining of crop system and crop rotation.

Based on the plots numbers, different crops can be planted in different months as shown in Annexes19.4, 19.5 and 19.6 and Figures19.5, 19.6 and 19.7.



**Figure 19.5.**North south facing beds for proper sunshine.



**Figure 19.6.**Some models of home gardens.

The design and planning of a home garden may be done from a small piece of land to an ideal piece of land having lawn, fish pond, resting swing, badminton court, ornamental plants, architectural idols and different amusing structures as per the availability of the

land and the will of the owner. Home garden is the pride for aristocrats and rich people. For middle class and poor people, it is the main source of food, nutrition and income generation from surplus sale.



**Figure 19.7.**Rural and urban models of home garden.

## *Important Points to be Consideredwhile Selecting Vegetable Types for Home Garden*

While planning and maintaining a home garden for maximum production and productivity, *layout, line sowing* and *live fence*are the three important components. Then, while selecting vegetables for planting, vitamin A rich vegetables like green leafy vegetables, carrot, *Bethe*, sweet potato, etc. should be included in the plan according to the region, season and the family's choice. Plots should be allocated for different vegetables, e.g. it would be easy if vegetable that requires frequent watering is planted in a plot nearest to the water source. Also we need to think about crop rotation. Instead of planting the same crop on the same plot every season, the crops should be rotated. This helps in pest/disease control. Similarly, if long rooted crop is planted following a short rooted crop, nutrients of both layers will be utilized. Planting strong smelling crops like garlic, *Tulsi, Hade lasun*, marigold, calendula, peppermint, leek, etc. with other crops helps in pest/disease control. The plots once laid out can be used again for the next crop. Families with limited land may plant vine crops by training and directing them on the wall of rooftop, e.g. pumpkin, beans, runner beans, bottle gourd, etc. Priority may be given to the crops like sweet potato and taro of which both leaves and roots can be consumed for long time. Vegetables like tomato and chili may be planted in pots in a place that gets maximum sunlight. Different crops require different amounts of nutrients, sun, shade, moisture, etc. and therefore complementary crops should be planted. Weeds should be utilized for making compost, putting it in compost pit or in drum incorporating earthworm. Waste from cattle and house and wastewater should be properly utilized. Perennial fruit crops according to the climate should be planted in order to maintain a nice environment around the house. The home garden should always have something to be planted. Planting vegetables at 10–15 days difference maintains regular supply. Irrigation and drainage should be carefully maintained in every plot and pots.

Temperature and the length of the day affect most vegetable crops. Some vegetable crops require high temperature to grow properly, e.g. taro, lady's finger, amaranth, cucumber, pumpkin, etc. while some vegetable crops require low temperature, e.g. cabbage, carrot, cauliflower, spinach, radish, turnip, mustard, etc. Some vegetables can

grow in very dry and hot season, e.g. sweet potato, Swiss chard, etc. Vegetable crops can be grown and harvested all the year round, if the crop and season are carefully planned. The vegetable crop which can be harvested earlier needs to be picked regularly and should be planted on the plot nearest to the house and the crop which grows slow and can be harvested at once should be planted on the farthest plot. Some special points to be considered are as:

- Planting crops like radish, carrot, Swiss chard, turnip, mustard, garlic, mint and coriander on the sides of cauliflower and cabbage plant saves space and act as insect repellent.
- Gourds can be planted by putting a shed on compost pit or near the fence.
- Perennial crops (mint, asparagus and tree tomato) are planted at one side of the field.
- Fruit trees are planted at the northern side to prevent shade on the field.
- If crops are planted in a row going north-south, all parts of the crop will get sunlight.
- Shade loving crops should be planted on part of the field with trees and big plants.

## Rooftop and Verandah Garden

The resident of cities and towns, who have limited land or no land for ground home garden, may go for rooftop and verandah garden (Figures19.8 and 19.9). Sunny side of the rooftop may be best for rooftop gardening; however, some shade loving plants (cress, Rayo, etc.) can be grown in shady areas also. Planting seasonal flowers and ornamentals in earthen pots (Gamala) are the old traditional culture in Nepal. However, the vegetable production in the pots was initiated during 1985/86 in Vegetable Research and Seed Production Center,Khumaltar using different sizes of earthen pots and plastic pots. After two years of study, 30 cm diameter pots and 25 cm diameter plastic bags were found suitable for most annual vegetable production. As a growing media,mixture of loam soil (2 parts), well decomposed farm yard manure (FYM) or compost (2 parts) and sand (1 part) was found best among other media (Pokhrel & Pandey, 1986; Pandey, 1998). Different production technologies developed and demonstrated by CEAPRED and Lalitpur Metropolitan city (CEAPRED, 2012; Pandey, 2013; Thapa, 2016) have been well recorded and documented.

Recently the government has also initiated rooftop gardening in Kathmandu valley by Agriculture Knowledge Center with new approaches of using coco peat and light plastic pots. Based on all these study and experiments, the average number of pots and plants, recommended crops and varieties, and estimated productions are presented in Annex 19.7. Rooftop gardening may also be grown for aesthetic amusement and complementary to land home garden. Each gardener may produce his/her own quality compost from house hold garbage and vermin-compost can also be used. They can also use quality compost and organic manure available in the market. In rooftop gardening, vegetables which give multi harvest for long time and grafted dwarf fruits plants like mandarin, peach, kumquat (Muntala), Japanese persimmon, dragon fruit, Papino melon, etc. may be planted. Rooftop garden increases greenery in the cities and play very important roles.



**Figure 19.8.**Some examples of rooftop garden.



Coriander Spinach Cress

**Figure 19.9.**Leafy vegetables in rooftop garden.

## *Management of Planting Pots for Rooftop Garden*

Different kinds of planting pots are available in the market. Earthen (Gamala), plastic (Gamala), cement (Gamala) and special light plastic pots are available for planting. The sizes vary from 15 cm diameter to as wide as 45 cm diameter. Depth varies as per the diameter. Besides, old buckets, ruined tires, wooden boxes, fish imported boxes from India and even card board boxes (at least for a season) can be used for planting. Among all these planting pots, earthen pots (Gamala) are environmental friendly, and if handled properly, last for five years or more. It maintains temperature and also preserves moisture and should be promoted for using. If earthen pot culture is promoted, local ceramic pot industry and traditional occupation and culture will be maintained, and also sustain the potter's occupation.

## *Preparation of Soil/Compost Media to Fill the Pots*

Though coco peats and imported materials for filling the pots are available in the market, locally prepared soil-compost pot filling media is cheaper and durable. This can be prepared as follows:

- Collect fertile, healthy soil and make it pulverized.
- Collect well decomposed compost or FYM or purchase organic manure available in the market.
- Collect clean sand and sieve them separately and make uniform.
- Mix one part of sand, two partsof soil and two partsof compost, and then stir to make a uniform mixture.
- To prevent from insect and fungus attack, mix 100 g Neem cake and 50 gtricoderma or any organic pesticide per 10 kg media mixture. Fill the pots with the mixture and plant seeds/seedlings.

## Multipurpose Resource Nursery

Home gardens and rooftop gardens need continuous supply of quality seed, seedlings and saplings. Gardner cannot produce all seedlings and saplings they need. Some seeds can be saved; however, for sustainability and continuity, Multipurpose Resource Nursery (MRN) as local enterprise in each ward should be established to serve the purpose(Figure19.10). Municipalities with the technical support from Agriculture Knowledge Center (AKC) should identify progressive entrepreneur farmers and support them to establish MRN. Such MRN could be established at least one in each present municipality ward. With the initial support from municipality, MRN will start producing seedlings and selling to the clients. During 1st and 2nd year, it may need some material and training support from the municipality and AKC may be needed. From 3rd year onward, MRN should sustain itself and continue imbedded services to the clients as business enterprise. MRN can also be used as training venue for the new clients. MRN also can manage sales of rooftop garden pots, locally prepared tricoderma-treated FYM and other inputs, organic pesticides in addition to seed, seedlings and saplings. MRN should be linked to Horticulture Farm/Centers for source seed and mother plants.



**Figure19.10.**A glance of multipurpose resource nursery.

## *Fencing*

Both home garden and MRN should be protected from animals, birds and children, for which permanent wall or hedgerow live fence may be built. Fences should be made with locally available, long-lasting and multi-purpose material. Building a wall around the home garden is expensive due to requirement of various building materials and labour. The temporary fence made with bamboo needs to be made every year and becomes expensive on the long run. Live fence is an easy alternative which is also environmentally friendly. Live fence may be made by hedgerow of useful plants which can be used to prepare botanical pesticide/medicine feed for cattle or even eat as vegetables. Planting small sized plants as fence protects the home garden and maintains the environmental condition as well. Therefore, having a live fence around the home garden is the most appropriate. Plants which can be used as live fence includes, depending on geographical areas, Nilkanda, *Flemingia*, Tanki, Karuna, Rambhuja, epil, croton, black and white chitu, Simali, Asuro, mulberry, Khursaniphul, Jai phul, bogamedula, Timur, raspberry, blackberry, *Jatropa*, Titepati, stinging nettle, *Moringa*, Kanikephul, etc. Other local plant species as per available may be used.

## *Irrigation and Drainage*

Most vegetable crops contain 80–90% water. Moisture content of soil plays an important role in growth and development of plants. To maintain this water content, crops need to be watered regularly. The main aim of managing irrigation for a home/rooftop garden is to provide the required moisture regularly at a low cost. The timing and the number of times the vegetable crops need watering depend on the root system, moisture content of soil, planting media and weather. Rainy season may not require much watering; however, winter and dry seasons need frequent irrigation. Roots and root hairs of the plants absorb moisture as well as the necessary nutrients from the soil. Low moisture content in soil pots results in wilting of the crop. Therefore, to maintain the turgidity of plants, regular watering and preserving moisture content of soil are most important. The critical stages of irrigation in garden plants include seed germination, transplanting, manuring, weeding, bolting, flowering and fruiting. The irrigation sources and methods may be as:

| Sources | Methods |
|---|---|
| Rivers/ Streams/ Wells | Irrigation channel/piping/fetching |
| Tap /Rain water | Storing in a tank/piping / fetching |
| Household used water | Collecting in tanks/drums /pits, decant and fetching |

Plant roots need air as well. If excess water accumulates around the roots, they get decayed and the plants wilt. So, good drainage system is required for air circulation around the roots. Home gardens need drainage from each plot to remove excess water. During monsoon, drainage channels should be dug around the plots or drainage pipes can be put under the soil. In case of pots or plastic bags, holes at the base of the pots or bags are made to drain the excess water.

## Compost Preparation

Plants need 16 different types of nutrients for growth and development. The main nutrients are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, magnesium, calcium, manganese, cobalt, boron, copper, molybdenum, zinc, iron, etc. Some plants need sodium and chlorine also. Carbon, hydrogen and oxygen are obtained from air and water. The remaining nutrients should be provided by using manure. Manures used for growth of plants are of two types:

*Organic manure*–compost, green manure, dung, etc.

*Chemical fertilizers*–urea, potash, di-ammonium phosphate (DAP), micronutrients, etc.

Compost is organic manure. It is prepared by mixing and rotting weeds, kitchen waste and animal dung, urine, chicken dropping, green and dry leaves of any plants and weeds, leaves of –soybean, peas, beans, Dhaicha (sesbania), etc. Compost provides balanced amount of nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, etc. in small amounts. Compost doesn't have negative, either physical or chemical, effect on soil. It improves texture and structure of soil and maintains general soil reaction. Nutrients are released slowly as needed by the plants. Therefore, using compost is more feasible as compared to chemical fertilizers.Compost can be prepared by the following three methods:

### *1. Pit Method*

Three pits, each of 1 $m^3$ size, should be dug in one corner of the home garden (see: Figure 19.4, plot no. 13) and fill the composting material in pit no 1. After a month, turn it on to pit no 2, and then after one month to pit no 3(Figure 19.11).

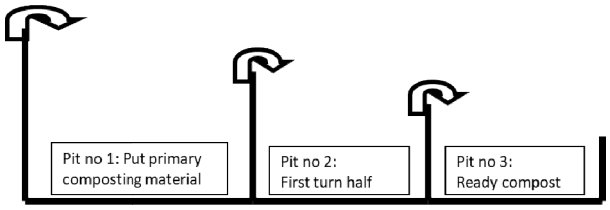



**Figure19.11.**Pits for compost preparation.

The materials to be rotted should be filled in the pit in layers. Free air flow and moisture allows quick rotting. Therefore, 1–2 bucket of water should be added to each layer of material while filling the pit. Using animal dung/urine and chicken dropping also brings quick decomposition. If dung and urine are not available, small amount of surface soil without chemical fertilizer should be added to each layer for quick decomposition of composting materials.

The materials should be turned once a month for two consecutive months, and finally after 3 months, the compost becomes ready. The time may be shortened to 1 and ½ months by adding effective microorganisms while piling the materials. The manure should be turned to move the bottom part to the top. The compost is ready when everything decomposes and comes in powder form when pressed between palms. A new technique of mixing about 25 percent soil while preparing compost is also in practice. This helps in quick decay of materials. It is easier to work if 3 pits are dug or a pit is divided into 3 parts to fill and turn the materials.

### *2. By Piling on the Surface*

The materials to be used are cut into small pieces, piled up to 30 cm on the surface and watered thoroughly. This is covered with a thin layer of soil or cow dung. Then the cut materials are layeredfollowed by soil or cow dung, and so on. Piling is continued until it becomes 1–1½ m high. The top-most layer should be covered with soil. This should be turned as the compost in pits. The manure will be ready in 3–4 months. The well prepared manure will be black or brown(Figure19.12). The materials used will be fully decayed and odourless. It will come to powder form when pressed.




**Figure19.12.**Surface methods of compost preparation.

### *3. Using Wooden Frames*

Similar to pile method, the materials to be used in frame method are cut into small pieces. The cut pieces should be 3–5 cm length and breadth. It is placed in the wooden frame uniformly and pressed lightly. Frame method is used in home garden. In frame the cut materials are piled up to 30 cm, lightly pressed and sprinkled with water. If possible, dung or urine is spread on the surface of the piled materials and watered thoroughly. The frame is lifted up and the materials are piled up till it becomes at least 1 m height. This is covered with a thin layer of soil or cow dung. It is turned up this twice for decomposition of the materials. It is easy method to prepare compost (Figure19.13).



**Figure19.13.**Compost preparation using wooden frame.

### *4. Using Drums/Bins*

Drum method is used for making compost for rooftop gardening (Figures19.14 and 19.15). Metal bins or plastic drums are available in the market. Such bins are sometimes subsidized by municipalities and by some INGO/NGOs also. If metal bins or perforated plastic bins are not available, simple hexagonal 100 L capacity plastic drums also can be used. At the base of the plastic drums, 6–9 holes,each of one cm diameter, are made and kept in raised place with a plate like structure beneath it to ease the rotten droppings of compost. The materials are kept on piling from the top and pressed it. It is covered with a lid to prevent the bad odour coming out of it. In case of perforated metal or plastic bins, different layers are there. The chopped materials, such as weeds, leaves, waste materials from the kitchen, etc., are kept in the bins regularly. In both the cases,earth wormsif available, can be introduced for vermi-composting also. In such bins, prepared compost drops from the base hole. To collect compost, two layers of news papers may be spread to ease the collection of compost.



**Figure19.14.** Compost preparation in drums.

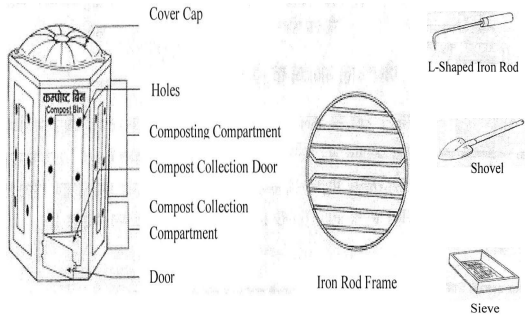



**Figure 19.15.**Internal structure of readymade compost bins.

To collect kitchen waste a bucket with lid should be managed and once or twice the collected materials should be put into the drum. While making compost in drum, the following steps may be followed:

- Kitchen waste must be cut into 3–5 cm pieces before putting them in to the bucket.
- Put this collected material in the drum every day.
- The materials inside the bins are stirred up with a small shovel and leveled it.
- If old compost as start material is put in the bins, the compost preparation is hastened,
- If the materials inside bin is dry, sprinkle water twice a week.
- Collect compost from the base opening and use in rooftop garden.

## Sowing and Transplanting

Vegetable crops can be divided into 4 groupsaccording to the method of planting:

***Grown by direct sowing:*** Some vegetables are grown by directly sowing seeds in the well prepared land. Those vegetables are, for examples,spinach, cress, carrot, radish, beans, peas, etc. The depth of sowing varies as per the size of seed. As a general rule, sowing depths should not be more than three times the size of seed. From practical point of view, depending upon the seed size, 2–5 cm deep sowing is recommended.

***Grown by transplanting seedlings:*** Vegetables having small seeds but needing wide spacing in the fields are grown in nursery first. The raised healthy seedlings are transplanted maintaining appropriate spacing in the main field. Those vegetables are cauliflower, cabbage, broccoli, eggplant, tomato, chili, onion, broad leaf mustard, Swiss chard, lettuce, etc. This method saves seed, gives enough time to prepare main field and seedlings can be grown with care in small well prepared nursery.

***Grown by planting cuttings/corms:*** Vegetables like sweet potato, malabar spinach, taro, yam, pointed gourds, mints (Pudina), etc. are grown by planting cuttings/corms etc.Cuttings/corms should contain 2–3 eyes (nodes) and at least one growing points.

***Grown by transplanting and direct sowing:*** Some vegetables are by nature direct sowing type. However, for earlier harvest and to escape adverse condition during seedling stage, they are grown in plastic pots and transplanted in main field when environment is

favourable. Cucurbits like cucumber, squash, bitter gourd, bottle gourd, watermelon, etc. grown in plastic pots and then transplanted in the main field. These vegetables in favourable condition are directly sown in the main field.

### *Care during Transplanting of Seedlings*

Following care should be taken while transplanting seedlings.

- The soil should be prepared before transplanting.
- The distance between rows to rows and plant to plant should be maintained as recommended.
- Soil and compost should be mixed well in the main field and it should be moistened for transplanting.
- The seedlings should be watered thoroughly before plucking from the nursery plot, plastic bag or wooden box.
- The seedlings should be uprooted with the help of hoe or some tool without disturbing the roots or if it is in a plastic bag, only the plastic cover should be removed before planting it.
- Transplanting should be done in the evening.
- After transplanting the seedling, gently press the soil around it to let the roots get the soil.
- Cover only up to the base of the seedling which was under soil in the nursery. Then water lightly which helps in the growth of root hairs. A shelter (shade) should be arranged to protect the transplants from harsh conditions such as sun and rain.

## Pest Management in Home and Rooftop Garden

Plant pests include diseases, insects, birds, rats and weeds. They cause damage alone or united. Nature maintains balance between plants and damaging pests in a natural condition. In nature, there are presences of useful insects which kill the harmful insects (pests). But knowingly or unknowingly, this balance is being disturbed by modern agriculture which is causing epidemic to the plants. People are using all sorts of chemical pesticides which have harmful effects on the beneficial insects, environment and people. People are affected by consuming fruits, vegetables and water contaminated with pesticides. Therefore, the use of various techniques other than the use of harmful chemical pesticides in pest's management to maintain the natural balance is the "Pest management in home gardening" (Neupane, 2002). One or more of the following techniques may be used to manage the harmful pests in home garden.

### *Biological Method*

When one living being is used to control another harmful living being, it is called biological control, e.g. a fungus *Trichoderma* used to prevent attack from other soil fungus to the plants.

Predator insects eat the harmful insects. Nature has created such insects to maintain balance, e.g. lady bird beetle eats aphids and glowworm (Junkiri)eats snails/slugs.Female wasp lays eggs on moths, beetles, flies and when the eggs hatched, they eat the host.

### *Cultural Method*

Using crop rotation, mixed cropping and crops with strong odour in the home garden is another method of crop safety. Crop rotation implies changing the plants grown in any one plot from season to season. Mixed cropping refers to mixing the different crops in the same plot. These methods help in pest control. Pests can also be controlled by frequent weeding, irrigation, use of healthy seeds/seedlings, etc.

### *Mechanical Control*

Pests may be controlled by picking or killing them manually or by using machine. They may be killed by trapping under the light or on sticky surface or by using lures. This method is used to collect enemy insects in traps, sticky surface or pheromone box and killed.

### *Use of Resistant Varieties*

Crops may be protected by planting pest/disease resistant varieties, e.g. some variety of potato is resistant to some specific potato disease and tomato varieties 'Srijana' and 'CL1131' can tolerate wilting disease.

### *Regulatory Method*

There is a law to control spread of pests from one country to another. It is called plant quarantine. '*Crop protection law BS 2029 (1972)*' and '*Crop protection regulation act BS 2030 (1973)*' are currently in use in Nepal. Similarly,seeds/seedlings from the areas infested with objectionable diseases/pests must not be used. For example, seedlings of cauliflower crop from the area infected with club root disease should never be used.

### *Botanical Pesticides*

Crop protection increases the production. Imported chemical pesticides have been haphazardly used in our country ignoring the long term harmful effects. Using botanical pesticides prepared from locally available resources can be an alternative to chemical pesticides. Some easy and locally used botanical pesticides are as under:

**Papaya leaf and soap water:** Collect 1 kg papaya leaf, chop it and make paste with 1 L water and squeeze out the leaf juice. Mix 1 L papaya leaf juice with 4 L of soap water. Spraying this mixture controls fungus like powdery mildew and also kills small sucking insects like aphids, thrips and white fly.

**Kerosene and ash:** Mix 50 mL kerosene with 1 kg ash and spread this on the garden every morning and evening, twice a week. This prevents sap sucking insects like aphid, white fly and thrips.

**Tobacco and soap water:** Crush 1 kg tobacco leaf and stem in 15 L water. Leave it for a day. Mix a handful of soap powder in this liquid, sieve/strain it and spray immediately. This kills larvae of many Lepidoptera insects.

**Chili and garlic mix:** Mix 3–4 garlic cloves, 2 handfuls of marigold leaves, 3–4 onions and 3–4 hot chilies with 1 L water. Grind them together and boil for 15 min. When cooled, sieve through a cloth or a sieve. Then, mix 1 part of this liquid with 2–3 parts of water, and spray on insect infected plants. Insects are killed instantly.

**Neem/Bakainoseed extract:** Remove the outer skin of the fruits of Neem/Bakaino(seed) and dry it under the sun. Store the dry seeds in a sack or in bamboo basket in a safe place and use as required. Powder about 2 handfuls of these dry seeds and mix with 1 L of water. Leave for 24 hr. Sieve it through a muslin cloth, and next day use the liquid as insecticide.

**Cattle urine:** Collect cattle urine and keep it whole night. Strain it and mix one part urine with 4–5 parts of water and spray on infected plants. Cattle urine is found to control aphid, caterpillars and virus. It specially controls leaf curling disease of chili and tomato.

**Human urine:** Collect human urine from the family members. Mix 4–5 parts water in one part of urine. Spray over infected plants. It controls aphid, thrips, white fly, caterpillars and virus. It specially controls leaf curling disease of chili and tomato, also similar to cattle urine.

There are many other local pesticides used by farmers based on experiences and indigenous learning. They are useful but most of them are not scientifically analyzed and proved. However, they are not harmful and have following benefits:

- Resistance of pests to this pesticide does not increase.
- The predator insects are not killed by it.
- Less effect on natural balance.
- Self reliability increases.
- Saves people from harmful effects.
- It is cheap and of low cost.

### *Organic Pesticides*

In addition to above indigenous pesticides, some recommended organic pesticides are available in the market. These are a bit costly but less harmful than chemical pesticides. The Registered Organic Pesticides in Nepal are presented in Annex 19.8 (SNMDP, 2017).

If the above mentioned botanicals and organic pesticides as presented in Annex 19.8 do not work, then it is advised to go for safe pesticides consulting agriculture Technician or Agro-vets. However, be careful not to use banned chemical pesticides.

## Insect Traps

### *Funnel Trap*

Funnel like traps made of mosquito nets with pheromone fixed at the base are put with the help of a stick in the field or in a corner of rooftop (Figure19.16).

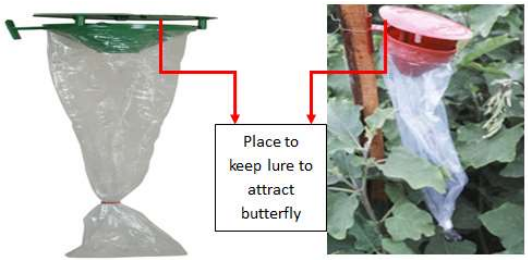



**Figure19.16.** Funnel trap.

The funneltrap attracts the enemy insects like egg laying butterflies of tomato fruit borer, tobacco caterpillar, fruits and stems borers of eggplants, etc. (Figure 19.17). Collect the trapped butterflies and burry in the soil.



**Figure19.17.**Tomato and bean borer.

## *Yellow Sticky Trap/Delta Trap*

Yellow sticky materials are spread on both sides of water proof paper (Figure 19.18). Yellow colour attracts many small insects like aphids, white flies, fruit fly, etc. Such yellow sticks are readily available in agro-vets. Put such traps in home garden or in rooftop garden and collect insects and destroy.



**Figure19.18.**Yellow sticky trap.

## *Wota T Trap*

This trap is very effective in collecting tomato leaf miner (*Tutaabsoluta*). It has a basin for putting water and an umbrella like canopy to keep lure (Figure19.19).

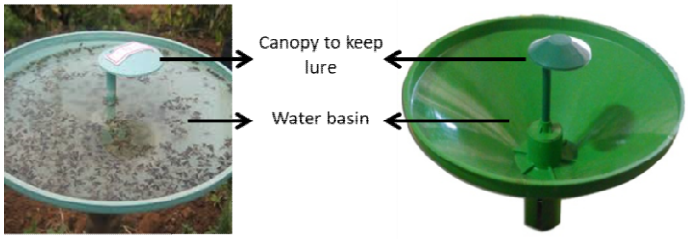



**Figure 19.19.** Wota Ttrap.

With the help of supporting stick it is put in the middle part of home garden or near tomato pots on the rooftop. The lure is kept in canopy and surf water is filled in basin. Adult Tuta is attracted by lure and falls in surf water. Killed Tuta are collected several

times from the water basin and destroyed. This trap should be placed in garden when tomato is transplanted. The apparatus and lure is available in agro-vets.

### *Fly T Trap / Pheromone Trap*

Fly T Trap or commonly known as pheromone trap is readily available in most agro-vets (Figure 19.20). There are different types of pheromone traps available to control fruit flies of cucurbits. It has three parts: (a) upper part is transparent, (b) base part looks like an inverted cup where lure (Bacto-Lure/Bado-Lure) is inserted, and (c) lower part is filled with surf water. There are holes from where male fruit fly enters due to the attraction of lure and drops in water and dies. This trap is hanged about 2 m height from the ground. This technique is used in the cucurbit crops like cucumber, bitter gourd, bottle gourd, snake gourd, squash, pumpkin, etc.



**Figure19.20.**Fly Ttrap or Pheromone trap.

This lure is effective for about two months. When water is covered by dead flies, water should be changed. Thus, destroying insects using sex attractants and light attractants are also considered as the part of organic pest management.

## Pesticides Used in Nepal

The Government of Nepal has banned following 21 chemicals due to their toxicity, persistence, tendencies of accumulation and biomagnifications, and long-term impact on humans and environment. Those banned pesticides are as follows: (1)chlordane, (2)dieldrin, (3)aldrin, (4)mirex, (5)lindane, (6)phosphamidon, (7) DDT, (8)endrin, (9)heptachlor, (10) BHC, (11)organo-mercury, (12)toxaphene, (13)monochrotophos, (14)methyl parathion, (15)endosulfan, (16)phorate, (17)carbofuran, (18) dichlorvos, (19)triazophos, (20)carbaryl, and (21)benomyl (Sharma, 2015).

### *Examples of Some Misuse of Pesticides in Nepal*

- Overdose and frequent application of pesticides in cotton, tea and commercial vegetable farming areas along with cocktail spray.
- Use of insecticide particularly endosulfan for killing fish in stream and ponds as fisherman's practice.
- Use of insecticide particularly DDT in the past, and dichlorvos and malathion at present for the control of the head louse as a public practice.
- Use of insecticide, particularly endosulfan, on cattle body for the control of mange.
- Use of pesticide treated grains (supposed to be dumped or buried) for making alcohol (local wine) and also for feeding horses in remote districts.

- Dipping green vegetables, particularly broad leaf mustard, tomato and brinjal (eggplant), in malathion solution in the evening to keep it fresh and shiny looking and taking the produce in the market next morning as a farmer's practice.
- Dipping tomato and brinjal (egg plant) in mancozeb solution just before taking it to the market to keep it fresh and shiny looking as farmer's practice.
- Spraying insecticides on body surface of fish to keep flies away while displaying it on the shop for selling (trader's practice).
- Throwing away date expired pesticides and empty containers in public area (green ground, open area), local streams and drainage/sewage without any hesitation (general practice).
- Use of fumigants, particularly aluminium phosphide, in cereals in the locally made mud bins/metal bins with loose cover that are kept either in bedroom or in store room adjacent to bedroom (Sharma, 2015).

### *Classification of Hazardous Level of Pesticide by WHO*

The hazardous level of toxicity of pesticide is expressed in terms of Lethal Dose 50 ($LD_{50}$). The standard measure of the toxicity of a material that kills half of the sample population of a specific test animal in a specific period of time through exposure via ingestion, skin contact, or injection is termed as $LD_{50}$. $LD_{50}$ is measured in µg (or mg) of the material per kg of test animal's body weight. Lower the amount, more toxic the material. Used in comparison of toxicities, $LD_{50}$ values cannot be directly extrapolated from one species to other species or to humans. This is also called median lethal dose and written also as $LD_{50}$.

WHO has categorized pesticides as follows: (1) First (IA),extremelyhazardous; (2) First (IB),highly hazardous; (3) Second (II),moderately hazardous; (4) Third (III),slightly hazardous; and (5) Relatively safe (U/NH),unlikely to present acute hazard, non hazard.

Hazardous level of pesticide in Nepal is expressed bysymbolsas indicated in Figure 19.21. By observing the marks on the container of pesticides, their level of toxicity can be recognized. The highly toxic is marked as red and the least toxic is marked as green. User has to see these marks while buying and using safe pesticide as the last alternative against the pests in home garden and rooftop garden.




**Figure 19.21.** Symbols used for hazardous level of pesticide in Nepal.

## Preservation of Fruits and Vegetables

Fruits and vegetables produced in home and rooftop garden sometimes are more than daily requirement. Such excess produce can be saved for future use by processing it by using natural or other methods and is referred as 'Food Preservation'. As preserving food

in a natural state is not very possible, it is processed by using different methods. Such processed foods should last for long time, should be clean and healthy, and should only contain permitted food colour and flavour. The food preservation has following advantages: (a) preserved fruits and vegetables can be used in lean/scarce season, (b) important nutrients can be available during lean season, (c) fruits and vegetables which may otherwise get spoiled can be saved, (d) selling excess preserved fruits and vegetables can be a way of additional income, etc.

## *Methods of Fruits and Vegetables Preservation*

Preservation basically refers to the saving from spoilage and keeping it for a long period of time. Fruits and vegetables may be preserved by preventing the causes of spoilage. The following methods can be used for simple preservation.

**Drying:** Foods may be preserved for long time by drying them under the sun or using solar drier (Figure19.22) or electric dryer. Drying decreases moisture content of fruits and vegetables to a large extent. Thus, microbes cannot survive and spoilage is prevented.



**Figure 19.22.** Simple solar drier.

**Using high temperature (Sterilization):** Fruits, vegetables, meat and fish are canned by first using high temperatures and then very low temperatures. Canning prevents enzyme reactions as well as killing microbes.

**Cooling/Freezing:** Microbial activities decrease in temperatures below 5°C and they die when kept under 0°C for a few days. Enzymic activities decrease as well. Fresh fruits and vegetables remain fresh for a longer time. Thus foods can be preserved for a long time.

**Using salt and sugar:** Fruits and vegetables can be preserved by putting them in salt and sugar solution. Sugar and salt destroy the microbes, e.g. pickled radish, salted lemon, etc.

**Using chemicals:** Various chemicals preserve fruits and vegetables by destroying microbes and inactivating enzymes, and keep the food safe and prevent spoilage. However, it must be noted that only permitted chemical should be used in a right amount. Potassium metabisulphite and sodium benzoate are chemicals used for preservation of fruits and vegetables.

**Using good microbes:** Some useful microbes can be used to prepare delicious and nutritious food. This is traditional in Nepalese society, e.g. pickled bamboo shoot, pickles, yoghurt – 'lactic acid bacteria' produces lactic acid from carbohydrate which destroys or deactivates the bad microbes; therefore, yoghurt can be kept for longer period than milk.

**Cold storage:** Cold stores are quite common. Cold store basically means an electricity operated room or house where the inside temperature is maintained cooler than outside so that fruits and vegetables can be kept in a natural state. Respiration process of fresh fruits and vegetables is decreased by cool temperature and high humidity (more than 90%) which delays wrinkling and spoilage. A refrigerator in the home also serves as cold storage.

## Conclusion

Nepal has suitable climate and comparative advantages for various fruits and vegetables production. By establishing year round home garden complemented by rooftop gardening, present level of malnutrition can be reduced to a minimum level. For the successful gardening and sufficient production, consumption and preservation of the surplus, demand based extension system combined with nutrition education including proper food preparation and consumption should be launched, and food behaviour should be changed by practical training and guidance to the household heads and female members of the household. Home and rooftop gardening need continuous supply of seeds, seedlings and saplings for sustainability. For this, MRN at appropriate location is important as self sustained enterprise. There is expanding demand for fresh fruits and vegetables in the local, provincial and federal markets. Using the comparative advantages, there is a plenty of scope of expanding commercial production of fruits and vegetables exporting niche fruits and vegetables to the national and international market. Fruits and vegetables are the high value crops and give more economic return to the growers and businessmen both and contribute to income generation, livelihood improvement and leads to prosperity. Fruits and vegetables help to combat the alarming situation of food and nutrition insecurity, increase the income from surplus and commercial sale, and increase food security from buying three times more cereal grains selling vegetables from the same piece of land (HMG/FAO, 1993).

Water harvesting and multiple use of water system, and drip and sprinkler irrigation technology are contributing in efficient utilization of water. Improvement in FYM, composting and vermi-composting technologies are gradually replacing chemical fertilizer in fruit and vegetable production. Most of the fruits and vegetables are environment friendly, increases greenery and some of the fruits can be grown even in pots. During corona pandemic time, home gardening and rooftop gardening has taken good momentum. Thus, smooth and dedicated implementation of home and rooftop gardening will certainly bring revolutionary changes in the development of fruits and vegetables, and improve food and nutritional situation of Nepal.

**Acknowledgment:**Author is thankful to NAST for the opportunity provided to be the part of writing this very important chapter of the book.

**Abbreviations:**ADB = Agriculture Development Bank; BHC = benzene hexachloride; CEAPRED = Center for Environmental, Agricultural Policy Research, Extension and Development; DDT = dichlorodiphenyl-trichloroethane; DoA = Department of Agriculture; FYM = farm yard manure; HKI = Helen Keller International; INGO = international non-governmental organization; Li-BIRD = Local Initiation for Bio-diversity Research and Development; MRN = Multipurpose Resource Nursery; NGO = non-governmental organization; UNICEF = The United Nations Children's Fund; USDA = United States Department of Agriculture;WHO = World Health Organization.

**Annex 19.1.** Recommended daily intake of nutrients for different age group children, women and men (average)

| Age in years | Body weight (Average) kg | Required energy (kilo calories) | Required vitamins | | | | | Required minerals | | Required proteins (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | β-carotene (μg) | Thiamin (mg) | Riboflavin (mg) | Niacin (mg) | Vitamin C (mg) | Calcium (mg) | Iron (mg) | |
| <1 | 7.3 | 820 | 1,200 | 0.3 | 0.5 | 5.4 | 20 | 500-600 | | 15 |
| 1-3 | 13.4 | 1,360 | 1,200 | 0.5 | 0.8 | 9.0 | 20 | 400-500 | 12 | 22 |
| 4-6 | 20.2 | 1,830 | 1,600 | 0.7 | 1.1 | 12.1 | 20 | 400-500 | 18 | 30 |
| 7-9 | 28.1 | 2,190 | 2,400 | 0.9 | 1.3 | 14.4 | 20 | 400-500 | 26 | 41 |
| **Adolescent boy** | | | | | | | | | | |
| 10-12 | 36.9 | 2,600 | 2,400 | 1.0 | 1.6 | 17.2 | 20 | 500-600 | 34 | 54 |
| 13-15 | 51.9 | 2,900 | 2,400 | 1.2 | 1.7 | 19.1 | 30 | 500-600 | 41 | 70 |
| 16-19 | 62.9 | 3,070 | 2,400 | 1.2 | 1.8 | 20.3 | 30 | 500-600 | 50 | 78 |
| **Adolescent girl** | | | | | | | | | | |
| 10-12 | 38.0 | 2,350 | 2,400 | 0.9 | 1.4 | 15.3 | 20 | 600-700 | 19 | 57 |
| 13-15 | 49.9 | 2,490 | 2,400 | 1.0 | 1.5 | 16.4 | 30 | 600-700 | 28 | 65 |
| 16-19 | 54.4 | 2,510 | 2,400 | 1.0 | 1.5 | 15.2 | 30 | 500-600 | 30 | 63 |
| **Adult male (65 kg)** | | | | | | | | | | |
| Light work | | 2,700 | 2,400 | 1.2 | 1.8 | 19.8 | 30 | 400-500 | 28 | 60 |
| Medium work | | 3,000 | 2,400 | 1.2 | 1.8 | 19.8 | 30 | 400-500 | 28 | 60 |
| Hard work | | 3,500 | 2,400 | 1.2 | 1.8 | 19.8 | 30 | 400-500 | 28 | 60 |
| **Adult female (50 kg)** | | | | | | | | | | |
| Light work | | 2,000 | 2,400 | 0.9 | 1.3 | 14.5 | 30 | 400-500 | 30 | 50 |
| Medium work | | 2,200 | 2,400 | 0.9 | 1.3 | 14.5 | 30 | 400-500 | 30 | 50 |
| Hard work | | 2,600 | 2,400 | 0.9 | 1.3 | 14.5 | 30 | 400-500 | 30 | 50 |
| **Pregnant women (additional)** | | +300 | | +0.2 | +0.2 | +2 | +30 | 1,000 | 38 | +15 |
| **Breasting feeding (first 6 months, additional)** | | +550 | +1,400 | +0.3 | +0.3 | +4 | +20 | | | +25 |
| **Breasting feeding (6 months to 1 year, additional)** | | +400 | +1,200 | +0.2 | +0.2 | +3 | +20 | 1,000 | 30 | +18 |

Source:(Passmore et al., 1974)

**Annex 19.2.** Vitamins and minerals available from 100 g of edible vegetables and fruits

| S.N. | Name of vegetables | Edible percent | Vitamins | | | | | Minerals | | | Proteins (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | β-carotene (µg) | Thiamin (mg) | Riboflavin (mg) | Niacin (mg) | Vitamin C (mg) | Calcium (mg) | Phosphorus (mg) | Iron (mg) | |
| 1 | Cauliflower | 71 | 30 | 0.06 | 0.01 | - | 56 | 626 | 107 | 40 | 5.9 |
| 2 | Cabbage | 88 | 120 | 0.06 | 0.09 | 0.4 | 124 | 39 | 44 | 0.8 | 1.8 |
| 3 | Broccoli | 80 | 630 | - | - | - | 111 | 45 | 109 | 1.5 | 5 |
| 4 | Knol-khol | 73 | 4,146 | 0.25 | - | 3 | 157 | 740 | 50 | 13 | 3.5 |
| 5 | Broad leaf mustard | 95 | 2,622 | 0.03 | - | - | 33 | 155 | 26 | 16.3 | 4 |
| 6 | Lettuce | 66 | 990 | 0.09 | 0,13 | 0.5 | 10 | 50 | 28 | 2.4 | 2.1 |
| 7 | Swiss chard | 95 | 2,660 | - | - | - | 33.83 | 86.39 | 26.82 | 4.57 | 2.21 |
| 8 | Onion green | 95 | 595 | 0.08 | 0.02 | 0.5 | 17 | 40 | 60 | 1.2 | 1.8 |
| 9 | Onion bulb | 95 | 0 | 0.08 | 0.01 | 0.4 | 11 | 47 | 50 | 0.6 | 1.2 |
| 10 | Garlic green | 92 | 845 | 0.10 | 0.13 | 0.6 | 36 | 53 | 42 | 0.6 | 2.4 |
| 11 | Hot chili | 100 | 390 | - | - | - | 111 | - | - | 1.2 | 2.9 |
| 12 | Sweet pepper | 100 | 421 | - | - | - | 137 | - | - | 1.2 | 1.3 |
| 13 | Tomato | 98 | 351 | 0.12 | 0. 06 | - | 27 | 48 | - | 0.4 | 0.9 |
| 14 | Eggplant | 95 | 74 | 0.04 | 0.11 | - | 12 | 18 | 0.9 | - | 1.4 |
| 15 | Squash | 99 | 13 | 0.04 | 0.08 | 0.3 | 18 | 25 | 24 | 0.9 | 1. 4 |
| 16 | Pumpkin shoot | 74 | 498 | - | - | - | - | 392 | 112 | 2.1 | 4.6 |
| 17 | Pumpkin fruit | 79 | 2,178 | 0.06 | 0.04 | 0.5 | 2 | 10 | 30 | 0.44 | 1.4 |
| 18 | Bottle gourd | 86 | 0 | 0.03 | 0.01 | 0.2 | 0 | 20 | 10 | 0.46 | 0.2 |
| 19 | Bitter gourd | 97 | 126 | 0.07 | 0.09 | 0.5 | 88 | 20 | 70 | 0.61 | 0.2 |
| 20 | Cucumber | 83 | 0 | 0.03 | 0 | 0.2 | 7 | 10 | 25 | 0..60 | 0.4 |
| 21 | Radish leaf | 100 | 1,301 | 0.18 | 0.47 | 0.8 | 81 | 265 | 59 | 0.09 | 3.8 |
| 22 | Radish root | 99 | 3 | 0.06 | 0.02 | 0.5 | 15 | 35 | 22 | 0.4 | 0.7 |
| 23 | Carrot leaf | 51 | 5,700 | 0.04 | 0.37 | 2.1 | 79 | 340 | 110 | 8.8 | 5.1 |
| 24 | Carrot root | 95 | 4,275 | 0.04 | 0.02 | 0.6 | 3 | 80 | 530 | 1.03 | 0.9 |
| 25 | Turnip root | 60 | 1.24 | - | - | - | - | 47.67 | 35.22 | 2.27 | 1.15 |
| 26 | Turnip leaf | 51 | 2,136 | 0.31 | 0.57 | 5.4 | 180 | 710 | 60 | 24.4 | 4.0 |
| 27 | Spinach | 80 | 3,049 | 0.03 | 0.26 | 0.5 | 28 | 73 | 21 | 1.14 | 2.0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Cress | 80 | - | 0.15 | - | - | - | 360 | 110 | 28.6 | 5.8 |
| 29 | Amaranths | 39 | 5,520 | 0.03 | 0.03 | 1.2 | 99 | 397 | 83 | 3.49 | 4.0 |
| 30 | Bush bean | 94 | 132 | 0.08 | 0.06 | 0.3 | 24 | 50 | 28 | 0.61 | 1.7 |
| 31 | Butter bean | 94 | 132 | 0.08 | 0.06 | 0.3 | 24 | 50 | 28 | 0.61 | 1.7 |
| 32 | Peas | 53 | 83 | 0.25 | 0.01 | 0.8 | 9 | 20 | 139 | 1.5 | 7.2 |
| 33 | Faba bean | 88 | 9 | 0.08 | - | 0..8 | 12 | 50 | 64 | 1.4 | 4.5 |
| 34 | Fenugreek | 59 | 2,340 | 0.04 | 0.31 | 0.8 | 52 | 395 | 51 | 1.93 | 4.4 |
| 35 | Okra | 84 | 52 | 0.07 | 0.10 | 0.6 | 13 | 66 | 56 | 0.35 | 1.9 |
| 36 | Beet root | 51 | 5,862 | 0.26 | 0.56 | 3.3 | 70 | 380 | 30 | 16.2 | 3.4 |
| 37 | Kang-kong | 95 | 1,980 | - | - | - | 37 | - | - | 3.9 | 2.9 |
| 38 | Sweet potato leaf | 100 | 750 | 0.07 | 0.24 | 1.7 | 27 | 360 | 60 | 1.14 | 4.2 |
| 39 | Sweet potato root | 97 | 8,802 | 0.08 | 0.04 | 0.7 | 24 | 46.0 | 50 | 0.21 | 1.20 |
| 40 | Taro leaf black | 95 | 12,000 | 0.06 | 0.45 | 1.9 | 63 | 460 | 125 | 0.98 | 6.8 |
| 41 | Taro leaf green | 95 | 10,278 | 0.02 | 0.26 | 1.1 | 12 | 227 | 82 | 10 | 3.9 |
| 42 | Coriander | 70 | 6,918 | 0.05 | 0.06 | 0.8 | 135 | 184 | 71 | 1.42 | 3.3 |
| 43 | Mint | 45 | 1,620 | 0.05 | 0.26 | 1.0 | 27 | 200 | 62 | 15.6 | 4.8 |
| 44 | Malabar spinach | 75 | 7,440 | 0.03 | 0.16 | 0.5 | 87 | 200 | 35 | 1.0 | 2.8 |
| 45 | Moringa leaf | 75 | 6,780 | 0.06 | 0.05 | 0.8 | 220 | 440 | 70 | 0.85 | 6.7 |
| 46 | Moringa bean | 83 | 110 | 0.05 | 0.07 | 0.2 | 120 | 30 | 110 | 0.18 | 2.5 |
| 47 | Asparagus spear | 75 | 378 | - | - | - | 20 | - | | 1.4 | 2.5 |
| 48 | Fern | 60 | 2,274 | - | - | - | - | - | - | - | - |
| 49 | Pointed gourd | 75 | 150 | - | - | - | 29 | - | - | 1.7 | 2.0 |
| 50 | Mango | 74 | 2,843 | 0.8 | 0.09 | 0.9 | 16 | 14 | 16 | 1.3 | 0.6 |
| 51 | Papaya | 75 | 666 | 0.4 | 0.25 | 0.2 | 57 | 17 | 13 | 0.5 | 0.6 |
| 52 | Persimmon | 93 | 2,268 | 0.03 | 0.01 | 0 | 35 | 15 | 20 | 0.3 | 0.7 |
| 53 | Apricot fresh | 86 | 2,160 | 0.04 | 0.3 | 0.6 | 6 | 20 | 25 | 2.2 | 1.0 |
| 54 | Apricot dry | 93 | 58 | 0.22 | - | 2.3 | 2 | 110 | 70 | 4.6 | 1.6 |
| 55 | Sweet orange | 67 | 0 | - | - | 0 | 54 | 30 | 20 | 1.0 | 0.7 |
| 56 | Mandarin | 67 | 1,104 | - | - | - | 30 | 26 | 20 | 0.32 | 0.7 |
| 57 | Lime | 75 | 15 | 0.2 | 0.03 | 0.1 | 63 | 90 | 20 | 0.3 | 1.5 |

Source:(DFTQC, 1994, 2017)

**Annex 19.3.** Recommended daily intake of food items to avail nutrients for different age group children, women and men (average)

| Age in years | Average body weight (kg) | Requiredenergy (kilo calories) | Recommended daily intake of different food items for balanced diet in g/day (24 hr cycle) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cereals | Legumes | Green leafy vegetables | Fruit vegetables | Root vegetables | Fresh fruits | Milk products | Fats (ghee/oils) |
| <1 | 7.3 | 820 | 50 | 20 | 30 | 10 | 20 | 50 | 300 | 20 |
| 1-3 | 13.4 | 1,360 | 150 | 50 | 50 | 20 | 30 | 50 | 300 | 20 |
| 4-6 | 20.2 | 1,830 | 200 | 60 | 75 | 30 | 40 | 50 | 250 | 25 |
| 7-9 | 28.1 | 2,190 | 250 | 70 | 75 | 40 | 40 | 50 | 250 | 30 |
| **Adolescent boy** | | | | | | | | | | |
| 10-12 | 36.9 | 2,600 | 320 | 70 | 100 | 50 | 50 | 50 | 250 | 35 |
| 13-15 | 51.9 | 2,900 | 430 | 70 | 100 | 35 | 40 | 30 | 250 | 35 |
| 16-19 | 62.9 | 3,070 | 450 | 70 | 100 | 35 | 40 | 30 | 250 | 35 |
| **Adolescent girl** | | | | | | | | | | |
| 10-12 | 38.0 | 2,350 | 320 | 70 | 100 | 35 | 40 | 30 | 250 | 35 |
| 13-15 | 49.9 | 2,490 | 430 | 70 | 100 | 35 | 40 | 30 | 250 | 35 |
| 16-19 | 54.4 | 2,510 | 430 | 70 | 100 | 35 | 40 | 30 | 250 | 35 |
| **Adult male (65 kg)** | | | | | | | | | | |
| Light work | | 2,700 | | 70 | 70 | 75 | 75 | 30 | 200 | 35 |
| Medium work | | 3,000 | | 80 | 125 | 75 | 75 | 30 | 200 | 40 |
| Hard work | | 3,500 | | 80 | 125 | 100 | 100 | 30 | 200 | 40 |
| **Adult female (50 kg)** | | | | | | | | | | |
| Light work | | 2,000 | | 60 | 125 | 75 | 50 | 30 | 200 | 35 |
| Medium work | | 2,200 | | 70 | 125 | 75 | 75 | 30 | 200 | 40 |
| Hard work | | 2,600 | | 70 | 125 | 100 | 100 | 30 | 200 | 45 |
| **Pregnant women (additional)** | | +300 | | | +25 | | | | +125 | |
| **Breasting feeding (first 6 months, additional)** | | +550 | | +10 | +25 | | | | +125 | |
| **Breasting feeding (6 months to 1 year, additional)** | | +400 | | +10 | +25 | | | | +125 | |

Source: (Passmore et al., 1974)

**Annex 19.4.** Cropping calendar related to Table 19.3 for high hill (1,500-2,000 m) regions. Home garden plots divided into 13 plots for year round supply of balanced vegetables.

| Plot No. | Dry Season | | | | Rainy Season | | | | | Winter Season | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | February | March | April | May | June | July | August | September | October | November | December | January | |
| 1 | Rayo | → | → | Bean | → | → | → | Radish (Mino Early) | → | → | → | → | Rayo |
| 2 | → | → | → | Okra | → | → | Spinach | → | Cress | → | → | → | Swiss chard |
| 3 | Early cauliflower | → | RayoMarpha | → | → | → | Radish (Mino Early) | → | → | Coriander | → | → | → |
| 4 | → | → | Coriander | → | Cauli Mid | → | → | → | → | Onion | → | → | → |
| 5 | Cress | → | → | Cabbage | → | → | → | → | Turnip | → | → | → | → |
| 6 | Nepali pumpkin | → | → | → | → | Radish 40-days | → | Peas, faba bean | → | → | → | → | → |
| 7 | Tomato, eggplant | → | → | → | → | Pole bean | → | → | → | Fenugreek | → | → | → |
| 8 | Squash | → | → | Okra | → | → | → | → | Carrot | → | → | → | → |
| 9 | Sweet pepper | → | → | → | → | Asparagus bean | → | → | Spinach | → | → | → | → |
| 10 | → | → | Sponge gourd | → | → | → | → | → | Late Cauli | → | → | → | → |
| 11 | → | → | Bitter gourd | → | → | → | → | Garlic | → | → | → | → | → |
| 12 | Amaranths | → | Bottle gourd | → | → | → | → | Broccoli, knol-khol | → | → | → | → | → |
| 13 | Compost preparation | → | → | → | Nursery | → | → | Compost Preparation | → | → | Nursery | → | → |

Notes: Plot no 13 is for compost preparation and nursery raising. (→)-Sign denotes crop growing and harvesting time. Composting requires 2-3 turnings. Three separate 1 $m^2$ pits may be prepared or may be separated by thin wall. Vegetables can be selected as per family choice and interest from Table 19.1 in the text. Sowing/Transplanting may be shifted a week ahead or back.

**Annex 19.5.** Cropping calendar related to Table 19.3 for mid hill (700-1,500 m) regions. Home garden plots divided into 13 plots for year round supply of balanced vegetables.

| Plot No. | Dry Season | | | Rainy Season | | | | | Winter Season | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | February | March | April | May | June | July | August | September | October | November | December | January |
| 1 | Tomato + Eggplant | → | → | → | → | → | Early Cauli | → | → | Spinach | → | Cress |
| 2 | Cucumber + Bottle gourd | → | → | → | → | → | Cabbage | → | → | → | Coriander | → |
| 3 | → | → | Okra | → | → | → | → | Turnip | → | → | Carrot | → |
| 4 | Sweet pepper + Chili | → | → | → | → | → | → | RayoKhumal | → | → | → | → |
| 5 | Transplant squash | → | → | → | Bush bean | → | → | Mid Cauli | → | → | → | → |
| 6 | → | → | → | Buckwheat | → | Radish 40-days | → | Spinach | → | Onion | → | → |
| 7 | Transplant Swiss chard | → | → | → | Soyabean | → | → | → | → | → | Cress | → |
| 8 | → | → | Ghiu bean | → | → | → | Broccoli | → | → | → | RayoMarpha | → |
| 9 | → | Sow Pumpkin | → | → | → | → | → | Peas | → | → | → | → |
| 10 | → | → | Taro | → | → | → | → | → | Garlic | → | → | → |
| 11 | → | Amaranth | → | → | → | Ghiu Bean | → | → | → | → | Fenugreek | → |
| 12 | → | Sponge gourd | → | → | → | → | Knol-khol | → | → | → | Coriander | → |
| 13 | Compost Preparation | → | → | → | Nursery | → | → | Compost Preparation | → | → | Nursery | → |

Notes: Plot no 13 is for compost preparation and nursery raising. (→)-Sign denotes crop growing and harvesting time. Composting requires 2-3 turnings. Three separate 1 $m^2$ pits may be prepared or may be separated by thin wall. Vegetables can be selected as per family choice and interest from Table 19.1 in the text. Sowing/Transplanting may be shifted a week ahead or back.

**Annex 19.6.** Cropping calendar related to Table 19.3 for terai and low hill (<700 m) regions. Home garden plots divided into 13 plots for year round supply of balanced vegetables.

| Plot | Dry Season | | | | Rainy Season | | | | Winter Season | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | February | March | April | May | June | July | August | September | October | November | December | January |
| 1 | Sow Amaranth | → | → | → | Plant chili | → | → | Broccoli | → | → | → | → |
| 2 | → | Okra | → | → | → | → | Sweet pepper | → | → | → | → | Coriander |
| 3 | Cucumber | → | → | → | → | → | Radish 40-days | → | Rayo | → | → | → |
| 4 | → | → | → | → | Cow-pea | → | → | Cabbage | → | → | → | Swiss chard |
| 5 | → | → | → | → | → | → | Ghiu bean | → | → | Turnip | → | Taro |
| 6 | → | → | Patuwa, Lapha | → | Ridge gourd | → | → | → | Mid Cauli | → | → | Squash |
| 7 | → | Kang-kong | → | → | → | → | Bush bean | → | → | Late Cauli | → | → |
| 8 | → | → | → | Asparagus bean | → | → | → | → | Carrot | → | Onion | → |
| 9 | Sow Pumpkin | → | → | → | → | → | → | Spinach | → | → | Cress | → |
| 10 | → | → | Sponge gourd | → | → | → | → | → | Garlic | → | → | → |
| 11 | → | → | Bitter gourd | → | → | → | → | Tomato | → | → | → | → |
| 12 | Bottle gourd | → | → | → | → | → | → | Knol-khol | → | → | Fenugreek | → |
| 13 | Compost Preparation | → | → | → | Nursery | → | → | Compost Preparation | → | → | Nursery | → |

Notes: Plot no 13 is for compost preparation and nursery raising. (→)-Sign denotes crop growing and harvesting time. Composting requires 2-3 turnings. Three separate 1 $m^2$ pits may be prepared or may be separated by thin wall. Vegetables can be selected as per family choice and interest from Table 19.3 in the text. Sowing/Transplanting may be shifted a week ahead or back.

**Annex 19.7.**Optimum plants in Rooftop Garden and average production (estimated)(Pandey, 2020)

| S.N. | Vegetables | Recommended Varieties | Plants | Estimated production (kg/plant) | Total production (kg) |
|---|---|---|---|---|---|
| 1 | Tomato | Monprecos, Srijana, Lapsigede, Manisha, Sworaksha | 5 | 3 | 15 |
| 2 | Eggplant | PPL, Nurki, Sarlahi Green, Chhaya, PokhraLurke | 5 | 2 | 10 |
| 3 | Okra | Parvati, ArkaAnamika | 10 | 1 | 10 |
| 4 | Chili | Jwala , Akbare, Nepali, Karma Yatsufusa | 5 | 1 | 5 |
| 5 | Sweet pepper | California Wonder, Sagar | 5 | 1 | 5 |
| 6 | Bitter gourd | Green Long, White Long Palee, Chaman | 2 | 3 | 6 |
| 7 | Swiss chard | Ford Hook Gaint | 5 | 2 | 10 |
| 8 | Broad leaf mustard | Khumal, Marpha, Khumal Red Leaf, Tangkhuwa | 10 | 2 | 20 |
| 9 | Broccoli | Desico, Green Sprouting, Calabridge | 10 | 2 | 20 |
| 10 | Bean | Trishuli, Chaumase | 10 | 2 | 20 |
| 11 | Squash | Grey Ziccini, Black Beauty | 4 | 3 | 12 |
| 12 | Sponge gourd | Kantipure, New Narayani, Basmati | 2 | 3 | 6 |
| 13 | Bottle gourd | NS 421, NS 443, PSPL | 2 | 5 | 10 |
| 14 | Onion, Garlic | Red Creole, Local | 4 | 2.5 | 10 |
| 15 | Coriander | Suravi, Nepali, Marpha, Kalami | 1 | 2 | 2 |
| 16 | Spinach | Patane, Thimile, Dewan | 2 | 2 | 4 |
| 17 | Cress | Nepali, Thimile | 2 | 1.5 | 3 |
| 18 | Early cauliflower | Deepali, Silver Cup 60 | 15 | 0.5 | 7 |
| 19 | Mid season cauliflower | Jyapu, Kathmandu Local | 10 | 1 | 10 |
| 20 | Late cauliflower | Snow Ball , Snow Moon | 10 | 1 | 10 |
| 21 | Cabbage | Green Coronet, T-621 | 10 | 1 | 10 |
| | **Total** | | 120+9 | | 205×3 =615 |

Notes: The description given above is for one season. Three seasons can be planted as per agro-climatic region selecting appropriate crops. Rooftop garden is complementary to the land garden. Both land garden and rooftop garden may go together.A lump sum production is given by using of 1.5 $m^2$ box.

**Annex 19.8.**Registered organic pesticides in Nepal

| S.N. | Common name | Trade name | Main ingredient |
|---|---|---|---|
| 1 | Neem(Ajadiractin) | Bilivi | 10% |
| 2 | | निकोनिम(Nikoneem) | 0.15% |
| 3 | | निम्बिसिडिन(Nimbicidine) | 0.03% |
| 4 | | सुपर निम(Super Neem) | 0.15% |
| 5 | युभेरिया (सेतो ढुसी)*Beauveria*(*White fungus*), *Beauveriabassiana* | गार्नेट (Garnet) | 0.15% |
| 6 | | बवा(Bawa) | 0.15% |
| 7 | | बायो पावर(Bio-power) | 0.15% |
| 8 | | दमन (Daman) | 1% |
| 9 | | जस्पर (Jasper) | 1.5% |
| 10 | | रेसर(Racer) | 1.5% |
| 11 | | बिवेयर(bewarer) | 1.5% |
| 12 | | माईकोजाल(Mucosal) | 10% |
| 13 | मेटाराईजियम (हरियो ढुसी),*Metarhizium*(*Green fungus*), *Metarhiziumanisopliae* | इमराल्ड (Emerald) | 0.15% |
| 14 | | रेसर (Racer) | 0.15% |
| 15 | | कालीचक्र (Kalichakra) | 1% |
| 16 | एन. पि. भि.*(Nuclear Polyhedrosis Virus)* | हेलिसाईड(Helicide) | 0.43% |
| 17 | | स्पोडोसाईड (Spodocide) | 0.50% |
| 18 | स्युडोमोनास (*Pesudomonasfluorescene)* | बायोक्यूर बि (Bio-cure B) | 1.75% |
| 19 | | फसल रक्षा (PhasalRaksha) | 1% |
| 20 | | स्पर्श (Sparsha) | 1.75% |

| | | | |
|---|---|---|---|
| 21 | | भुपारिस(Bhuparis) | 0.5% |
| 22 | | मोर्चा (Morcha) | 0.5% |
| 23 | | सुमोना (Sumona) | 1% |
| 24 | भर्टिसिलियम लेकानी(*Verticilliumlecani*) | मिलिकिलर(Milikiller) | 1.15% |
| 25 | | ट्राईडेन्ट(Trident) | 1.15% |
| 26 | | भर्टिजाईन एल(Vertijain L) | 1.2% |
| 27 | | चट्टान (Chattan) | 1.15% |
| 28 | ट्राईकोडर्मा हार्जियानम(*Trichodermaharzianum*) | निप्रोट (Niprot) | 0.5% |
| 29 | ट्राईकोडर्मा भिरिडी(*Trichodermaviride*) | वायोक्यूर एफ(Bio-cure F) | 1.15% |
| 30 | | निसर्ग (Nisarga) | 1% |
| 31 | | सञ्जिवनी (Sanjivani) | 1% |
| 32 | | क्यारियर (Carrier) | 1% |
| 33 | | निकोडर्मा (Nicoderma ) | 1% |
| 34 | | अस्तन टि.भि. (Austen T.V ) | 1.5% |
| 35 | | भोपारिसट्राईको (Voparis Trico) | 1% |

Source:(Sharma, 2015)

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## Author's Biography



Indra Raj Pandey, born in Nuwakot, Rawalaswanra, has received M.Sc. Agriculture (Horticulture) degree from Himachal Pradesh Krishi Vishwa Viddhyalaya, India in 1982. He has involved in vegetable and vegetable seed research and development work for the Government of Nepal from 1972 to 2003. He has served as an Expert and Specialist in Hellen Keller International funded by USAID, Senior Agriculturist in Integrated Bagmati Watershed Management funded by EU, Team Leader of Vegetable Seed Production project funded by SDC in CEAPRED, Technical Advisor of Nepal Market Development Project funded by DFID. He is continuing works and studies as free lancer horticulturists and consultants for different project. He has written 10 books and mannuals, and published several papers and research articles.

# Chapter 20

## Nepal's Vegetable Exports: Prospects and Problems

**Neelu Thapa**
*26 Mamta Galli, Baluwatar, P O Box 19366, Kathmandu, Nepal*
Email: neelu.thapa@sawtee.org

*Vegetables are an integral part of daily diet and, thus, the demand for nutritious, fresh and organic vegetables increases with rising income. Nepal's agro-climatic diversity makes it possible to grow various kinds of vegetables all over Nepal. Traditionally, vegetables were grown at the subsistence level for household consumption of the farmers, but commercial farming is gaining popularity with the ongoing commercialization of agriculture. There are high returns on investment in vegetable farming compared to that of cereal and other cash crops. Farmers and traders are more attracted to off-season vegetables that normally get higher prices. India remains the single largest market for export of Nepalese agricultural products including vegetables. There has been little effort towards diversification of export to other markets. There is a huge potential to export to overseas markets provided that there is enough effort put to maintaining the quality of the produce. This includes improvement in post-harvest operations and trade infrastructure.*

**Keywords:** Commercialization of agriculture; exports; non-tariff barriers; off-season vegetables; post-harvest; quarantine.

## Introduction

With nearly 18.7% of population living below the poverty line (NPC, 2020) and majority of them engaged in agriculture, improving agricultural productivity and income is indispensable to reduce poverty in Nepal. However, agriculture sector in Nepal is characterised by low productivity and high dependency on subsistence farming. Amidst the generally bleak outlook of the agriculture sector, horticulture, especially vegetable farming, has emerged as an important sub-sector that has recorded high level of productivity as well as commercialisation in the recent years.

The area used for vegetable cultivation has been steadily on the rise as farmers have increasingly recognised the better financial returns offered by the farming of fresh vegetables. In the decade between 2005 and 2015, area under vegetable cultivation jumped by 40%. Unlike cereal crops, vegetable farming does not require large area for

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bumper production; vegetable farming is considered better suited for the subsistence farmers as majority of the farmers hold less than two hectares of land. It also allows upscaling and gradual commercialisation of farming activities, leading to improved income of small farmers. Vegetable farming is lucrative due to its greater potential for higher commercialisation rates; 30–50% higher than maize and fruits (Bhandari et al., 2015). Likewise, vegetables do have higher cost benefit ratio of 1:3 in comparison to cereals 1:1.5 (Bhandari et al., 2015).

Vegetables are classified as winter and summer vegetables based on the time of production. Vegetables such as cabbage, cauliflower, carrot, radish, etc. that are grown in winter months are considered winter vegetables, while pumpkins, beans, bottle gourds, etc., which are grown in summer months are called summer vegetables. However, due to its topography and climatic conditions, Nepal's hilly region is suitable for growing winter vegetables throughout summer as well. These winter vegetables that could be cultivated during spring, summer and monsoon are referred as off-season vegetables in Nepal. Owing to higher demands and superior prices, off-season vegetables have emerged as effective means of reducing poverty. Moreover, vegetables have high potential for market growth not only within Nepal but also across the border in India (HVAP, 2011). Of late, off-season vegetable is being recognised as a major agriculture commodity that holds a comparative advantage for exports to India. During the months between July and September, agro-climatic condition in Indian and Nepali plains of Terai become unsuitable for vegetable production due to water-logging and flooding which affects the production of major vegetable crops such as cauliflower, cabbage and cucurbits. However, Nepal's agro-climatic feature makes its hilly regions suitable for all-year round cultivation of the vegetables, even the ones that are considered winter vegetables in the plains. Growing these winter vegetables to be sold between the rainy, summer and autumn seasons in India is slowly gaining pace among Nepali farmers and has opened up a whole new export market for them.

Recognizing the high potential for commercialization of vegetables, government has encouraged commercial vegetable farming through policy interventions. However, Nepal is still a net importer of vegetables and thus policy is intended to facilitating vegetable production for domestic consumption rather than export. Household survey conducted by Central Bureau of Statistics (CBS) in 2010 has shown that the farmers consume 39% of the total production while 61% is sold in the market (CBS, 2010). Despite surplus production at farm level, higher cost of production, fragmented markets and absence of proper logistic and transport facilities have created disconnect in the supply chain of vegetables. In many pocket areas, vegetable export is considered only as a means of disposing seasonal gluts. Besides, farmers in the hilly districts of Dadeldhura, Makwanpur and Tehrathum find markets in India closer than in Kathmandu.

In spite of the potential of exports of the vegetables, farmers have not been able to fully exploit this potential to their advantage. Thus, exploring export potentials of Nepali vegetables will require a thorough examination of the structural factors that are impeding their production and sales within and outside the country.

This study takes stock of the current state of vegetable production and trade from Nepal through major customs points to uncover the obstacles faced by the farmers and

vegetable traders while bringing vegetables from the farm to the export markets. Therefore, this study does not completely disregard the production side of vegetable but it focuses on export and market-related issues faced by the farmers, traders and wholesalers. This study tries to find effective ways to utilise Nepal's comparative advantage in vegetable production provided by its unique geography and climatic condition. This study also assesses the export potential of Nepal's major vegetables to India and other countries. The information in this chapter is gathered mostly from literature review and draws from a report titled 'Export potential of fresh vegetables to India and other countries'. This report documented the findings of a field survey undertaken in 2016 by the author. The survey was supported by Samarth-NMDP (Nepal Market Development Program).

## Literature Review

Agriculture Development Strategy (ADS), which envisions a framework to transform Nepal's agriculture sector in the next two decades, has recognised vegetable farming as one of the keys for unlocking Nepal's agro-export potential (MOAD, 2014). Vegetables are important part of a meal in any household as they are considered important sources of energy and nutrition.

Nepal's annual vegetable production currently stand 13.7 metric tonne per hectare (MT/ha) which is lower than its potential of 17 MT/ha/year (MOAD, 2014). The area of cultivation under vegetable production has jumped by almost 34% in the past decade (Table 20.1).

**Table 20.1.** Trend of vegetable cultivation and production in Nepal

| Fiscal year | Area (ha) | Production (MT) | Yield (kg/ha) |
|---|---|---|---|
| 2005/06 | 189,832 | 2,190,100 | 11,537 |
| 2006/07 | 191,922 | 2,298,689 | 11,977 |
| 2007/08 | 208,108 | 2,538,904 | 12,200 |
| 2008/09 | 225,154 | 2,754,406 | 12,233 |
| 2009/10 | 235,098 | 3,003,821 | 12,777 |
| 2010/11 | 244,102 | 3,203,563 | 13,124 |
| 2011/12 | 245,037 | 3,298,816 | 13,463 |
| 2012/13 | 246,392 | 3,301,684 | 13,400 |
| 2013/14 | 254,932 | 3,421,035 | 13,419 |
| 2014/15 | 266,937 | 3,580,085 | 13,412 |
| 2015/16 | 280,807 | 3,929,034 | 13,992 |
| 2016/17 | 277,393 | 3,749,802 | 13,518 |
| 2017/18 | 286,864 | 3,958,230 | 13,798 |

Source: (MOAD, 2018)

Nepal's agro trade balance is in deficit as Nepal exports lentils, tea, cardamom, fruit, ginger, and medicinal and aromatic plant products (MAPs), while imports essential commodities such as fruit, cereals, vegetables, beans (mostly peas), dairy products, meat animal and raw materials for processing (oil seeds) in a larger quantity. Vegetable farming could play pivotal role in reversing Nepal's agro trade imbalance. According to the ADS, agriculture sector could be an important source of foreign exchange due to the potential for import substitutionin vegetables, fruit, beverages, dairy and meat. The strategic plan has calculated that Nepal has ample space to improve its vegetable production to generate higher return. Thus, by developing value chain for vegetable farming and marketing, Nepal could improve its export position. Annually, Nepal produces about 3.5 million MT of fresh vegetables and exports about 7% of it, according to the statistics provided by national agencies on agriculture. In the past five financial years, export volume of vegetables from Nepal has grown exponentially but at the same time import has also risen steadily.

Table 20.2 shows the total volume of export and import of vegetables over the last five years. The calculation made from the available data shows that trade deficit is increasing every year as huge volume of vegetables are imported and only a minimum amount, exhibiting significant decline, is exported.

**Table 20.2.** Trend of vegetable export and import

| Year | Export (NRs) | Export (Kg) | Import (NRs) | Import (Kg) | Trade deficit (NRs) |
|---|---|---|---|---|---|
| 2013/14 | 2,101,249,645 | 28,112,591 | 12,903,121,701 | 458,563,320 | 10,801,872,056 |
| 2014/15 | 1,644,492,171 | 31,544,950 | 15,982,520,586 | 502,193,653 | 14,338,028,415 |
| 2015/16 | 1,653,756,677 | 24,671,587 | 19,201,819,118 | 515,986,755 | 17,548,062,345 |
| 2016/17 | 1,185,334,814 | 13,280,928 | 22,499,810,663 | 618,493,594 | 21,314,475,849 |
| 2017/18 | 952,899,814 | 13,736,282 | 20,620,926,755 | 882,963,798 | 19,668,026,941 |

Source: (Web, 1)

A study done by High Value Agriculture Project (HVAP) on the off-season vegetable export has found that farmers have been able to fetch good returns by selling vegetables in spite of the obvious structural issues such as absence of sufficient irrigation and cold storage facilities. However, presence of non-tariff barriers (NTBs) and lack of proper handling practice and storage facilities mean that only a small portion of the vegetables produced in the country is exported. Moreover, the current export goes to India mostly through unofficial routes because of NTBs and it represents a vast market opportunity for the vegetable sector. The export of vegetables to India occurs mostly during the rainy season or off-season, which runs from July to October, as Nepali vegetables cannot compete with Indian vegetables in terms of price during other months (HVAP, 2011).

Similarly, a study carried out by the National Planning Commission (NPC) had pointed out Nepal's huge opportunity in the production and marketing of fresh vegetables and fruits. The report considers off-season vegetables as one of the most promising export commodities for the markets in India such as Delhi, Lucknow, Kolkata, Kanpur and

Siliguri. There are prospects of exporting almost all kinds of vegetables produced during rainy and summer seasons in the mid hills and mountains of Nepal which could not be grown in India (AEC-FNCCI, 2005). Off-season vegetable production and marketing is popular among farmers and marketers as the prospect is good both within and outside the country, especially in Bangladesh and the markets in the northern border of India including Siliguri, Muzzafarpur, Patna, Gorakhpur, Lucknow, Bareli, Pilibhit and Delhi (NEAT-USAID, 2011). A feasibility study of agriculture products' export in selected rural districts in Nepal found the production of fresh vegetables in the identified pockets could fetch good market outside Nepal only when the production is done in the off-season in the target markets (Auetragul & Thapa, 2003). The study's financial analysis showed positive net return in all the identified commodities and pockets. The report also lauded the role of vegetable farming in employment generation.

Though exporting vegetables appear to be feasible in theory, the structural issues related to production has created difficulty, and more importantly, Nepali vegetables need to maintain certain quality to become competitive in the export market. Nepali vegetables are not graded or sorted and are packaged in traditional containers such as bamboo baskets or gunny sacks, which compromises their quality. Post-harvest loss is highest for tomato which is about 33%, followed by cauliflower, cabbage, green pea and bean (HVAP, 2011). Lack of proper post-harvest technology causes losses in weight and quality which results in lower market value. Moreover, absence of organised market to connect farmers in Nepal to the exporters of perishable commodities is preventing Nepali produce from reaching the international markets (NEAT-USAID, 2011). At present, the farmers have, through their own efforts, established linkages with wholesalers and retailers in the local markets but the lack of awareness among farmers about grading and packaging of the vegetables leads to considerable post-harvest loss. Similarly, lack of proper dissemination of information of the market also prevents the farmers from fetching better price. A report by Agro Enterprise Centre (AEC) cautions that delay in the adoption of measures to improve Nepali vegetables' competitiveness might lead to loss of the existing opportunities provided by Nepal's geo-climatic condition as North Indian hills with similar climatic zone might get into vegetable farming threatening the advantage enjoyed by Nepal (AEC-FNCCI, 2009).

Likewise, there is also an absence of mechanism to encourage small producers to produce adequate volumes of high-quality produce that could be supplied to the wider markets (HVAP, 2011). There is a limited industrial-scale processing operation in agriculture sector in Nepal. At the same time, there is no premium for the fresh and high-value produce to incentivise bulk production. A major challenge to enable small producers to gain access to markets is to reliably produce adequate volumes of high-quality produce to supply to the wider markets.

Most of these studies are focused on selling vegetables within Nepal or in the neighbouring Indian cities. If handled properly, Nepali produces have the potential for standing out in the foreign market as well. However, absence of proper post-production and marketing infrastructure has hindered Nepali produces' potential in the overseas market. Nepali farmers and traders have no knowledge about non-Indian market which bars the possibility of gaining benefits from overseas exports (Promar Consulting, 2014).

In order to be able to establish effective linkages with the foreign market, Nepali vegetable producers need to be careful about disease management during production stage and be able to use improved storage facilities for maintaining the quality. Likewise, the vegetables need to be securely packaged with essential labelling as required by the importing countries. In addition, the farmers or traders have no idea about the pricing in the markets abroad and how does their own cost – including packaging, freight, insurance and customs – compare with that in those markets. Traders need to improve their production capacity as well as marketing infrastructure so that Nepali traders could compete in the overseas market (Promar Consulting, 2014).

Recognising high potential for commercialisation of vegetables, Government of Nepal (GoN) has encouraged vegetable farming. Vegetable farmers get subsidy on the interest of loans they obtain for farming purposes (NPC, 2016), as well as get direct subsidy for vegetable cultivation in selected districts (MOAD, 2013). Likewise, government provides 75% subsidy on the premium paid for agro insurance products by the farmers (NPC, 2016). However, there is lack of specific incentives provided to the farmers and traders for exporting vegetables. The government policies are, at present, concentrated only on increasing overall vegetable production and to engage more youth, women and disadvantaged groups in the process.

Moreover, the studies are unanimous in suggesting the Nepali farmers and traders to improve their production and packaging techniques to enter into new markets. Likewise, the farmers are incurring losses due to poor handling of produce during transportation stage. Although Indian market seem to be tolerant of importing unpackaged unlabelled vegetables but if Nepal wants to create a space for its produces in the vegetable markets overseas, more care has to be given at grading and packaging.

In conclusion, there is substantial evidence regarding Nepali vegetables' potential for export. The most suitable foreign market seems to be India, especially due to geographical proximity; closeness is crucial as Nepali exporters still use primitive means to package and transport the perishable products. All of the studies presented the case that exporting vegetables to India is viable provided the produces are exported in the off-season. However, the area of scope of these studies is limited, as most of the studies have picked up certain geographical region to investigate the possibilities of vegetable export. None of these reports have done a comprehensive study on the prospects of vegetable export from Nepal as a whole. Likewise, the studies focused mostly on exporting vegetables to India only. There is an absence of literature that looks into possibility of exporting vegetables to the third countries. Thus, there is lack of study that look into important factors affecting exports such as market access conditions, sanitary and phytosanitary (SPS) measures that affect export of Nepali plant produces in the third countries, and other non-tariff measures (NTMs) and NTBs. Likewise, hardly any study has been done which focuses on the international market access for Nepali vegetables. The focus so far has always been given to produces such as ginger and vegetable seeds, which are quite different than fresh vegetables that are perishable in nature. There are lack of studies and relevant literatures as to examine the export outlook of Nepali fresh produces such as vegetables and fruits that have low shelf life and are subjected to stringent SPS rules in the destination markets.

## Status of Vegetable Export and Import

Tables 20.3 and 20.4 show data of export and import of vegetables over five years through major custom points in Nepal. Data of seven major custom points have been provided below to get an idea of vegetable exports and imports in Nepal.

**Table 20.3.** Vegetables imports from various custom points (Figures in NRs)

| Custom points | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Bhairahawa | 3,177,118,387 | 3,504,625,298 | 4,834,072,277 | 5,374,605,834 | 4,972,616,558 |
| Biratnagar | 1,220,774,175 | 1,658,352,414 | 1,668,552,229 | 2,076,988,731 | 2,164,240,187 |
| Birgunj | 1,690,806,678 | 1,551,130,915 | 821,505,598 | 1,943,143,690 | 1,642,325,682 |
| Kanchanpur | 6,134,351 | 257,923 | 98,921,530 | 92,751,022 | 78,565,958 |
| Mechi | 1,637,755,587 | 3,041,647,540 | 3,185,847,164 | 1,714,615,294 | 1,816,118,352 |
| Nepalgunj | 620,687,101 | 635,164.998 | 1,528,012,261 | 2,071,783,330 | 1,281,097,425 |
| Tribhuvan International Airport (TIA) | 232,481 | 407,501 | 468,540 | 548,516 | 607,364 |

Source: (Web, 1)

**Table 20.4.** Vegetables exports from various customs points (Figures in NRs)

| Custom points | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Bhairahawa | 12,954,795 | 36,305,704 | 16,899,420 | 3,967,860 | 4,580,362 |
| Biratnagar | 36,879,165 | 88,372,513 | 154,784,879 | 27,119,349 | 28,450,741 |
| Birgunj | 40,487,590 | 176,203,610 | 35,866,387 | 58,062,060 | 219,102,192 |
| Kanchanpur | 584,000 | 87,000 | 2,409,025 | 444,000 | |
| Mechi | 1,920,738,228 | 1,211,822,759 | 1,347,195,367 | 995,622,779 | 821,003,325 |
| Nepalgunj | | 7,200,000 | | | |
| TIA | 23,360,643 | 43,805,306 | 20,943,349 | 17,032,521 | 19,388,494 |

Source: (Web, 1)

Looking at the data, it can be inferred that vegetable imports are significantly higher than exports. The amount of export is negligible. As shown in Table 20.3, Bhairahawa is found to be importing a huge amount of vegetables followed by Biratnagar and Mechi. Birgunj is also found to be an important route for vegetable import.

During the field survey, it was found that the Birgunj customs recorded almost all the forms of vegetable trade, even the ones being transported on motorcycles and rickshaws, while other custom points completely ignored these transactions. Birgunj customs recorded each and every cross-border movement of goods taking place. It is completely at the discretion of the custom officials whether to record or not the transactions in bicycles

and rickshaws. Since the custom officials did not give much importance to smaller vehicles crossing the border with goods loaded, this trend of recording these transactions may or may not be followed when the customs staff are transferred and replaced by new officials. Vegetables exported from Birgunj were mostly sourced from Palung VDC in Makwanpur district and the vegetables exported from Mechi and Biratnagar were sourced from Dhankuta and Tehrathum districts in the eastern region. Farmer's cooperative at Sindhuwa village in Parewadin VDC of Dhankuta district has been exporting vegetables since many years and they seem to have a permanent market. This has incentivised the farmers in this area to keep up the production of vegetables. The exporters have a permanent market in the sense that they supply it to orphanages and military camps which have been regularly taking these products. They have been supplying to these customers regularly. Most of the export items comprise of cabbage, tomato, cauliflower, green chilli, beans, okra, beet root and pointed gourd.

Export of vegetable takes place mainly in an informal manner. Vegetables are packed in small consignments and passed through rickshaws, three wheelers, motorcycles and bicycles. These vehicles have an option of registering or not registering at the custom office as they are seldom stopped.

Data of export and import of vegetables from all of these seven custom points are given in detail in Annexes 20.1 and 20.2, respectively. The data also shows the top vegetables that were exported in various years. Nepal has been exporting potato, leguminous vegetables and mixed vegetables but it is neither consistent nor in substantial quantities. Potato, tomato and onion have consistently topped the import list. Tomato is being exported in small quantities but imported in larger quantities.

Nepal enjoys duty free access to Indian markets for almost all the goods as mentioned in the bilateral trade treaty between Nepal and India, if they fulfil the rules of origin criteria. Vegetables as primary agricultural products are categorized as wholly produced products and accordingly enjoy duty free access into Indian markets. Apart from the custom clearance, 'No Objection Certificate' from Food Import Clearance System (FICS) of the Food Safety and Standards Authority of India (FSSAI) is required. But the incidence of non-tariff barrier is excessively high.

Being a plant product, vegetable export needs to meet the obligation of plant quarantine requirements (Ojha, 2016). At the same time food safety regulations under FSSAI are also imposed on vegetables as a product is used for human consumption. Nepalese quarantine certifications are seldom honoured by the Indian plant quarantine authorities. Similarly, lack of food laboratories at the border posts on the Indian side and the non-accreditation of the Nepalese laboratories have been major factors hindering the export of Nepalese vegetables.

## Export Process

The export process of vegetables starts with the collection of the products from the farms by the local collectors who have maintained contact with the wholesalers in bigger markets. Normally, the importers from India establish contacts with the wholesaler in these markets and announce prices to be offered to the latter. Such prices are derived on

the basis of prevailing selling prices of vegetables in bulk in the market in India and by deducting the cost of transportation, customs charges, quarantines and other border clearance charges. The profit margin to the importer and commissions to the wholesaler transportation cost from the production centre to the wholesale market are also deducted from the wholesale price in India and the farmers are entitled to get the final price after deducting all those expenses on supply chain. The supply chain of vegetable export is depicted in Figure 20.1.

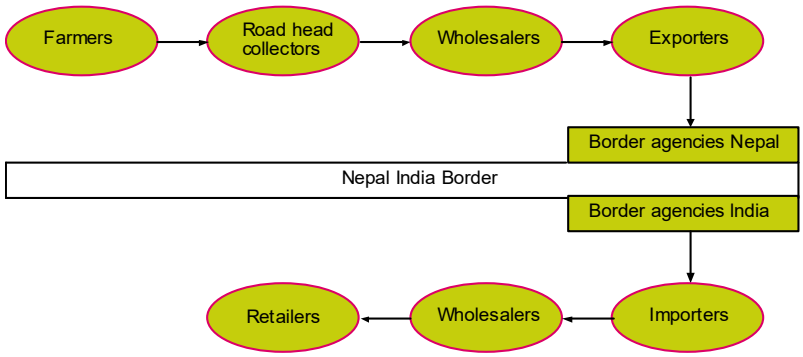



**Figure 20.1.** Supply chain of vegetable export from Nepal to India.

The export of vegetables is heavily dependent on middle persons who make a deal with the wholesalers on the other side of the border and the local collector of vegetables. Export process moves ahead with the permission of import from plant quarantine offices on the other side of the border, and the letter of import permit requires: name and addresses of importers and exporters, description, quantity and the SPS related conditions of the plant products. Such parameters normally include free from soil, weed seeds and plant debris while specific requirements are also mentioned depending upon the potential risk of insect pest and diseases in the related plant products. A typical case in export of cabbage from Kakarbhitta shows that the permit issued by Indian Plant Quarantine Office at Panitanki requires certification from the Nepalese Plant Quarantine Office stating that the consignment is free from following pests (as noted from the transaction file of Plant Quarantine Office at Kakarbhitta): Black leaf spot (*Pseudomonas maculiocola*), Back rot (*Xanthamanas compestris*) and Black leg (*Phama lingam*). Further, the certification confirming appropriate physical appearance of the goods and absence of soil particle and plant debris is required. The Plant Quarantine Office at Kakarbhitta normally checks the sample of the export consignment and make sure that the plant product in question meets all the criteria required by the Indian Plant Quarantine Offices.

## Issues Affecting Export of Vegetables

As indicated above, the export outlook of vegetables does not look encouraging. What exactly were the factors creating hurdles in the export of vegetables? An attempt was made to analyse the issues from the perspectives of demand, supply and market.

## 1. Supply Side Issues

***Inconsistency and fluctuating production:*** The farmers engaged in vegetable production do not have the capacity to plan the production which often leads to over-production in some places and under-production in others. The farmers in Nepal produce various types of vegetables at a time but in small quantities. The production pattern is not well planned and the volume of production not enough to cater to the need of markets. Palung valley in Makwanpur district had a huge potential to produce off-season vegetables which could be exported from Birgunj. Many agricultural locations face problems of availability of agricultural inputs like fertilizers and irrigation affecting the production. In addition, the shortages of labour also come up as a major problem in many places. The growing attraction for temporary migration abroad for employment has also affected the production of vegetables as there are not enough farm hands engaged in farming.

***Cost of production is comparatively high in Nepal and a deterrent factor for export:*** The reasons mentioned above explain the high price of Nepalese vegetables. The farmers and subsequently the consumers have failed to benefit from the economies of scale. The cost of vegetables production is lower in India in comparison to Nepal due to:

1) higher level of commercialisation of agriculture in India,
2) the subsidies provided by the Indian government (for instances; in fertilizer, irrigation, energy, agricultural machineries and equipments) are higher than provided by the GoN,
3) better technology and extension services,
4) the agricultural productivity in Nepal is lower than in India. For example; according to the World Bank data, the cereal yield in India is 2,981 kg/ha in 2014 while it is 2,748 kg/ha in Nepal (Web, 2)

Thus, there is a direct impact of these factors in cross border trade of vegetables resulting in higher level of import of vegetables into Nepal with negligible amount of export due to price differences.

***Government support program for vegetable production has some inherent deficiency:*** The GoN has been implementing various programmes to increase production of vegetables; but these have not worked very well and have failed to reach the actual target group. One of the major programmes implemented earlier was *The Youth Targeted Program.* This programme envisaged providing NRs 60,000 as subsidy per *bigha* (0.65 ha) of vegetables cultivation to the farmers with successive two crops in a year. This is output based support programme and provides opportunities to all farmers to benefit from the scheme. However, the programme had some inherent weaknesses, such as, scattered location of the farms in various corners of the district, making the support and monitoring task more difficult, production was not linked with export and marketing, often causing losses of production, and mostly well off farmers being benefitted at the cost of small and marginalized farmers.

***Unchecked flow of low quality Indian vegetables:*** The production of vegetables is increasing on one hand while at the other imported Indian vegetables is posing a threat to

the Nepalese farmers due to influx of vegetables. Indian vegetables have access to Nepalese market following a simple quarantine check without going into rigorous test which is required for the Nepalese vegetables while being exported to India. The detailed checks are done only when the quarantine officer feels the need that is enforced as a very rare case. The Nepalese labs are also not fully equipped and lack the technical expertise to carry out the advanced level of checks and tests. The production of vegetables is at a larger scale in India with the business more organised and the huge amount of subsidies provided makes the Indian vegetables cheaper in the market. Therefore, the Nepalese products are unable to compete with them and this is creating adverse impact on the production of vegetables in Nepal.

***Vegetable production expected to increase further in future:*** Some of the policies of the government are supportive of production of vegetables. Various international and national non-governmental organizations are also working to support the initiatives of increasing production. Some of them are supporting the river bed farming in the western, mid-west and far western region with an objective of raising the income of landless farmers through vegetable farming. Riverbed farming which started with only 670 households in 2006/07 was extended to 6,219 households by the mid of 2014 in 12 districts in terai. Mapping was done in 14 terai districts with more than 45,000 hectares of riverbed areas available for vegetable production. This is expected to increase the production of fresh vegetables in Nepal. There are many instances where there have been excessive production causing a fall in sales price. There are cases when farmers had to dispose their produces in their fields when there was over-production and they were unable to find any suitable markets.

A strategy needs to be developed for the proper utilization of surplus production. Obstruction in export often ends up forcing the farmers to sell their products at throw away prices. Therefore, the marketing aspects also need to be taken into consideration.

***Lack of integrated pest management (IPM) is causing erosion of confidence over the quality of vegetables produced in Nepal:*** GoN is implementing the IPM system in various districts that disciplines the farmers in judicious use of chemical and organic pesticides and insecticides. But, the enforcement is not effective. As a result, farmers often end up excessively using the chemical fertilizers, insecticides and pesticides without giving due consideration to the impact of residue on human health. This has been a major concern for the consumers of vegetables in the domestic front as well as in export markets; also a reason for problem in export. Effective pest management would be able to enhance the confidence of consumers and thus increase their preferences towards Nepalese vegetables.

## 2. Demand Side Issues

This section explores the demand of Nepalese vegetables in various markets like India, Bangladesh and Middle-East countries. Available import-export data were analysed to identify whether any vegetable was being exported to some other countries and also to see if there is any possibility of exporting vegetables to these countries. Table 20.5 shows Nepal's vegetable exports to different countries. The details of vegetable exports are given in Annex 20.6.

**Table 20.5.** Nepal's vegetable exports to different countries (in US$ '000)

| Country | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| Bangladesh | 58,340 | 23,839 | 36,781 | 15,930 | 17,767 | 6,567 | 12,133 | 8,555 |
| India | 340 | 784 | 2,993 | 1,152 | 2,345 | 3,647 | 1,668 | 797 |
| Singapore | 369 | 331 | 397 | 802 | 590 | 635 | 778 | 663 |
| France | 104 | 276 | 132 | 242 | 427 | 147 | 133 | 174 |
| Vietnam | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 41 |
| United Arab Emirates | 0 | 33 | 48 | 0 | 34 | 0 | 0 | 37 |

Source: (Web, 3)

## *India*

Interactions with various stakeholders in different districts during the field survey had indicated that the quality of Nepalese vegetables was much better than Indian vegetables. The Nepalese pointed gourd (parwal) was considered to be of superior quality. The stakeholders' perception about quality was lower use of pesticides and complete non-use of inedible colours. Both the pesticides and inedible colours were used at a higher degree in the Indian vegetables. Pointed gourd produced in Dodhara-Chandani municipality in Kanchanpur district used to be sold at a much higher price than the produce of India and provided a good source of income to the farmers. But the export was discouraged over the last few years due to obstructions on account of "quarantine requirement" enforced by the Government of India (GoI). Similarly, Patani VDC in Bhairahawa district is also famous for pointed gourd of very good quality. But these products are not being exported and rather sold off only in the local market and sometimes even wasted. Hassles related with cumbersome procedural requirement and non-tariff measures (NTMs) were the impeding factors of export to India.

While analysing the prospects of exporting vegetables to the Indian market, there is a need to identify the level of demand in the market. Therefore, an effort was made to record the number of vehicles with vegetables crossing the border informally. Such a count of means of transport was done in Mechi border crossing and the findings are given in Annex 20.3. The figure shows that the number of bicycles and rickshaws loaded with vegetables, crossing the border on daily basis was quite high. Almost 8,000 kg of vegetables was traded informally in a single day. This observation was done for two days and this provides preliminary indication of the scenario at other customs points as well. Though on the second day, the number was dropped down to 3,800 kg, the probable reason might be that the carriers have suspected that they are being watched by some agencies. Nevertheless, taking an average of the two, everyday 5,950 kg of vegetables is taken across the border, which is a substantial amount. The trend would have been clearer if this could be followed for a number of days, ideally for six months. The informal trading of vegetables on a large scale indicates that there are many problems in formal trading and subsequently it can also be inferred that there is demand for Nepalese vegetables in the Indian market. The vegetables that were traded informally were chayote squash, cauliflower, leafy greens, cabbage and tomato.

Looking at India's vegetables import (Table 20.6) in the last five years, it was high till the year 2017 and decreased drastically in 2018 and 2019. But it still imports a substantial amount of vegetables as Indian vegetable production has not been able to keep up with the demand. The comparative advantage of Nepal in the Indian market is very clear, primarily due to the preference for Nepalese products despite it being expensive and the proximity. We could also look at Annex 20.5D (changed from Annex 20.4A-C to Annex 20.5D) which shows the categories of vegetable imported in India, which would further help us to determine the opportunities for Nepalese vegetables in Indian market.

**Table 20.6.** India's vegetables import (in US$ '000)

| 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| 3,678,312 | 4,026,070 | 3,959,483 | 1,087,491 | 1,605,941 |

Source: (Web, 3)

Cabbage was the major vegetable item exported from Mechi and Biratnagar to India when the survey was being undertaken in 2016. Some of the vegetable traders had mentioned that there was a period when tomato used to be exported to India in large quantities but the export of tomato came to a halt when the tomato could not meet the SPS standards. Export of summer and winter vegetables mainly takes place during the rainy season which is considered to be the lean season in India. During this period, the traders from neighbouring areas in India come to the vegetable wholesalers in Nepal to collect vegetables. If the Nepalese traders could preserve the vegetables for a little longer period, they could earn hefty profit out of the sales of their products. But they do not have enough resources or support to execute it. During the rainy season, the collection centre in Hetauda sends off vegetables in almost 300 trucks of vegetables, half of them belonging to Indian traders. But these trucks are off-loaded in the border and then re-loaded in small vehicles and taken across the border through Birgunj custom point. This is mainly due to the quarantine issues.

## *Bangladesh*

Bangladesh does not have sufficient land for vegetable production and most of the land is inundated during monsoon. The country falls short of supply and need to import a huge quantity of fresh vegetables. Though Bangladesh offers some opportunities for export of fresh vegetables, the tariff level is normally higher; particularly for tomato, cabbage, lettuce, carrot and all other green vegetables (include commodities under Chapter 7 of Harmonized Systems (HS) Code developed by the World Customs Organization) attract 25% import duty. Besides, the prevalence of NTBs also poses problems in export. Data shows that Bangladesh imported almost US$ 704 million worth of fresh vegetables in 2015 (Annex 20.4). The trend of importing vegetables has been increasing and was almost double in the year 2016 compared to 2013. But then though it has been declining, the import value still remains high as shown in Annex 20.4 (A and B). Bangladesh imported vegetables worth of US$ 58.34 million from Nepal in 2010 and US$ 23.80 million in 2011. But the imports from Nepal has declined and reached to the tune of US$ 8.5 million in the year 2017 (Annexes 20.4B and 20.5B). We could also look at Annex

20.5A which shows the categories of vegetable imported in Bangladesh. Disintegrated data (refer to: Annex 20.5B) shows that in all the years, out of the total amount of vegetables exported to Bangladesh, Nepal has only supplied dried leguminous vegetables to Bangladesh and none of the other items were exported.

Whether declining or increasing, it shows that Nepalese leguminous products have already penetrated the Bangladeshi market (see: Annex 20.5B), and the issue is either to sustain or increase it, but unfortunately this does not seem to be happening. There is a need to explore other possibilities as well. Bangladesh has been importing from several European countries, African countries and USA (see: Annex 20.4). The existing opportunity for Nepalese vegetables in the Bangladeshi markets is pretty clear considering the proximity location of the two countries. The issue here again is maintaining quality and uninterrupted supply, otherwise the markets will be diverted towards other countries.

## *Bhutan*

Bhutan as the next neighbour in South Asia could be the destination for Nepalese products. But the prospect of vegetable export to this country seems very bleak due to small market size and similar geographical settings with similar production. Rather, Nepal has been importing potato from Bhutan since last couple of years and there is no export of any kind of agricultural products to this country. Table 20.7 presented below shows that vegetables import in Bhutan is mostly from India. Data for vegetable imports were only available only till 2012.

**Table 20.7.** Vegetable imports by Bhutan (in US$ '000)

| Exporters | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|
| World | 2,260 | 2,381 | 3,392 | 3,478 | 3,765 | 4,700 | 5,305 | 8,494 |
| India | 2,234 | 2,363 | 3,345 | 3,408 | 3,723 | 4,586 | 5,249 | 8,424 |
| Turkey | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 37 |
| Thailand | 18 | 15 | 7 | 14 | 7 | 19 | 21 | 33 |
| Bangladesh | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Canada | 0 | 0 | 39 | 0 | 34 | 0 | 0 | 0 |
| China | 0 | 0 | 1 | 5 | 0 | 0 | 0 | 0 |
| Nepal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Singapore | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |

Source: (Web, 3)

## *Middle-East*

In view of the increasing demand of fresh vegetables in the Middle-East countries, there are possibilities of exporting fresh vegetables to these countries as well. Their domestic production is constrained due to lack of adequate arable land. The Middle-East countries have low or no tariffs on a number of vegetable commodities which makes these potential markets for Nepalese vegetables. Among the SAARC countries, Pakistan and India have

been supplying fresh vegetables to these countries. Middle-East countries have a huge market for vegetables, a small country like Bahrain imports vegetables almost equal to what a country of the size of Bangladesh imports (Annex 20.4C). The consumption of vegetables in other countries like United Arab Emirates (UAE) and Saudi Arabia is also very high. The data shown in Annex 20.5C also shows the categories of vegetables imported by UAE from the world, and comparing this to Nepal's exports to the world (Annex 20.6), the market that Nepal has penetrated is minimum. Nepal could export green and fresh vegetables but this of course requires meeting their national standards and food safety regulations. Targeting these markets would also mean that Nepal ensures a sustainable supply of quality products. Nepal is yet to explore this market but channelling the efforts towards penetrating this market would surely payoff to the Nepalese exporters and farmers.

Despite all these possibilities, the volume of vegetable exports from the various land customs is very minimum. There is a need to see what are the challenges and obstructions in Nepalese fresh vegetables reaching its market.

## Marketing Issues

As mentioned above, the potential of the Nepalese vegetables export seems encouraging. Supply side looks good, the demand side also looks promising, yet the data from various customs point show dismally low amount of vegetable exports. Among the shortcomings, low priority in marketing could be one of the reasons contributing low performances of export. Relevant issues are discussed below.

***Marketing aspect is not gaining much attention:*** As stated above, the supply side is good with quality produce and export surplus but yet the export volume is very low. This strongly suggests that Nepal has not been marketing its produce well in the neighbouring countries and elsewhere. The exports are done in a haphazard manner without proper planning. The GoN has been focusing on increasing production but there is virtually no support when it comes to the marketing of vegetable products. Most of the programmes and incentives run by the government intend to increase the production, but the farmers and traders are left to their own when it comes to marketing of the product. Government is providing partial subsidy for packaging materials, particularly plastic crates, for safe handling of vegetables; however, this initiative is not sufficient for marketing. The government effort is insufficient when it comes to linking products with the markets, enabling them, building their capacity to be able to effectively reach out to international and domestic markets.

***Inconsistency in data collection and recording:*** When it comes to data collection at the custom points, it largely depends upon the discretion of the concerned officials as to what level of disaggregation they wish to collect and maintain the data. For example, Birgunj customs has collected data of each and every sack of vegetables crossing the border even on bicycles and rickshaws while others have totally ignored them. This has created discrepancies in the data which makes it difficult to draw rational conclusion based on the secondary data obtained through government sources. This would definitely impact the policy level decisions and further in formulating any effective marketing strategies and plans based on incomplete data and subsequent information.

***Plant quarantine certificates provided by the Nepalese authorities are seldom recognized by the Indian authorities:*** A primary document which is required to export Nepalese produce in the Indian market is the Quarantine Certificate. But the hassle related with quarantine certification is another major impeding factor in marketing and export of vegetables. It has been found that certificates provided by the Nepalese quarantine authorities are occasionally accepted by the Indian authorities depending upon their discretion based on demand and supply of vegetables in India. Such certificates are accepted if there is scarcity of the products in the Indian market, and not accepted if there is glut in production, creating a sense of uncertainty among Nepalese producers and exporters. Lack of harmonization of standards, test and certification, and lack of mutual recognition agreement is the reason for such arbitrary decisions by the Indian authorities. But there has been a positive development regarding this issue as India has issued a notification that the test analysis certificates issued by the National Food and Feed Reference Laboratory, Nepal, shall be accepted by the authorities in India, with an annex of a list of goods including vegetables.

Border posts in the Indian side of Bonbasa and Gauriphanta, corresponding to Gaddachauki and Dhangadi in Nepal, do not have the full-fledged quarantine facilities. Hence, the Nepalese exporters require visiting either Lucknow (Uttar Pradesh) or Nainital (Uttarakhand) for receiving the SPS certificates of their products, if they choose to export fresh fruits and vegetables. The time and costs required for completion of the processes is excessive and consequently exporters abstain from exporting perishable items to India.

***Constrained cross-border connectivity and logistical difficulties:*** Connectivity is one of the major problems in facilitating trade of all goods including vegetables, particularly in the far western region. Gaddachauki and Dhangadi are the major customs for bilateral trade with India. However, both of these border posts are heavily constrained on account of the limitation on transport connectivity. Gaddachauki in Kanchanpur district is connected with Bonbasa border post in India which is located at the vicinity of Sharada barrage. The barrage also served as the bridge for movement of traded goods between Nepal and India for a long time, but now needs major rehabilitation and replacement due to its exhausted life span, which is almost 100 years old. Only vehicles weighing upto 10 MT with laden goods or empty are allowed to ply over the barrage within the specified time period, in day time. This causes major road block in using this border crossing for bilateral as well asoverseas trade. Similarly, Dhangadi border post also poses problem for trade as the Indian side of the border post lies within the forest reserve area called Dudhwa National Park and GOI seems disinterested to maintain the border post. There is no proper maintenance of the road passing through the park. There are limited movement of the trade traffic from those border posts in the far western region.

Likewise, the quarantine check posts are also not suitably located creating problems in export of Nepalese agricultural products. The sample of the export product for quarantine and food test certification need to be sent to Lucknow and Nainital cities of India. Belouri in Kanchanpur serves as the minor customs (Chhoti-Bhansar) serving the agricultural traded, and vegetables are traded across the border from this customs station. However, there is no proper recording of the trade data due to the absence of the corresponding customs on the other side of the border.

***Lack of proper market linkages and intelligence:*** The production of vegetables is not uniform at all places; some places witness over-production while there is under-production in other places. This calls for a collective management so that export possibilities could be increased with a substantial volume of vegetables crossing the borders. The traders would then feel that it would be worthwhile to find a market and export vegetables. The case of exports from the eastern border can be an example. Vegetable exports from the eastern border of Nepal are mainly due to assured market and sizable volume of production. The vegetable importers in India, particularly from West Bengal, supply the imported vegetables to the Bagdogra Military Camp and to orphanages in the Siliguri area. The consumption in such case is regular and in bulk, having assured market of the products. Thus, supply of vegetables has been taking place for a long time now and a process has been set. The vegetable traders in other areas are not able to follow this modality and hence facing problems in export.

Another reason for low performances in export is the lack of proper understanding of the market dynamics by the Nepalese traders. They neither have the capacity nor the resources to enquire about their products. The preferences of the Indian customers or anything of that sort so that they are able to act according to the market demand. This means that they are only selling the products and not bothered about the market, which means they are not aware of the market dynamics and if it changes with the passage of time, they will not be aware about it and may not be able to act accordingly.

***Post-harvest handling is not up to the standard:*** Nepalese products are not being properly handled and treated in the post-harvest processes. These leads to substantial losses in quality by the time the products reach the market. Hence, despite the products being of superior quality in harvesting, they may have to be sold off at the cheapest rate as compared to the similar products.

## Key Issues

### Data Inaccuracy and Inconsistency

- Vegetable exports are mainly taking place in an informal manner in rickshaws, motor bikes and carts; these modes of export do not end up in formal records.
- All the customs do not follow the same procedure for maintaining data. The collection of data is entirely at the discretion of the custom officers. This creates discrepancy in data.
- The available data shows that exports of vegetable are minimal as compared to imports despite having a surplus in the Nepalese market.

### Lack of Market Linkages and Intelligence

- There are more positive aspects in supply side and demand side but the efforts towards marketing both from the public as well as the private side is lacking.
- Lack of marketing skills and management is the major hindrance in the efforts towards exporting vegetables.
- Potential of export to India and other countries can be realized only by improving and easing market access conditions which could be pursued through constructive and

effective trade negotiations between the two governments. GoN should take a proactive approach in bilateral negotiations in view of continued difficulties faced by the Nepalese farmers and exporters.

- Mutual recognition of test and certification is important in order to enhance market linkages. There is no proper coordination between the regulatory agencies and insufficient harmonization of SPS measures and other technical regulations/standards between Nepalese and Indian requirements. But the recent development on Mutual Recognition Agreement (MRA) may be helpful in overcoming this barrier.
- Nepalese traders are not bothered about the market dynamics.

**Production Management**

- The unchecked flow of Indian vegetables could hamper the Nepalese production in future.
- There is a need of carrying out intensive and extensive training on post-harvest operations and build the capacity of farmers to enable them to market their produce.
- The production of off-season vegetables is becoming more attractive to the farmers due to the high export potential.
- Some of the Nepalese vegetables (like bitter gourd, pointed gourd, sponge gourd, mustard leaf, etc.) are better in quality and can be sold off at a higher price compared to Indian vegetables.
- Inadequacy of pest risk management (PRM) and pest risk analysis (PRA) is one of the reasons behind low preferences for Nepalese vegetables.

**Regulations and Quarantine Issues**

- Quarantine issues reign supreme in the exports of vegetables. Hassles in meeting the quarantine requirement of India is the major impeding factor in export.
- Exporting to other countries would also require building national capacity regarding food test and SPS. For example, fulfilling Saudi Arabian Standards could be helpful for Nepali produce to get an entry into the Gulf countries, but it is also not an easy option.
- Nepal needs to strengthen and streamline the capacity of SPS related laboratories
- Nepal also needs to take measures to protect agriculture from unfair competition on account of large subsidies provided by the neighbouring countries for the similar products.

## The Way Forward

## 1. Short Term Measures

***Bring uniformity in data recording and management:*** The first and foremost measure that needs to be undertaken is maintaining consistency in data collection and recording throughout all the customs points including data pertaining to informal import. This becomes necessary to ensure accuracy of data in vegetable exports and imports which can contribute in making policy and decision making easier and effective.

***Ensure acceptable quality of the products and regular supply:*** Despite having potential, Nepalese vegetables have failed to find markets as the quality and supply vary according to the type of product and the season of supply. So in order to cash on the opportunity and remain in the market, the farmers need to ensure quality as well as a stable supply that can be relied on. In order to ensure the quality and a stable supply, there is a need of identifying one or two products in the beginning and invest resources on development and supply of these products. The informal trading shows that squash is one such product which has a significant potential for export. So the focus should be on creating a stable supply of quality squash and market it. The volume of production is not uniform at all places and hence there is a need to develop collection and distribution centres at selected places targeting the export markets.

***Facilitate the linkages of the Nepalese exporters with importers from India:*** Although the production of vegetables has been increasing, it is surprising to see that no substantial efforts are being made to enhance the currently dismal export. Therefore, there is a need to facilitate market access and establish linkages with the importers in India so that the other farmers and traders are motivated to enter the export business.

***Implement the capacity development measures targeting the farmers and traders:*** None of the farmers (assuming large scale farmers would possibly want to export their products, if they can find a way) or traders has thought of exporting the vegetables across the border or any other country for that matter. But at present, they seem to be pretty lost. Therefore, a marketing strategy needs to be developed and capacity building exercises of those interested persons should be carried out. Once the trend is set like the way seen in the exports of cabbages from the eastern region, there will be no need of looking back by the farmers and traders in vegetable products. The Indian markets could just be the beginning and it can be extended to other potential markets as discussed above.

***Carry out intensive and extensive training on post-harvest operations:*** One of the various reasons for a poor export performance of vegetables is associated with the poor post-harvest handling of the products. The perishable nature of the product demands for proper post-harvest operations like adoption of proper harvesting methods, sorting, grading, packaging, storage and labelling. This requires awareness programmes for the farmers and relevant extension workers through training and capacity development, and also calls for support programmes like development of cold warehouses, and subsidy for transportation and in availing appropriate packaging materials. A post-harvest support programme needs to be developed and implemented focusing the vegetables and other perishable agricultural products.

***Help in organising the farmers and traders for a collective effort:*** Vegetable farmers and traders are not organised like the producers and traders of tea, coffee, ginger, medicinal herbs, etc. It is important for them to organise through the cooperatives or farmers/traders associations to push the collective efforts, and demand for production and export of vegetables. This will also help in establishing linkages with the vegetable importers in India and in other markets at the trader's level. The formation of such interest

groups would also enable them to bring out their collective voices in terms of demanding services and working together with the support agencies within and outside the government.

***Expedite the border clearance process:*** Protocol to Article-XI of Nepal-India Treaty of Trade has created a coordination mechanism between the two border officials headed by chief customs officers of the land customs stations on both sides of the border to resolve any problem in the clearance of goods. Since speedy customs clearance is crucial for vegetable exports, the border agencies should work to fulfil the objectives of the treaty protocol. However, the mechanism has remained dormant for quite a long time. Both governments should consider reorganising and re-invigorating the border level trade facilitation mechanism that would help in increasing bilateral trade in agricultural products including vegetables.

## 2. Long Term Measures

***Focus on marketing with continued support in production:*** All relevant value chain actors need to focus on marketing of vegetables along with the concerted support programmes in production. Only when the produce doesn't go to waste and finds a market the programmes on production can be termed as successful. But this is not happening; the government has supported the farmers to increase the production but is not bothered where the produce goes and what is being done with it. Therefore, the government needs to develop a complete strategy from production to marketing.

***Re-negotiate and revise the deterrent provisions of the Nepal India Treaty of Trade:*** The bilateral trade treaty between Nepal and India completed its seven years cycle in October 27, 2016. Though the treaty was renewed without any changes, revision in the treaty is warranted in view of sustaining the Nepalese export and maintaining complementarity in bilateral trade.

The bilateral treaty of trade provides reciprocal tariff concessions on agriculture and primary goods. Normally, subsidies available for agricultural production are much higher in India in comparison to the similar product in Nepal. Similarly, the economies of scale have also made the Indian products cheaper than the Nepalese products. The provision on reciprocal tariff concessions caused massive influx of agricultural goods, particularly vegetables from India, thus hurting the Nepalese production. So, while negotiating the provisions of the treaty, Nepal needs to prioritise listing some of the agricultural products as import sensitive and should take leeway to impose tariff on such products.

Other important initiatives to be considered while re-negotiating the trade treaty would be the simplification, standardisation and harmonisation of SPS related regulatory requirements and enhancing cooperation between the relevant agencies that would help to lessen burden and reduce cost in doing the cross border trade.

***Enhance the capacity of Nepalese SPS laboratories to align with the regional and international standards:*** The plant quarantine laboratories and the food safety laboratories of Nepal need enhancement in terms of technical capacity to carry out test and certification as required by the importing countries. Particularly, the plant quarantine

laboratories in the border posts lack adequate number of equipment and reagents (chemicals) to carry out the tests. Lack of trained human resources and frequent transfer of the quarantine staff are also impeding the operation of the quarantine related works. Food laboratories in some cases are located far away from the border posts. Government should consider developing a comprehensive plan for strengthening and streamlining the SPS laboratories in terms of provisioning equipment, test and certification capacity, mobilization of human resources, co-location of the facilities and improvement in the governance structure of such laboratories.

***Promote off-season vegetables:*** It has been found that farmers are able to fetch higher prices for the off-season vegetables in comparison to the same crop grown during its normal season. However, off-season vegetables require extra effort to save the crop from the adverse weather, pests and diseases, and also require careful tending of the crop. Growing off-season vegetables brings more profit to the farmer on one side, while on the other side; it helps in maintaining the supply of a particular vegetable or crop round the year. Government should provide support for poly-house technology and drip irrigation, and provide trainings to farmers to enhance their knowledge and capacity regarding the cultivation of off-season vegetables.

***Promote organic production in order to harness the competitive edge:*** Enhancing export of vegetables would also require organic production vis-à-vis the production of off-season vegetables. Organic production has a big market potential not only in India but in other overseas countries like Qatar, the United Arab Emirates, Kuwait, Japan, South Korea and countries in the European Union (EU). Hence, Nepal needs to focus on organic vegetables in order to tap the potential markets in other countries as well as in India. Promoting organic vegetables may require phased-in approach starting from IPM and introduction of agricultural insurance policies.

***Establish effective mechanism to support PRA:*** PRA basically entails assessment of risks at various stages of production, storage and transportation with identification of critical control points in order to manage the risk. Such a mechanism requires collaboration between the plant quarantine and food safety authorities between the exporting and importing countries in respect of data and information exchange and remedial measures to be adopted therein.

Indian food safety authorities normally require pest-related data in order to make an assessment of the risks associated with entry of diseases and insect pests along with import of living plant and plant products. Nepal should start the process of collecting data on incidence of insect pests and diseases for the specific and potential fruits and vegetables. This would be largely helpful in marketing and export of Nepalese vegetables and plant products not only to India but also to other countries.

***Provide adequate logistical support:*** The logistics provision in Nepal is also not very suitable for the exports of vegetables. The roads are in poor conditions, cold storage facilities are not adequately available near the production centres and border posts, and markets are not developed. Exporting vegetables to countries in Middle-East would also

require proper logistical support at the Tribhuvan International Airport (TIA). Hence, there is a need for strengthening the transport and warehousing related logistics services in order to facilitate the exports of vegetables. This is particularly important since vegetables are perishable items and need to reach the market within a short span of time after harvest.

## Future Agendas

The research shows that significant potential exists for exporting fresh vegetables but much need to be done to achieve the untapped potential. Some of the policy recommendations for short and long term are already listed above. Apart from that, some recommendations for the private sector, researchers and development partners are listed below.

### *Research on Identifying Other Potential Partners for Vegetables*

The paper has taken examples of some countries, which are just indicative to show that the Nepalese vegetables do have potential to be exported. A detailed investigation is likely to identify other lucrative markets. This can form a research agenda for interested researchers, private partners and development organisations in order to identify other potential countries where vegetables could be exported. For example, a study could be carried out to identify the export potential of Nepal's vegetables into China. Although China accounts for over 50% of world's vegetable production, it also imports a huge quantity of vegetables. As consumption of vegetables are income elastic, the demand for vegetables in China may be attributed to the rise of the new middle class. China's middle class grew to 109 million adults in 2015 which is more than the number of American middle class (i.e. 92 million). The average consumer spending rose to US$ 2,522 in 2013 from US$ 1,368 in 2008. Therefore, there is a need to carry out in-depth analysis of the consumers' preferences and the possibility of marketing Nepalese products. Being a next door neighbour, the agricultural trade with China is not only associated with increasing the market access opportunities in technical term (meeting the SPS standards) but it should also be considered from the political economy perspectives.

### *Inventory of Key Exportable Vegetable Products from Various Pockets*

A separate study could be carried out to identify the key products that could be exported from various production pockets of Nepal to India and other potential countries. These products could be the one where government could focus in terms of production and facilitate in the marketing of these products. Pocket areas for the production of these priority vegetables could be developed. It is important to maintain the safety of these products and minimize the risks of microbial and chemical food safety hazard in these areas. The adoption of good agricultural practices like using of organic manure and organic pest control methods, improved cultivation and harvesting should be encouraged. Good handling practices also need to be adopted due to succulent nature of fresh vegetables. The farmers should be educated in Good Agricultural Practices (GAP) implementation in a gradual manner, selecting the exportable products first and then later extendingit further.

## Implementation Plan

It is important to develop a concerted action agenda that needs to be followed up in order to address the problems related with exporting vegetables and establishing effective linkages with export markets. Table 20.8 presents the list of interventions to be made by the government and the stakeholders in order to promote vegetable exports from Nepal. The explanation of this action plan matrix has been given in greater detail in The Way Forward section.

**Table 20.8.** Action matrix for promoting vegetable export from Nepal

| Deliverables | Major Steps | Action Plan | Responsible Agency |
|---|---|---|---|
| ***Customs Related Measures*** | | | |
| 1. *Consistency in data recording and management* | 1.1. Maintain record of each entry and exit of vegetables at border points | • Sensitise officials at the customs offices (through workshops) | Customs Offices, Ministry of Finance, Development Partners |
| | 1.2. Maintain data consistency in terms of itemsacross the customs points. Follow similar templates | • Sensitise officials at the customs offices (through workshops) | |
| 2. *Speedy clearance of fresh produce* | 2.1. Set up a separate counter for facilitation of fresh produce at custom points | • Sensitise the Customs Officers to coordinate with Ministry of Finance and Ministry of Agricultural Development in order to set up a separate clearance desk for fresh produces, especially for SPS treatment | Ministry of Finance, Ministry of Agricultural Development, Department of Food Technology and Quality Control, Customs Offices |
| ***Production and Supply Related Measures*** | | | |
| 3. *Consistent quality and regular supply of the vegetables* | 3.1. Identify major vegetable products that have good demand in the foreign market | • Conduct a survey on export trends of vegetables<br>• Identify possible importing countries and carry out a survey<br>• Identify viable vegetables<br>• Develop pocket areas to promote the production of these vegetables | Ministry of Agricultural Development and related departments and divisions, private sector associations (such as FNCCI, CNI), development partners |
| | 3.2. Ensure stable supply of the identified vegetables | • Provide incentives to the farmers to make them follow better production techniques, training the best practices in cultivation<br>• Design special incentives to promote the production of identified vegetables | Department of Agriculture, local agriculture services offices, local farmers group and cooperatives, private sector associations (such as FNCCI, CNI) |
| | 3.3. Ensure consistency inquality of the products throughout the year | • Ensure availability of best quality seeds and fertilisers<br>• Train the farmers regarding best practices in vegetable cultivation | Department of Agriculture, local agriculture services offices, local farmers groups and development partners |

| | | | |
|---|---|---|---|
| 4. *Organising farmers into groups* | 4.1. Encouragefarmers involved in vegetables farming to be organised into producer groups to negotiate better terms for themselves and to raise capital for collective investment in storage units and transport vehicles | • Create groups (e.g. producer groups) by providing seed capital or subsidised loans | Department of Agriculture, Department of Cooperatives (if subsidised loans are to be provided), Nepal Rastra Bank, licensed financial institutions, private sector associations (such as FNCCI, CNI) |
| 5. *Pest Risk Management (PRM)* | 5.1. Identify control points (maybe the identified pocket areas) for measuring and monitoring use of pesticides to ensure quality | • Develop and implement standard on pesticide use<br>• Provide training to farmers on the best practices regarding pesticide use.<br>• Monitor pesticide use in the farms and vegetables | Department of Food Technology and Quality Control; Nepal Bureau of Standards and Metrology and Department of Agriculture |
| ***Post-production Related Measures*** | | | |
| 6. *Improved post-harvest operations* | 6.1. Minimise post-harvest loss of the vegetables caused by poor handling | • Provide necessary tools and techniques for grading, sorting and packagin to the farmers and collection centres<br>• Organize awareness programmes for farmers<br>• Set up cold storage facilities in the major markets | Department of Agriculture, Regional and local level vegetable traders' associations, private sector |
| 7. *Enhance the capacity of Nepalese SPS labs* | 7.1. Enhance the capacity in terms of provisioning of equipment, test and certification capacity, mobilization of human resources, co-location of the facilities and improvement in the governance structure of such laboratories | • Develop and implement a comprehensive plan for strengthening and stream-lining the SPS laboratories | Ministry of Agricultural Development,; Department of Food Technology and Quality Control, Development partners |
| 8. *Capacity building of wholesalers and exporters* | 8.1. Enhance storage and transport capacity of Nepali vegetable wholesalers | • Construct large collection centres for vegetables with necessary facilities including storage | Department of Agriculture, Department of Commerce, local and regional private sector association, local and regional vegetable traders association, private sector |
| | 8.2. Facilitate traders to help them seek markets abroad | • Organise seminars and visits to markets in Bangladesh, Middle East and Europe | Department of Agriculture, Department of Commerce, local and regional private sector associations, Nepalese Embassies abroad |
| | 8.3. Build farmer's capacity to analyse existing markets and identify market opportunities | • Provide farmers with training and support | Local and regional private sector associations, development partners |
| | 8.4. Provide support in logistics | • Provide interest subsidy to the farmer's group for the development of cold ware-houses and transport vehicles | Ministry of Agricultural Development, Ministry of Finance, Nepal Rastra Bank |

| | | | |
|---|---|---|---|
| ***Future Agenda*** | | | |
| 9. *Research on identifying other potential partners for exporting vegetables* | 9.1. Conduct research on country-specific potential for vegetable export to figure out possible markets in the neighbouring countries (for example: China) | • Conduct research on possibility of exporting fresh produce to the identified countries<br>• Conduct research on Nepal's comparative advantage in vegetables against specific countries<br>• Conduct research on country-specific SPS, PRM standards | Ministry of Commerce, Development partners, Country-specific Chambers of Commerce, private sector associations (such as FNCCI, CNI) |
| 10. *Keeping an inventory of key exportable vegetable products from various pockets* | 10.1. Identify the key products that could be exported from various production pockets of Nepal in order to develop specialisation | • A study could be carried out to identify the key products in different production pockets<br>• A detailed study could be conducted to figure out the measures to facilitate production and marketing of these products | Department of Agriculture, Department of Commerce, local and regional private sector association, local and regional vegetable traders association, private sector |

## Conclusion

Vegetable exports from Nepal are negligible compared to imports flowing into Nepal. Exports are mainly taking place in an informal manner using rickshaws, motor bikes and pull-carts, instead of packaged consignment. The government has been focusing on production and there is significant demand for fresh vegetables in various markets like Bangladesh and several Middle-East countries. Some specific types of vegetables (like bitter gourd, pointed gourd, sponge gourd, mustard leaf, etc.) that are grown in Nepal are better in quality and can be sold off at a higher price compared to Indian vegetables. Similarly, off-season vegetables are becoming more attractive for farmers due to their high export potential, particularly to India.

That rosy picture does not extend to the market. Efforts towards marketing are woefully inadequate, from both public and private sectors. Management skills, especially those related to marketing, appear to be absent on the part of relevant actors and this seems to be the major hindrance for vegetables export.

Technical standard is another area beckoning reform. Mutual recognition of test and certification is important in order to enhance market linkages. There is no proper harmonisation of standards between Nepalese and Indian SPS and technical standards. The export potential to India and other countries can be realised only by improving and easing market access conditions which could be pursued through constructive and effective trade negotiations between governments. Nepal's approach to bilateral negotiations should be proactive in view of the continued difficulties faced by Nepalese farmers and exporters. These marketing issues are not seen when it comes to vegetable imports. There is unchecked flow of Indian vegetables into Nepalese markets which potentially hampers Nepalese production.

Nepalese farmers need intensive and extensive training on post-harvest operations to enable them to market their produce. Inadequacies in support mechanism to PRA and lack of implementation of PRM mechanisms are the reasons behind low preferences for Nepalese vegetables.

Quarantine issues reign supreme in the exports of vegetables. Hassles in meeting the quarantine requirements of India are a major impeding factor. Exporting to other countries would also require building national capacity regarding food testing and SPS related measures. For example, fulfilling Saudi Arabian Standards could be helpful for Nepali produce to get an entry into the Gulf countries, but it is not an easy option. Nepal needs to strengthen and streamline the capacity of SPS laboratories and also take measures to protect agriculture from unfair competition on account of large subsidies provided by neighbouring countries for similar products.

**Annex 20.1.** Export of vegetables from some major custom points in Nepal (Source: Web, 1)

**A.** Exports from Bhairahawa (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Leguminous vegetable, shelled or unshelled | 60,057 | 3,576,673 | 47,850 | | 24,330 |
| Vegetables, fresh or chilled | 77,250 | | | | 13,440 |
| Onion dried | 2,362,216 | | | 3,967,860 | |
| Dry garlic, neither crushed nor ground | 555,000 | | | | |
| Lentils | 9,900,272 | | | | |
| Potato seed | | 151,776 | | | |
| Tomato, fresh or chilled | | 614,473 | | | 317,592 |
| Cauliflower and headed broccoli | | 228,235 | | | |
| Vegetables, fresh or chilled | | 659,062 | | | |
| Fresh green vegetable | | 31,951 | | | |
| Mixtures of vegetables | | 33,648 | 25,300 | | |
| Onion, dried | | 2,402,253 | 4,884,005 | | |
| Dried truffles | | 1,201,126 | | | 4,225,000 |
| Lentils | | 27,406,507 | 11,942,265 | | |
| **Total** | **12,954,795** | **36,305,704** | **16,899,420** | **3,967,860** | **4,580,362** |

**B.** Exports from Biratnagar (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Leguminous vegetables | 579,448 | 300,584 | | | |
| Potato, fresh or chilled | | 456,578 | | | |
| Vegetables | 16,300 | 76,000 | | | |
| Vegetables, fresh or chilled | 405,900 | 19,305,863 | 5,608,923 | 2,000,400 | 1,372,800 |
| Vegetables, fresh or chilled | 2,152,874 | | | | |
| Bean of the species *Vigna mungo* or *Vigna radiata* | | | | | 1,184,800 |
| Beans (*Vigna* spp., *Phaseolus* spp.), shelled, whether or not skinned or split | | 391,408 | | 641 | 12,766,000 |
| Red lentils | | | | 3,604,650 | 2,997,251 |
| Lentils | 6,436,788 | 6,974,608 | 9,503,340 | | |
| Potato seed | | | | | |
| Potato | | 96,960 | | | |
| Tomato, fresh or chilled | 22,811 | 6,169,119 | 1,347,339 | | |
| Cabbage, lettuce | 23,401,707 | 34,420,791 | 6,822,013 | 11,780,038 | |
| Peas | 15,848 | 17,600 | | | |
| Fresh peas | | 17,600 | | | |
| Garlic | | 20,134,202 | 131,484,544 | 5,120 | |
| Fresh green vegetable | | 3,200 | 18,720 | | |
| Mixtures of vegetables | 1,308,540 | | | | |
| Chickpea | | | | | 60,450 |
| Dried truffle | | | | | 6,613,440 |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | 2,435,672 | | | 8,976,000 | 3,456,000 |
| Leeks and other alliaccous vegetables | | | | 112,500 | |
| Beans (*Vigna* spp., *Phaseolus* spp.) | 6,400 | 8,000 | | | |
| Fruits of genus *Capsicum* or *Pimenta* | 12,000 | | | 640,000 | |
| Pumpkins, squash and gourds | 84,877 | | | | |
| **Total** | **36,879,165** | **88,372,513** | **154,784,879** | **27,119,349** | **28,450,741** |

**C.** Major exports from Birgunj (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Leguminous vegetable, shelled or unshelled | 3,692,500 | 3,882,700 | 126,200 | 112,000 | |
| Potato, fresh or chilled | 6,871,550 | 35,774,620 | 6,223,546 | 1,939,000 | 118,000 |
| Potato | 133,000 | 166,200 | 44,825 | | 1,727,900 |
| Vegetables, fresh or chilled | 18,200 | 137,200 | 744,606 | 8,547,450 | 14,615,800 |
| Lentils | 4,191,600 | 99,062,800 | | | |
| Potato seed | | | | 757,200 | 4,225,950 |
| Tomato, fresh or chilled | 894,900 | 5,905,400 | 464,100 | 5,472,440 | 4,655,200 |
| Cauliflower and headed broccoli | 23,760,650 | 31,190,690 | 27,672,680 | 38,658,400 | 64,700 |
| Brussels sprout | 23,000 | | | | |
| Cabbage, lettuce | | | | 9,000 | 279,600 |
| Cucumber | | | | | 9,000 |
| Peas (*Pisum sativum*) | 81,444 | | | | |
| Leguminous vegetable | 3,050 | 24,000 | 6,000 | | |
| Vegetables | 14,414 | 60,000 | | | |
| Dried vegetables | 317,986 | | | | |
| Dry garlic | 249,323 | | | | |
| Dried peas | 180,973 | | | | |
| Cucumber and gherkin | | | | | 87,000 |
| Dried leguminous vegetables | 55,000 | | 584,430 | | |
| Wood ears | | | | 2,566,570 | 3,319,042 |
| **Total** | **40,487,590** | **176,203,610** | **35,866,387** | **58,062,060** | **219,102,192** |

**D.** Exports from Kanchanpur (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Pumpkins, squash and gourds | 24,000 | | | | |
| Dried leguminous vegetables | 560,000 | | | | |
| Mushrooms and truffle, fresh or chilled | | 87,000 | | | |
| Mushrooms and truffle, provisionally preserved | | | 215,000 | | |
| Lentils | | | 2,194,025 | 444,000 | |
| **Total** | **584,000** | **87,000** | **2,409,025** | **444,000** | |

**E.** Major exports from Mechi (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Leguminous vegetable | 996,425 | | | | |
| Leguminous vegetable, shelled or unshelled | | 149,897 | | | 27,500 |
| Potato, fresh or chilled | 2,672,000 | 530,200 | | | |
| Potato | | | | | |
| Vegetables, fresh or chilled | 1,247,560 | 4,842,942 | 13,718,425 | 1,492,840 | 2,122,600 |
| Vegetables | 1,142,285 | 156,080 | 252,500 | | |
| Mixture of vegetables | | 3,562,500 | 19,500 | | |
| Fresh green vegetables | 369,000 | 352,325 | 33,240 | | |
| Dried vegetables | 2,000 | | | | |
| Onion, dried | 11,070,000 | 14,360,000 | 16,470,000 | 12,200,000 | 17,228,000 |
| Dried peas | 57,440 | 9,350 | | | 65,600 |
| Chick pea | 10,000 | | | | |
| Lentils | 1,866,322,199 | 1,136,972,792 | 1,238,669,962 | 611,234,833 | |
| Red lentils | | | | 370,197,586 | 793,877,953 |
| Bean of the species *Vigna mungo* or *Vigna radiata* | 14,414 | 37,850 | | | 59,000 |
| Beans (*Vigna* spp., *Phaseolus* spp.), shelled, whether or not skinned or split | 635,956 | 66,150 | 1,857,305 | | |
| Beans (*Vigna* spp., *Phaseolus* spp.) | | | 7,040 | | |
| Cow peas | | 988,010 | 14,080 | | |
| Broad beans and horse beans | | | 16,600 | | |
| Dried truffel | | | 8,000 | | |
| Small red (Adzuki) beans | | 24,750 | | | |
| Tomato, fresh or chilled | 258,962 | 4,223,667 | 3,708,375 | 252,720 | |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | 33,805,038 | 30,304,041 | 33,520,200 | 94,400 | 7,622,672 |
| Mushrooms and truffle, fresh or chilled | 855,615 | 596,700 | 24,800 | | |
| Fruits of genus *Capsicum* or *Pimenta* | | 3,200 | 15,960 | | |
| Pumpkins, squash and gourds | | 10,000 | | | |
| Cauliflower and headed broccoli | | 40,600 | 219,300 | | |
| Cabbage, lettuce | 1,688,800 | 204,320 | 37,602,000 | 138,400 | |
| Lettuce | 48,000 | | | | |
| Edible roots | 309,590 | 26,200 | | | |
| Carrot and turnip | | 21,000 | | | |
| Fresh peas | 338,004 | 450,970 | | | |
| Cucumber | | | | | |
| Brussels sprouts | | 13,844,315 | | | |
| Peas (*Pisum sativum*) | | 13,200 | 948,080 | | |
| Cucumber and gherkin | | | | 12,000 | |
| Dried leguminous vegetables | 14,940 | 31,700 | | | |
| **Total** | **1,920,738,228** | **1,211,822,759** | **1,347,195,367** | **995,622,779** | **821,003,325** |

**F.** Major exports from Nepalgunj (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Lentils | | 7,200,000 | | | |
| **Total** | | **7,200,000** | | | |

**G.** Major exports from TIA (Value in NRs

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato, fresh or chilled | 24,597 | | | | 61,656 |
| Tomato, fresh or chilled | | | | | 166,376 |
| Potato seed | | | 6,433 | 15,176 | |
| Onion and shallot | | | 22,290 | | 1,094,197 |
| Garlic | 12,492 | 20,983 | 2,298,275 | 564,340 | 69,715 |
| Cauliflower and headed broccoli | | | | 14,846 | |
| Cabbage, lettuce (head lettuce) | 674,924 | 642,083 | 666,265 | 1,504,948 | 46,033 |
| Witloof chicory | | | | | 54,409 |
| Leguminous vegetables, shelled or unshelled | | | | | 48,148 |
| Cucumber and gherkin, fresh or chilled | | | | 23,123 | |
| Edible roots | | 337,626 | | | |
| Fresh mushrooms | 8,880 | 226,008 | 17,634,513 | 14,831,517 | 17,791,772 |
| Potato | | | 7,004 | | |
| Spinach, New Zealand spinach and orache spinach | | | 58,855 | | |
| Vegetables, fresh or chilled | 20,818 | | | | |
| Vegetables | 23,361 | 32,382 | | | |
| Mushrooms of the genus *Agaricus* | | | | | 56,188 |
| Mushrooms and truffle, provisionally preserved | 22,595,571 | | | | |
| Dried truffle | | 42,546,224 | 15,428 | | |
| Yams | | | 234,286 | 78,571 | |
| **Total** | **23,360,643** | **43,805,306** | **20,943,349** | **17,032,521** | **19,388,494** |

**Annex 20.2.** Import of vegetables from some major custom points in Nepal (Source: Web, 1)

**A.** Imports from Bhairahawa (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato, fresh or chilled | 1,345,678,057 | 1,156,101,219 | 1,605,536,884 | 2,023,561,012 | 1,897,595,496 |
| Potato seed | 142,316 | 139,917 | | | |
| Tomato, fresh or chilled | 26,913,367 | 30,465,084 | 44,559,688 | 69,140,204 | 30,496,753 |
| Onion and shallot | 1,213,694,844 | 1,595,335,536 | 1,850,043,577 | 2,504,537,172 | 2,678,325,149 |
| Garlic | 25,462,964 | 37,050,446 | 54,038,148 | 33,143,047 | 64,978,046 |
| Leeks and other alliaccous vegetables | | | 5,562 | | 126,671 |
| Cauliflower and headed brocolli | | | | 25,832 | |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | | | | | 67,266 |
| Cabbage, lettuce | | | 86,533 | | 4,305 |
| Carrot and turnip | | | 40,182 | | |
| Edible roots | | | 64,036 | | 1,345 |
| Cucumber and gherkins, fresh or chilled | 6,765 | 1,901 | | | 1,256 |
| Fresh peas | 1,963,783 | 395,953 | 90,403 | 13,064,140 | 10,063,135 |
| Olives | | 39,181 | | | |
| Beans (*Vigna* spp., *Phaseolus* spp.) | | 51,570 | | | |
| Mushrooms and truffle, fresh or chilled | 13,222 | | 180,805 | 180,804 | |
| Dried mushrooms, truffle | | 68,878 | | | |
| Leguminous vegetable, shelled or unshelled | | 52,213,527 | 92,958,169 | 160,932,438 | 91,194,553 |
| Fresh mushrooms | | 358,415 | | 119,463 | 462,241 |
| Fruits of genus *Capsicum* or *Pimenta* | 4,495,137 | 3,094,055 | 1,704,225 | 2,474,431 | 590,874 |
| Globe artichokes | | | 3,588 | | |
| Spinach, New Zealand spinach and orache spinach | | 267,870 | | | |
| Vegetables, fresh or chilled | 481,024 | 324,093 | 39,860 | 31,355 | 44,070 |
| Vegetables, fresh or chilled | 14,674 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Vegetables | 35,642 | | | 2,152 | 393,008 |
| Fresh green vegetables | 890,547 | | | 309,393 | 264,279 |
| Cucumber | | | | 125,026 | 439,947 |
| Mixtures of vegetables | 809,717 | 842,486 | 80,811 | 330,531 | 66,009 |
| Mushrooms of the genus *Agaricus* | 587,928 | 1,278,611 | 1,997,335 | 4,915,118 | 1,579,486 |
| Mushrooms and truffle, provisionally preserved | | | | 435,575 | |
| Onion, dried | 71,749 | 287,129 | 1,215,078 | 4,091,218 | 2,577,764 |
| Dried truffle | | | 6,466 | | 3,972 |
| Dry garlic, neither crushed nor ground | 8,719,084 | | 8,171,875 | 12,751,013 | 16,283,616 |
| Dry garlic, crushed or ground | 1,176,655 | 5,845,158 | 9,461,022 | 3,197,717 | 3,988,246 |
| Dry garlic | 21,525 | | 471,616 | 227,689 | 5,317,730 |
| Dried peas | 138,169,479 | 175,824,553 | 93,827,753 | 81,254,184 | |
| Chick pea | 129,958,424 | 150,616,169 | 149,896,763 | 92,302,891 | 34,876,792 |
| Potato | 2,131,337 | 4,008,994 | 1,641,082 | 4,720,361 | 1,524,127 |
| Bean of the species *Vigna mungo* or *Vigna radiata* | 27,574,460 | 100,334 | 16,414,083 | 284,042,188 | 97,517,772 |
| Small red (Adzuki) bean | | 70,522 | | | |
| Kidney bean, including white pea beans | | | 1,229,687 | 2,367,556 | 1,314,888 |
| Bambara bean | | | 75,598 | | |
| Beans shelled, whether or not skinned or split | 17,188 | 1,284,529 | 36,371,239 | 3,024,622 | 480,434 |
| Lentils | 243,101,296 | 202,436,112 | 807,879,526 | 63,569,135 | |
| Broad bean and horse bean | | 6,280 | 32,287 | | |
| Peas (*Pisum sativum*) | 4,434 | 34,986 | 5,381,043 | 2,230,319 | 6,664,745 |
| Pigeon peas (*Cajanus cajan*) | 503 | 57,182,161 | 467,764 | 71,038 | |
| Dried leguminous vegetables | 4,737,178 | 28,871,724 | 49,884,347 | 3,526,122 | |
| Sweet corn | 79,772 | | 215,242 | 2,812,719 | 8,867,009 |
| Sweet potato | 161,007 | 27,905 | | 1,089,369 | |
| Red lentils, unskinned, unsplit | | | | | 16,505,574 |
| Arrowroot, salep, Jerusalem artichokes | 4,309 | | | | |
| **Total** | **3,177,118,387** | **3,504,625,298** | **4,834,072,277** | **5,374,605,834** | **4,972,616,558** |

**B.** Imports from Biratnagar (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato, fresh or chilled | 380,955,247 | 444,833,427 | 270,424,685 | 487,133,701 | 201,298,114 |
| Potato seed | | 30450 | 16564 | | 17,659 |
| Tomato, fresh or chilled | 16,018,425 | 3,805,475 | 3,852,723 | 19,297,541 | 12,487,612 |
| Onion and shallot | 248,477,305 | 360,723,249 | 308,295,761 | 380,024,607 | 260,802,969 |
| Garlic | 96,566,642 | 121,593,663 | 168,380,742 | 130,939,715 | 67,547,469 |
| Leeks and other alliaccous vegetables | | | | | 1,514,225 |
| Cauliflower and headed brocolli | 19,740 | 4,756 | | | 4,108,326 |
| Brussels sprouts | | | | | 3,587 |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | 46,644 | | | | 8,986 |
| Cabbage, lettuce | 114,826 | | | 166,355 | |
| Lettuce (*Lactuca sativa*) and chicory | 42,356 | 2,852 | | 2,379 | 67,279 |
| Carrot and turnip | 28,215 | 75,110 | 103,350 | | |
| Edible roots | 19,559 | | 2,693 | 4,485 | |
| Cucumber and gherkin, fresh or chilled | 4,846 | 20,985 | | | |
| Fresh peas | 4,459,530 | 837,384 | 10,946 | | 1,771,227 |
| Beans (*Vigna* spp., *Phaseolus* spp.) | 29,966 | 8,054,175 | 3,717,596 | | 2,165,386 |
| Mushrooms and truffle, fresh or chilled | | | 3,230 | | 1,437,658 |
| Dried mushrooms, truffle | | | | 239,225 | 48,336 |
| Wood ears | | | | 459,195 | |
| Leguminous vegetable, shelled or unshelled | 30,861 | 80,718 | | 144,423 | |
| Fruits of genus *Capsicum* or *Pimenta* | 8,077,979 | 3,451,537 | 2,634,622 | 6,946,581 | 2,712,078 |
| Spinach, New Zealand spinach and orache spinach | 10,091 | | | | |
| Vegetables, fresh or chilled | 15,298,690 | 2,757,139 | 1,077,689 | 9,851,687 | 35,413,573 |
| Vegetables | 791,024 | 2,873 | 14,174 | | |
| Fresh green vegetables | 190,119 | 1,017,925 | 491,538 | 1,468,626 | 22,922 |
| Cucumber | 49,524 | | | | |
| Mixtures of vegetables | 170,636 | 111,812 | 260,474 | 4,848 | 212,561 |
| Onion, dried | 4,707,072 | 3,133,087 | 10,429,025 | 4,446,559 | 9,231,995 |
| Dried truffle | | 6,113 | 8,366 | 99,834 | 188,435 |
| Dried vegetables | 184,678 | | | | |
| Dry garlic, neither crushed nor ground | 15758266 | 35,730,547 | 54,882,410 | 66,021,938 | 12,325,000 |
| Dry garlic, crushed or ground | 3,215,428 | 140,654 | 12,664,565 | 6,103,305 | 10,992,779 |

| | | | | | |
|---|---|---|---|---|---|
| Dry garilc | 2,414,276 | 5,018,904 | 3,152,474 | | 4,201,400 |
| Dried peas | 215,544,295 | 341,999,544 | 269,442,509 | 423,985,408 | 301,336,904 |
| Chick pea | 134,635,193 | 171,062,558 | 127,131,472 | 158,645,608 | 456,690,909 |
| Potato | | 36,841 | 2,157 | 546,525 | |
| Bean of the species *Vigna mungo* or *Vigna radiata* | 36,988,545 | 15,486,215 | 39,450,833 | 59,706,536 | 230,842,923 |
| Kidney bean, including white pea bean | 120,178 | | 4,921,319 | 18,140,865 | 43,183,149 |
| Beans, shelled, whether or not skinned or split | 1,114,928 | 3,050,358 | 52,969 | 5,153,991 | 86,763,134 |
| Lentils | 16,137,272 | 133,265,219 | 296,302,269 | 69,342,097 | |
| Broad bean and horse bean | 179,732 | | | | 4,485,571 |
| Peas (*Pisum sativum*) | | 133,640 | 5,679,219 | 2,647,494 | |
| Pigeon pea | 898 | 8,514 | 54,458,128 | 167,654,054 | 216,895,100 |
| Dried leguminous vegetables | 18,371,189 | 1,876,690 | 30,687,727 | 8,669,383 | 2,175,054 |
| Sweet corn | | | | 2,148,583 | |
| Sweet potato | | | | 27,560 | |
| Red lentils, unskinned, unsplit | | | | 46,965,623 | 193,287,867 |
| **Total** | **1,220,774,175** | **1,658,352,414** | **1,668,552,229** | **2,076,988,731** | **2,164,240,187** |

**C.** Imports from Birgunj (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato, fresh or chilled | 368,912,686 | 230,300,355 | 100,984,096 | 67,511,925 | 85,555,407 |
| Potato seed | | | 226,004 | 174,383 | 9,945,348 |
| Tomato, fresh or chilled | 4,447,805 | 13,371,624 | 8,030,432 | 20,254,938 | 37,339,928 |
| Onion and shallot | 376,158,804 | 371,948,499 | 212,950,686 | 429,087,204 | 321,111,687 |
| Garlic | 212,485,266 | 276,082,827 | 60,686,097 | 114,037,275 | 157,887,785 |
| Leeks and other alliaccous vegetables | 12,914 | | | | |
| Cauliflower and headed broccoli | 4,865 | 31,734 | | 2,678,928 | 119,793 |
| Brussel sprout | | 68,516 | | | |
| Witloof chicory | | | 20,808 | | |
| Edible roots | | | 291,129 | | |
| Cucumber and gherkin, fresh or chilled | | | 12,028 | 811 | |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | | 8,076 | | | |
| Cabbage, lettuce (head lettuce) | 35,026 | 1,173,979 | 174,493 | 332,731 | 493,982 |
| Carrot and turnip | 15,712 | 22,904 | 42,250 | 13,063 | 1,351 |
| Fresh peas | 1,261,105 | 1,257,339 | 6,032,545 | 2,462,080 | 72,929,050 |
| Pumpkins, squash and gourds | | | | | 43,236 |
| Beans (*Vigna* spp., *Phaseolus* spp.) | 14,487 | 98,367 | 16,125,509 | 12,557 | |
| Leguminous vegetables, shelled or unshelled | 25,770,778 | 37,144,548 | 12,239,503 | 13,210,295 | |

| | | | | | |
|---|---|---|---|---|---|
| Fresh mushrooms | | 2,884 | 70,046 | | |
| Mushrooms and truffle, fresh or chilled | | 2,162 | | | |
| Fruits of genus *Capsicum* or *Pimenta* | 1,972 | 7,568 | 107,986 | | |
| Vegetables, fresh or chilled | 11,670,224 | 8,277,412 | 15,874,716 | 16,490,890 | 52,372,662 |
| Potato | 3,017,568 | 10,233,581 | 5,664,464 | 6,493,530 | 795,158 |
| Peas (*Pisum sativum*) | 608,141 | 1,681,044 | 631,199 | 13,492,076 | 3,862,813 |
| Beans (*Vigna* spp., *Phaseolus* spp.) | 24,314 | | | | |
| Leguminous vegetables | 78,098 | 502,411 | 104,795 | | |
| Sweet corn | 101,946 | 933,129 | 690,521 | | 2,961,095 |
| Vegetables | 569,879 | 45,570 | 1,412,098 | 3,779 | |
| Cucumber | | | | 1,262 | |
| Mushrooms of the genus *Agaricus* | | 44,555 | | 590,044 | |
| Mushrooms and truffle, provisionally preserved | | 187,129 | | | |
| Fresh green vegetables | 139,498 | | | | |
| Mixtures of vegetables | 347,154 | 13,578 | | | 336,959 |
| Onion, dried | 3,321,038 | 5,161,678 | 6,753,063 | 10,806,640 | 5,336,034 |
| Dried mushrooms, truffle | | 217,482 | | 15,696 | 3,809,258 |
| Dried truffle | 2,820,569 | 3,069,816 | 301,250 | 825,719 | 271,377 |
| Dry garlic, neither crushed nor ground | 10,142,161 | 19,644,806 | 28,075,599 | 39,819,085 | 29,402,977 |
| Dry garlic, crushed nor ground | 7,327,486 | 39,840,751 | 27,829,721 | 157,072,182 | 58,738,555 |
| Dry garlic | 780,979 | 467,066 | 3,690,216 | 14,836,002 | 13,629,367 |
| Dried peas | 219,047,369 | 159,472,435 | 128,294,619 | 176,921,166 | 87,986,525 |
| Chick pea | 5,195,270 | 13,672,137 | 22,415,082 | 218,974,179 | 248,345,281 |
| Bean of the species *Vigna mungo* or *Vigna radiata* | 3,578,109 | 130,964 | 4,567,293 | 160,744,574 | 143,400,639 |
| Small red (Adzuki) beans (*Phaseolus* or *Vigna angularis*) | | | | | 227,204 |
| Kidney bean, including white pea bean (*Phaseolus vulgaris*) | 500,681 | 200,647,471 | 29,781,148 | 26,383,287 | 40,780,183 |
| Bambara bean | | | | 1,194,280 | 801,257 |
| Beans (*Vigna* spp., *Phaseolus* spp.), shelled, whether or not skinned or split | 648,227 | 20,418,964 | 5,165,310 | 16,922,889 | 38,051,844 |
| Lentils | 29,668,043 | 105,806,746 | 111,690,069 | 296,075,251 | |
| Red lentils, unskinned, unsplit | | | | 105,999,791 | 43,281,169 |
| Red lentils | | | | 29,229,760 | 116,403,027 |
| Broad bean and horse bean | 2,730,882 | | 720,978 | | 1,040 |
| Pigeon pea (*Cajanus cajan*) | 45,640 | | 1,997,946 | 5,388 | 66,103,691 |
| Dried leguminous vegetables | 399,321,982 | 28,572,347 | 7,847,939 | 462,231 | |
| Arrowroot, salep, Jerusalem artichokes | | | | 7,799 | |
| Sweet potato | | 568,461 | 3,960 | | |
| **Total** | **1,690,806,678** | **1,551,130,915** | **821,505,598** | **1,943,143,690** | **1,642,325,682** |

**D.** Imports from Kanchanpur (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato, fresh or chilled | | | 71,891,078 | 57,406,478 | 48,241,484 |
| Tomato fresh or chilled | | | 5,326,256 | 9,858,895 | 13,238,635 |
| Onion and shallot | 49,077 | | 9,994,273 | 11,448,050 | 10,752,802 |
| Garlic | | | 142,018 | 164,807 | 47,776 |
| Leeks and other alliaccous vegetables | | | 4,755 | | |
| Fresh mushrooms | | | 6,280 | | |
| Fruits of genus *Capsicum* or *Pimenta* | | | 500 | 1,436 | |
| Potato | | | 61,991 | 139,477 | |
| Potato seed | | 4,306 | | | |
| Cauliflower and headed broccoli | 2,153 | | | 8,323 | |
| Cucumber and gherkin, fresh or chilled | | | | 3,158 | |
| Fresh peas | 855,180 | | | | |
| Vegetables, fresh or chilled | 3,501,700 | | | 19,087 | |
| Fresh green vegetable | 8,396 | | 6,463,132 | 5,556,085 | 3,974,022 |
| Mushrooms of the genus *Agaricus* | | | 3,588 | | |
| Mushrooms and truffle, provisionally preserved | | | 629 | | |
| Dried peas | | | 11,611 | 2,154 | 2,289 |
| Bean of the species *Vigna mungo* or *Vigna radiata* | | | 7,751 | | |
| Small red (Adzuki) beans | | | 522,762 | 5,024 | |
| Mixture of vegetables | | | 39,003 | 5,528 | 5,255 |
| Beans (*Vigna* spp., *Phaseolus* spp.), shelled, whether or not skinned or split | 2,692 | 26,533 | 232,932 | | |
| Broad bean, horse bean | | | 629 | | |
| Lentils | 1,713,,000 | | 3,788,387 | | |
| Dried leguminous vegetables | 2,153 | 227,084 | 423,955 | 8,031,411 | 2,135,724 |
| Sweet potato | | | | 101,109 | 167,971 |
| **Total** | **6,134,351** | **257,923** | **98,921,530** | **92,751,022** | **78,565,958** |

**E.** Imports from Mechi (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato, fresh or chilled | 879,014,681 | 1,877,167,202 | 998,500,475 | 251,340,646 | 458,002,104 |
| Potato seed | 382,593 | | | | |
| Tomato, fresh or chilled | 20,619,456 | 19,114,994 | 9,170,384 | | 22,831,039 |
| Onion and shallot | 108,065,214 | 179,296,768 | 218,722,070 | 7,981,673 | 109,500,805 |
| Garlic | 3,829,801 | 2,072,409 | 166,211,174 | 12,109 | 49,729,631 |
| Brussels sprout | 99,020 | | | | |
| Cauliflower and headed broccoli | | 268,959 | 655,450 | | |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | 302,421 | 195,523 | 1,874,888 | | |
| Lettuce | 2,183,207 | | | | |
| Edible roots | 136,916 | | | | |
| Cabbage, lettuce (head lettuce) | | 23,140 | 349,850 | | 73,184 |
| Cucumber and gherkin, fresh or chilled | 83,398 | 428,008 | 26,906 | | 55,964 |
| Leguminous vegetable, shelled or unshelled | | 919,262 | | | |
| Fresh mushrooms | 7,175 | 42,152 | | | |
| Beans (*Vigna* spp., *Phaseolus* spp.) | | | | | 42,164 |
| Fruits of genus *Capsicum* or *Pimenta* | 118,405 | | | | 69,125 |
| Vegetables, fresh or chilled | 52,388,243 | 136,257,914 | 106,426,337 | 4,743,462 | 244,334,439 |
| Vegetables, fresh or chilled | 4898 | | | | |
| Potato | | 7,037,952 | 502,375 | | 547625 |
| Fresh peas | | | 215,243 | | |
| Mushrooms and truffle, fresh or chilled | 18,194,936 | 13,737,432 | 2,152,725 | | |
| Fruits of genus *Capsicum* or *Pimenta* | | 1,589,054 | 589,565 | | |
| Peas (*Pisum sativum*) | 34,978 | 2,871 | 1,429,558 | 1,604,504 | 1,223,245 |
| Vegetables | 39,045,796 | 2,174,781 | 88,738,686 | 423,925 | 187262 |
| Fresh green Vegetables | 2,213,762 | 48,555,454 | 1,171,265 | | |
| Cucumber | 108,209 | 139,918 | 113,541 | | |
| Mushrooms of the genus *Agaricus* | | 228,518 | | | |
| Mushrooms and truffle, provisionally preserved | 109,596 | 307,807 | | | |
| Dried mushrooms, truffle | | 88,807 | | | |
| Jelly fungi | | 3,714 | | | |
| Mixture of vegetables | 17,056,133 | 1,122,759 | 18,011,035 | | |
| Onion, dried | | | | | 15,572,740 |
| Dried truffle | | 718 | | | |
| Dry garlic, neither crushed or ground | | 83,917 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Dry garlic, crushed or ground | | | 48,434 | | 145,374 |
| Sweet corn | | | 876,146 | 1,245,914 | |
| Dried peas | 951,838 | 24,980,223 | 111,701,987 | 121,172,392 | 147,559,335 |
| Chick pea | 28,880 | 36,530,608 | 112,762,684 | 62,383,103 | 54,661,704 |
| Bean of the species *Vigna mungo* or *Vigna radiata* | 107,169 | 2,615,970 | 73,968,181 | 146,395,929 | 188,614,827 |
| Small red (Adzuki) beans | | 86,097 | | | |
| Bambara bean | | 103,318 | 740,866 | | |
| Cow pea | | 5,130 | 192,645 | | |
| Pumpkins, squash and gourds | | 552,132 | | | |
| Kidney beans, including white pea beans | | 339,375 | | | 8,737,497 |
| Beans (*Vigna* spp., *Phaseolus* spp.) | 86,460 | | | | |
| Beans (*Vigna* spp., *Phaseolus* spp.) shelled, whether or not skinned or split | 18,716,396 | 1,040,831 | 3,866,414 | | 11,349,208 |
| Lentils | 221,479,596 | 581,476,973 | 1,157,097,396 | 605,911,860 | |
| Broad bean and horse bean | 1,233,388 | 251,116 | | | |
| Red lentils, unskinned, unsplit | | | | 468,299,742 | 442,154,272 |
| Red lentils | | | | | 78,027 |
| Pigeon pea | 17,580 | 1,087,139 | 341,413 | 42,702,126 | 60,441,878 |
| Dried leguminous vegetables | 251,135,442 | 101,718,595 | 109,382,296 | 397,909 | 206903 |
| Arrowroot, salep, Jerusalem artichokes | | | 7,175 | | |
| **Total** | **1,637,755,587** | **3,041,647,540** | **3,185,847,164** | **1,714,615,294** | **1,816,118,352** |

**F.** Imports from Nepalgunj (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato seed | 3,137,115 | 1,100 | 143,138 | | |
| Potato, fresh or chilled | 85,597,257 | 141,520,126 | 210,188,765 | 45,427,632 | 165,109,909 |
| Tomato, fresh or chilled | 3,070,416 | 801,086 | 4,259,821 | 3,682,449 | 4,046,055 |
| Onion and shallot | 3,913,947 | 8,380,444 | 68,176,733 | 151,358,205 | 44,285,428 |
| Garlic | | | 334,164 | 2,804,831 | |
| Leeks and other alliaccous vegetables | | 143,462 | 1,934,658 | | |
| Cauliflower and headed broccoli | 580,180 | | 1,834,833 | 475,426 | |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | 756,305 | 342,388 | 339,244 | 40,360 | |
| Cabbage, lettuce | | | 129,477 | | |
| Cucumber and gherkins, fresh or chilled | | | 50,224 | | 2,691 |
| Fresh peas | | | | | 17,112 |

| | | | | | |
|---|---|---|---|---|---|
| Leguminous vegetable, shelled or unshelled | 24,485 | 20,995 | | | |
| Fruits of genus *Capsicum* or *Pimenta* | 356,882 | | 59,463 | 34,815 | |
| Spinach, New Zealand spinach and orache spinach | | | 33,748 | | |
| Vegetables, fresh or chilled | 4,639,371 | 5,358,117 | 288,414 | | |
| Potato | | 4,237,697 | 358,362,660 | 742,810,901 | 506,393,781 |
| Leguminous vegetables | | 11,840 | | | |
| Leguminous vegetable, shelled or unshelled | | | 297,877 | | |
| Peas (*Pisum sativum*) | 2,692 | | | 6,965,198 | 4,793,251 |
| Sweet corn | | | | 4,014,429 | 2,777,796 |
| Vegetables | 3,391,370 | 2,593,309 | 1,531,679 | | |
| Fresh green vegetables | 2,513 | 32,597,871 | 46,278,706 | 750,974 | 34,977 |
| Cucumber | 18,835 | | | | |
| Mixture of vegetables | 53,828 | 9,689,900 | 8,143,415 | 7,334,590 | 2,059,853 |
| Onion, dried | 31,498 | 1,409,241 | 11,680,779 | 50,926,816 | 23,880,226 |
| Dry garlic, neither crushed nor ground | | | 7,756,863 | 33,326,425 | 7,544,117 |
| Dry garlic, crushed or ground | | | | 10,433,160 | 121,076 |
| Dry garlic | | | 4,496,861 | | 2,685 |
| Dried peas | 321,968 | 308,337 | 956,751 | 16,572,037 | 7,011,501 |
| Chick pea | 42,246,222 | | 7,673,220 | 15,567,394 | 1,521,760 |
| Beans of the species *Vigna mungo* or *Vigna radiata* | 7,387,984 | 354,014,988 | 591,098,448 | 896,228,567 | 428,492,635 |
| Kidney beans, including white pea beans (*Phaseolus vulgaris*) | | | 1,294,241 | 1,575,212 | 4,749,460 |
| Bambara bean | | | 9,540,731 | 6,174,316 | |
| Small red (Adzuki) beans (*Phaseolus* or *Vigna angularis*) | 503,667 | | | 357,841 | |
| Beans (*Vigna* spp., *Phaseolus* spp.), shelled, whether or not skinned or split | 182,060 | 628 | 2,870 | 1,822,832 | 356,083 |
| Lentils | 99,861,328 | 58,993,145 | 160,678,738 | 59,610,831 | |
| Red lentils | | | | 11,309,879 | 67,916,632 |
| Red lentils, unskinned unsplit | | | | | 9,980,397 |
| Asparagus | | | 26,905 | | |
| Broad bean and horse bean | 50,155,554 | | 4,843 | | |
| Pigeon pea | | | 21,525 | 886,760 | |
| Dried leguminous vegetables | 314,451,624 | 14,740,324 | 30,392,467 | 1,291,450 | |
| **Total** | **620,687,101** | **635,164,998** | **1,528,012,261** | **2,071,783,330** | **1,281,097,425** |

**G.** Imports from TIA (Value in NRs)

| Vegetables | July 2013-June 2014 | July 2014-June 2015 | July 2015-June 2016 | July 2016-June 2017 | July 2017-June 2018 |
|---|---|---|---|---|---|
| Potato seed | | | 2,872 | | |
| Potato, fresh or chilled | | | 48,912 | | |
| Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled | 618 | 2,103 | | | |
| Brussels sprouts | | 2,805 | | | |
| Cabbage, lettuce | | 2,384 | | | |
| Carrot and turnip | | 7,013 | | | |
| Fresh peas | | 1,262 | | | |
| Asparagus | | 196,224 | 124,196 | 54,568 | 132,715 |
| Edible roots | | | 8,115 | | |
| Aubergines | | 561 | | | |
| Fresh mushrooms | | 16,413 | 58,427 | 151,135 | 66,548 |
| Leguminous vegetable, shelled or unshelled | 1,157 | | | | |
| Mushrooms and truffle, fresh or chilled | 1,649 | | | | 201,485 |
| Fruits of genus *Capsicum* or *Pimenta* | 74,192 | 5,610 | | | 10,776 |
| Vegetables, fresh or chilled | 1,162 | 18,359 | | 2,950 | |
| Vegetables, fresh or chilled | 831 | | | | |
| Mixture of vegetables | | | 93,470 | | |
| Sweet corn | 4,999 | 4,208 | 45,824 | 41,759 | 67,329 |
| Vegetables | 1,029 | 10,629 | | | |
| Olives | | 21,868 | 39,048 | 82,090 | 80,346 |
| Dried truffle | 137,144 | 113,815 | 38,221 | | 17,067 |
| Dried peas | | | | | 7,683 |
| Bean of the species *Vigna mungo* or *Vigna radiata* | | | | 630 | |
| Beans (*Vigna* spp., *Phaseolus* spp.), shelled, whether or not skinned or split | | 4,247 | 2,670 | | |
| Kidney bean, including white pea bean | | | | | 1,216 |
| Sweet potato | | | 840 | | |
| Lentils | | | | 27,358 | |
| Mushrooms of the genus *Agaricus* | 4,191 | | | | 22,199 |
| Garlic | | | 5,945 | | |
| Dry garlic | | | | 188,026 | |
| Dry garlic, neither crushed nor ground | 704 | | | | |
| Dried leguminous vegetables | 4,805 | | | | |
| **Total** | **232,481** | **407,501** | **468,540** | **548,516** | **607,364** |

**Annex 20.3.** Informal trading of vegetables in Mechi custom point (this exercise was carried out in 2016 during the field survey)

| Date: 18-07-2016 | | |
|---|---|---|
| **Means of transportation (no.)** | **Gunny sacks (approx. 50 kg/sack)** | **Vegetables** |
| **Cycle** | | |
| 9 | 9 | chayote squash, cauliflower, radish |
| 4 | 8 | chayote squash, radish, 3 crates tomato |
| 2 | 3 | chayote squash, leafy greens |
| 1 | 4 | chayote squash, cabbage, radish |
| 1 | 3 | cabbage, 1 crate tomato |
| 1 | 5 | chayote squash |
| 2 | 5 | chayote squash, 2 crates tomato |
| 2 | 4 | chayote squash, cabbage, 1 crate tomato |
| 2 | 4 | chayote squash, cabbage, 2 crates tomato |
| 1 | 4 | chayote squash, radish |
| 3 | 4 | chayote squash, radish, cucumber, 2 crates tomato |
| 5 | 4 | chayote squash, radish, cucumber, cauliflower |
| **Rickshaw** | | |
| 2 | 20 | Chayote squash |
| 1 | 22 | Chayote squash |
| 2 | 23 | Chayote squash |
| 1 | 20 | Chayote squash |
| 3 | 20 | Chayote squash |
| **Total** | **162** | **162 × 50 = 8,100 kg** |
| **Date: 19-07-2016** | | |
| **Cycle** | | |
| 6 | 6 | chayote squash, radish, leafy greens, cabbage, 2 crates tomato |
| 4 | 4 | Cucumber, tomato |
| 2 | 4 | chayote squash, cauliflower, leafy greens, cabbage |
| 2 | 4 | chayote squash, cauliflower, leafy greens, cucumber |
| 5 | 4 | Chayote squash, cauliflower, leafy greens, tomato, radish |
| 2 | 4 | chayote squash, cauliflower, radish |
| 3 | 4 | chayote squash, radish |
| 3 | 4 | chayote squash, cauliflower, radish |
| **Rickshaw** | | |
| 1 | 22 | Chayote squash |
| 1 | 22 | Radish, cabbage |
| 1 | NA | Tomato |
| **Total** | **78** | **78 × 50 = 3,900 kg** |

**Annex 20.4.** Trading values of vegetables in different Asian countries (Source: Web, 3)

**A.** Vegetable imports by Bangladesh from different countries (in US$ '000)

| Exporters | Value in 2010 | Value in 2011 | Value in 2012 | Value in 2013 | Value in 2014* | Value in 2015 |
|---|---|---|---|---|---|---|
| World | 399,951 | 303,655 | 370,868 | 516,596 | | 704,758 |
| Canada | 199,315 | 112,095 | 143,202 | 241,740 | | 226,190 |
| Thailand | 70 | 72,041 | 113 | 352 | | 512 |
| Australia | 109,802 | 56,490 | 154,605 | 193,134 | | 184,696 |
| China | 48,432 | 29,538 | 20,494 | 34,869 | | 54,310 |
| India | 14,507 | 8,494 | 14,473 | 16,281 | | 205,170 |
| USA | 2,164 | 2,895 | 2,542 | 1,631 | | 1,093 |
| UAE | 38 | 18 | 862 | 61 | | 666 |
| Netherlands | 3,982 | 4,629 | 4,608 | 105 | | 4,053 |
| Belgium | 625 | 312 | 399 | 0 | | 264 |
| Germany | 29 | 203 | 119 | 61 | | 36 |
| United Kingdom | 22 | 127 | 46 | 2 | | 2 |
| France | 170 | 54 | 0 | 0 | | 62 |
| Nepal | 0 | 0 | 0 | 0 | | 0 |

*Imported value in 2014 was not available

**B.** List of supplying markets for vegetables imported by Bangladesh (Mirror data) (in US$ '000)

| Exporters | Value in 2014 | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019 |
|---|---|---|---|---|---|---|
| Canada | 223,414 | 192,697 | 197,657 | 100,365 | 93,226 | 233,104 |
| Australia | 156,682 | 174,852 | 247,776 | 285,801 | 240,593 | 240,817 |
| India | 102,913 | 82,453 | 70,078 | 60,868 | 70,305 | 93,609 |
| China | 48,395 | 50,604 | 53,965 | 43,569 | 33,816 | 82,649 |
| Russian Federation | 0 | 6,778 | 8,089 | 25,710 | 16,483 | 11,506 |
| Nepal | 17,767 | 6,567 | 12,133 | 8,555 | | |
| Turkey | 123 | 5,601 | 7,824 | 183 | 817 | 5,946 |
| Pakistan | 1,686 | 5,281 | 100 | 165 | 0 | 6,117 |
| Netherlands | 4,255 | 3,271 | 3,799 | 4,612 | 3,370 | 3,053 |
| USA | 685 | 400 | 747 | 645 | 682 | 445 |
| Belgium | 372 | 257 | 136 | 38 | 7 | 0 |
| Bulgaria | 0 | 153 | 83 | 0 | 0 | 0 |
| Thailand | 193 | 120 | 234 | 324 | 461 | 584 |
| Singapore | 32 | 49 | 1,206 | 113 | 95 | 63 |
| Malaysia | 17 | 43 | 15 | 271 | 26 | 12 |
| Republic of Korea | 0 | 1 | 0 | 0 | 8 | 2 |
| Taipei, Chinese | 1 | 1 | 3 | 2 | 2 | 2 |
| **Total** | **559,007** | **537,107** | **628,718** | **554,714** | **512,074** | **702,084** |

**C.** Vegetable imports by different countries in Middle-East and its partners (in US$ '000)

| Importers | Partner (Exporter) | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019* |
|---|---|---|---|---|---|---|
| UAE | World | 1,232,615 | 1,262,904 | 1,342,007 | 973,327 | 734,080 |
| | South Asia | 206,246 | 217,303 | 216,631 | 198,348 | |
| | Nepal | 16 | 3 | 12 | 3 | |
| | Bangladesh | 4,509 | 4,347 | 4,386 | 4,190 | |
| | India | 150,237 | 168,414 | 178,348 | 154,834 | |
| | Pakistan | 43,283 | 40,021 | 27,844 | 33,722 | |
| Saudi Arabia | World | 688,249 | 754,848 | 664,596 | 611,617 | 608,060 |
| | South Asia | 36,406 | 49,707 | 58,073 | 59,773 | 61,067 |
| | Nepal | – | – | – | – | |
| | Bangladesh | 6,374 | 10,534 | 9,681 | 6,902 | 4,416 |
| | India | 26,722 | 35,507 | 46,750 | 45,620 | 53,201 |
| | Pakistan | 3,100 | 3,431 | 1,538 | 6,238 | 2,814 |
| Qatar | World | 283,706 | | 275,403 | 292,082 | 148,318 |
| | South Asia | 76,312 | | 81,944 | 91,911 | |
| | Nepal | – | – | 3 | 95 | |
| | Bangladesh | 4,081 | | 4,131 | 6,359 | |
| | India | 58,765 | | 68,003 | 68,825 | |
| | Pakistan | 10,509 | | 7,909 | 14,730 | |
| Bahrain | World | 110,511 | 116,932 | 123,987 | 121,424 | 47,896 |
| | South Asia | 27,341 | 31,255 | 30,800 | 33,288 | |
| | Nepal | – | – | – | – | |
| | Bangladesh | 1,723 | 2,387 | 1,901 | 1,617 | |
| | India | 18,702 | 21,616 | 23,261 | 24,691 | |
| | Pakistan | 6,499 | 6,808 | 5,307 | 6,507 | |
| Kuwait | World | 398,266 | 319,288 | 328,414 | 385,794 | 128,177 |
| | South Asia | 66,946 | 65,414 | 69,685 | 77,994 | |
| | Nepal | – | – | – | – | |
| | Bangladesh | 6,997 | 6,821 | 6,792 | 6,889 | |
| | India | 48,466 | 50,680 | 58,059 | 60,202 | |
| | Pakistan | 10,150 | 6,567 | 3,781 | 8,752 | |
| Oman | World | 127,564 | 145,863 | 167,329 | 162,405 | 91,985 |
| | South Asia | 19,706 | 46,824 | 30,929 | 43,335 | 360,643 |
| | Nepal | – | – | – | – | |
| | Bangladesh | 479 | 442 | 467 | 492 | |
| | India | 14,884 | 38,714 | 26,425 | 33,628 | |
| | Pakistan | 4,219 | 7,546 | 3,722 | 8,977 | |

*Data given is mirror data. – = Data for Nepal was not available

**Annex 20.5.** Different vegetables imported by different Asian countries (Source: Web, 3)

**A.** Bangladesh's imports from world (in US$ '000)

| Vegetables | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019 |
|---|---|---|---|---|---|
| Dried leguminous vegetables, shelled, whether or not skinned or split | 426,530 | 501,442 | 441,006 | 406,790 | 517,971 |
| Cucumber and gherkin, fresh or chilled | 1 | 4 | 7 | 2 | 3 |
| Dried vegetables, whole, cut, sliced, broken or in powder, but not further prepared | 1,145 | 1,657 | 3,389 | 3,230 | 1,417 |
| Tomato, fresh or chilled | 8,180 | 5,279 | 64 | 433 | 13,052 |
| Lettuce, fresh or chilled | 49 | 55 | 134 | 61 | 38 |
| Leguminous vegetables, shelled or unshelled, fresh or chilled | 9 | 172 | 869 | 6,745 | 12 |
| Roots and tubers of manioc, arrowroot, salep, Jerusalem artichokes, sweet potato and similar edible roots | 345 | 382 | 408 | 163 | 233 |
| Carrot, turnip, salad beet root, salsify, celeriac, radishes and similar edible roots | 378 | 1,643 | 2,219 | 2,407 | 2,855 |
| Cabbage, cauliflower, kohlrabi, kale and similar edible brassicas, fresh or chilled | 12 | 162 | 288 | 20 | 15 |
| Onion, shallot, garlic, leek and other alliaceous vegetables, fresh or chilled | 255,432 | 112,327 | 98,616 | 87,709 | 162,981 |
| Vegetables, uncooked or cooked by steaming or boiling in water, frozen | 500 | 193 | 238 | 233 | 214 |
| Potato, fresh or chilled | 4,413 | 4,422 | 4,667 | 3,376 | 2,630 |
| Other vegetables, fresh or chilled (excluding potato, tomato, alliaceous vegetables) | 7,762 | 933 | 2,728 | 850 | 624 |
| Vegetables provisionally preserved, e.g. by sulphur dioxide gas, in brine, in sulphur water | 1 | 48 | 81 | 51 | 43 |

**B.** Nepal's exports to Bangladesh (in US$ '000)

| Vegetables | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019 |
|---|---|---|---|---|---|
| Dried leguminous vegetables, shelled, whether or not skinned or split | 6,567 | 12,133 | 8,555 | | |

**C.** United Arab Emirates' imports from world (in US$ '000)

| Vegetables | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019 |
|---|---|---|---|---|---|
| Dried leguminous vegetables, shelled, whether or not skinned or split | 158,104 | 162,266 | 155,562 | 123,091 | 136,775 |
| Cucumber and gherkin, fresh or chilled | 1,074 | 1,360 | 1,016 | 1,651 | 1,193 |
| Dried vegetables, whole, cut, sliced, broken or in powder, but not further prepared | 6,035 | 4,091 | 5,115 | 3,845 | 6,535 |
| Tomato, fresh or chilled | 94,002 | 99,394 | 69,828 | 79,110 | 86,784 |
| Lettuce, fresh or chilled | 37,145 | 37,971 | 38,245 | 37,082 | 39,141 |
| Leguminous vegetables, shelled or unshelled, fresh or chilled | 5,145 | 7,201 | 6,891 | 7,889 | 8,193 |
| Roots and tubers of manioc, arrowroot, salep, Jerusalem artichokes, sweet potato and similar edible roots | 10,646 | 11,437 | 18,641 | 20,064 | 15,516 |
| Carrot, turnip, salad beet root, salsify, celeriac, radish and similar edible roots, fresh | 21,968 | 25,720 | 21,940 | 31,933 | 30,147 |
| Cabbage, cauliflower, kohlrabi, kale and similar edible brassicas, fresh or chilled | 6,744 | 7,045 | 9,228 | 7,798 | 8,186 |
| Onion, shallot, garlic, leek and other alliaceous vegetables, fresh or chilled | 187,188 | 214,564 | 204,042 | 156,627 | 137,090 |
| Vegetables, uncooked or cooked by steaming or boiling in water, frozen | 67,806 | 90,452 | 46,550 | 51,137 | 48,120 |
| Potato, fresh or chilled | 33,485 | 26,324 | 21,618 | 31,379 | 35,510 |
| Other vegetables, fresh or chilled (excluding potato, tomato, alliaceous vegetables) | 52,523 | 58,586 | 56,761 | 49,900 | 44,351 |
| Vegetables provisionally preserved, e.g. by sulphur dioxide gas, in brine, in sulphur water | 6,385 | 8,437 | 9,158 | 10,110 | 10,518 |

**D.** India's imports from world (in US$ '000)

| Vegetables | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019 |
|---|---|---|---|---|---|
| Dried leguminous vegetables, shelled, whether or not skinned or split | 3,637,608 | 4,017,156 | 3,947,300 | 1,075,709 | 1,553,166 |
| Cucumber and gherkin, fresh or chilled | 0 | 0 | 1 | 0 | 0 |
| Dried vegetables, whole, cut, sliced, broken or in powder, but not further prepared | 4,146 | 4,955 | 5,947 | 5,141 | 5,238 |
| Tomato, fresh or chilled | 0 | 0 | 4 | 0 | 0 |
| Lettuce, fresh or chilled | 34 | 10 | 16 | 7 | 0 |
| Leguminous vegetables, shelled or unshelled, fresh or chilled | 100 | 0 | 43 | 60 | 0 |
| Roots and tubers of manioc, arrowroot, salep, Jerusalem artichokes, sweet potato and similar edible roots | 0 | 0 | 1 | 0 | 24 |

| | | | | | |
|---|---|---|---|---|---|
| Carrot, turnip, salad beet root, salsify, celeriac, radish and similar edible roots, fresh | 21 | 10 | 11 | 25 | 42 |
| Cabbage, cauliflower, kohlrabi, kale and similar edible brassicas, fresh or chilled | 641 | 451 | 173 | 127 | 657 |
| Onion, shallot, garlic, leek and other alliaceous vegetables, fresh or chilled | 32,588 | 39 | 1,984 | 1,264 | 40,518 |
| Vegetables, uncooked or cooked by steaming or boiling in water, frozen | 161 | 54 | 87 | 118 | 313 |
| Potato, fresh or chilled | 13 | 0 | 139 | 160 | 16 |
| Other vegetables, fresh or chilled (excluding potato, tomato, alliaceous vegetables) | 739 | 873 | 956 | 1,107 | 2,448 |
| Vegetables provisionally preserved, e.g. by sulphur dioxide gas, in brine, in sulphur water | 2,262 | 2,522 | 2,820 | 3,774 | 3,519 |

**Annex 20.6.** Nepal's exports to the world (in US$ '000) (Source: Web, 3)

| Vegetables | Value in 2015 | Value in 2016 | Value in 2017 | Value in 2018 | Value in 2019 |
|---|---|---|---|---|---|
| Dried leguminous vegetables, shelled, whether or not skinned or split | 8,383 | 13,754 | 9,384 | 467 | 377 |
| Cucumbers and gherkin, fresh or chilled | 0 | 0 | 1 | 15 | |
| Dried vegetables, whole, cut, sliced, broken or in powder, but not further prepared | 165 | 220 | 238 | 285 | 169 |
| Tomato, fresh or chilled | 48 | 6 | 109 | 3 | |
| Lettuce, fresh or chilled | 246 | 117 | 15 | | |
| Leguminous vegetables, shelled or unshelled, fresh or chilled | 17 | 2 | 1 | 28 | |
| Roots and tubers of manioc, arrowroot, salep, Jerusalem artichokes, sweet potato | 0 | 22 | 1 | 3 | 7 |
| Carrot, turnip, salad beet root, salsify, celeriac, radish and similar edible roots | 0 | 0 | 0 | 3 | |
| Cabbage, cauliflower, kohlrabi, kale and similar edible brassicas, fresh or chilled | 538 | 487 | 107 | 129 | 657 |
| Onion, shallot, garlic, leek and other alliaceous vegetables, fresh or chilled | 1,257 | 16 | 9 | 18 | |
| Vegetables, uncooked or cooked by steaming or boiling in water, frozen | 5 | 9 | 12 | 1 | 5 |
| Potato, fresh or chilled | 66 | 43 | 18 | | 288 |
| Other vegetables, fresh or chilled (excluding potato, tomato, alliaceous vegetables) | 305 | 213 | 421 | 74 | 5 |
| Vegetables provisionally preserved, e.g. by sulphur dioxide gas, in brine, in sulphur water | 2 | 1 | 1 | 4 | 3 |

**Abbreviations:** AEC = Agro Enterprise Centre; CBS = Central Bureau of Statistics; CNI = Confederation of Nepalese Industries; FICS = Food Import Clearance System; FNCCI = Federation of Nepalese Chambers of Commerce and Industry; FSSAI = Food Safety and Standards Authority of India; GAP = good agricultural practices; GoI = Government of India; GoN = Government of Nepal; HVAP = High Value Agriculture Project; IPM = integrated pest management; MAP = aromatic plant product; NPC = National Planning Commission; NRs = Nepali rupees; PRA = pest risk analysis; SAARC = South Asian Association of Regional Cooperation; SAWTEE = South Asia Watch on Trade, Economics and Environment; SPS = sanitary and phytosanitary; TIA = Tribhuvan International Airport; VDC = Village Development Committee.

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## Author's Biography



Ms. Neelu Thapa has been working in the areas such as trade, food security and commercialisation of agriculture for the last 21 years. Her specific areas of interest are gender and trade and competition issues. She has various publications on a variety of topics. She has been associated with South Asia Watch on Trade, Economics and Environment (SAWTEE) since 2002 in various capacities and is currently in the executive committee of SAWTEE. She holds a Master's Degree in Economics from Tribhuvan University, Kathmandu, and an MBA (Executive) from Kathmandu University.

# Chapter 21

## Prospects of Vegetables Based Enterprises in Nepal

**Asmita Khanal[1], Prasamsha Panta[1], Raksha Dangol[1,2] and Rameshwar Adhikari[1,3]***

[1]*Research Centre for Applied Science and Technology (RECAST)*
*Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*National Innovation Center (NIC), Kirtipur, Kathmandu, Nepal*
[3]*Central Department of Chemistry, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
*Email: r_adhikari@recast.edu.np; ram.adhikari.tu@gmail.com

*The vegetables have been serving, from time immemorial, as vital source of nutrition for both physical and psychological wellbeing of all the human civilizations on earth. The developed as well as emerging nations have the history of modernizing their traditional knowledge of food processing and turning them to enterprises of different scales. In this context, Nepalese vegetables have great potential of transforming the traditional food processing knowledge and technology into small and middle scale enterprises that may in turn contribute significantly to the public aspiration of prosperous Nepal. There is, however, urgent need of rethinking and remodelling of vegetable marketing to achieve such an endeavour. Introduction of novel technologies and marketing strategies towards preserving the traditional heritage of food and nutrition, safeguarding the public health and promoting vegetable based businesses are the prerequisites. The purpose of this chapter is to analyse the opportunities in developing vegetables based enterprises in our country with emphasis on introducing innovative ideas towards vegetable processing, nutritional labelling, branding and marketing for both local and global citizens. The challenges and opportunities of such enterprises in Nepal will be addressed.*

**Keywords:** Enterprises; innovation; nutrition; traditional knowledge; vegetables.

## Introduction

The importance of vegetables in daily diet for health and nutrition is obvious. Vegetables are the source of vitamins, protein, minerals, essential micronutrients, fibers and multiple bioactive compounds that are crucial for functioning of the human body (Ülger et al., 2018). In fact, vegetables are affordable sources of dietary food. And in the countries like

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Nepal, where the population of vegetarians are considerably higher, and the vegetables are cheaper than the animal products, the former form the basic source of nutrition and essential aspect of food security to be considered. In this context, along with the ever-growing population and subsequent migration of people to urban areas, increased income, emigration of the work forces in many regions and changing food habits of people have created a rise in market demand for vegetables (FAO, 2015). As a result, unlike the tradition of home-grown vegetables, people rely on the market due to the lack of cultivable land in the city area. Thus, the situation of increasing vegetable production can create small holder farmers an economic opportunity in local level.

There is a good trade potential for small scale farmers where local markets demand for vegetables is high. Moreover, when planned properly; vegetable farming requires neither a large land area nor a high investment. Thus, a profitable cultivation can be achieved in a relatively short period of time leading to employment opportunities within family and surroundings enhancing their income, and thus improving their livelihoods.

Although most of the Nepali farmers own a piece of agricultural land suitable for food production, there are several challenges that need to be addressed in order to promote developing an enterprise. The application of innovative technology, improvement in input supply, diversity in vegetable crops, access to land and financial support are critically important to develop a vegetable based enterprise that eventually might attract country's large population of youth (Schreinemachers et al., 2018). This aspect is particularly important today as quite a large population of youth, having experience and skills to work under odd environments, from overseas employment, is supposed to return to the country as a consequence of the ongoing pandemic, and they urgently can be provided employment opportunities in vegetable enterprise sectors.

This chapter aims at analysing the prospects of developing the vegetable based enterprises in Nepal that can ultimately contribute to the nation's aspiration to become a land of happiness and prosperity. First, we will briefly introduce the opportunities that our traditional entrepreneurial knowledge would offer towards the development of the modern enterprises. Then, a few global trends of the vegetable based enterprises will be discussed with some success stories. Finally, the opportunities offered by innovative uses of traditional ways for such entrepreneurial developments and associated challenges will be discussed.

## Opportunities with Traditional Knowledge and Technologies

Nepal is an ethnically, geographically and culturally diverse country with an imposing variety of local foods. An abundance of vegetarian cuisines is practicable in all eateries as meat is considered as a luxury item in Nepali kitchen. Vegetables as food contribute an important component in Nepali meal accompanying rice and *Daal*. Varieties of vegetable parts (such as flower, fruit, leaf, steam, root, seed, tuber, bark) and all other edible plant parts are in use. Spinach, lettuce, cabbage, cauliflower, pumpkin, snake gourd, sponge gourd, potato, yam, corms, bamboo shoot, taro, fresh beans, peas, etc. are some example of commonly used vegetables in Nepal. Furthermore, dried, fermented and value-added vegetable products are evenly in practices. Vegetables are highly perishable and have very short life. Thus, there is a local practice where almost all types of vegetables can be dehydrated when cannot be consumed at once and stored as dried items for out of season

future use. Dried vegetable like *Chhana, Sinki, Gabba*, value-added like *Gundruk*-fermented green leafy vegetable, *Tama*- pickled bamboo shoot, and others like *Masyura*, *Titaura*, etc. are common famous traditional vegetable items in Nepali cuisine (Figure 21.1). Indeed, Nepal, having a unique climatic condition and geography, harbours diversity in vegetable crops where about 200 species of plant are consumed as a vegetable. Furthermore, indigenous culture, technology and foods have played an important role to preserve few indigenous vegetables which are considered to be valuable in terms of nutritional availability, adoption to adverse environmental condition, their production throughout the year and resistances towards several diseases (Shrestha, 2013). However, during the last decades, the availability of indigenous vegetables has declined. However, in fact, the production and commercialisation of indigenous vegetables and their products in local as well as wider market would contribute to the food security, and nutrition enhancing the economy of people, particularly in remote areas (Uprety et al., 2012). According to survey in two different geographical locations, namely hills and terai regions of Chitwan, shows a low market access for the vegetable produced by local farmers, especially in hilly region (Devkota & Mishra, 2020). This may be because of lack of transport, lack of technology for storage and poor market-network. Creating an enabling market environment for vegetables is important. Today, the global marketing trends like online market, supermarkets, long distance shipping, different processing and packaging practices have given away the traditional system of marketing. So, in this digitalized era, it is tremendously important to improve and upgrade the marketing strategy for sustainable enterprises.



*Gundruk*: dried green mustard leaves *Masyura*: made from black lentils and taro stem

**Figure 21.1.** Common famous traditional vegetable items in Nepali cuisine.

There is a high potential of local markets for fresh, dried, pickled and value-added products with equal possibilities of export. Indigenous food and traditional technology are now finding a new possibility which can widen the local processing and product that may find a wide market. To develop successful vegetable based enterprises and to survive as a business, it needs a good strategy for the commercialisation. Evaluating the market demand, developing a consistently quality product and value addition, a suitable marketing plan would be necessary.

The vegetable cultivation has sharply risen in Nepal during the last decades. For instance, a rise in vegetable cultivation area by 40% was recorded within a period

between 2005 and 2015. Compared to other cereals and fruits, their commercialisation rate also was found to increase from 30 to 40% (CASA, 2020; Gurung et al., 2016).

There is a high demand of off-season vegetables for export in India and other third countries. A large quantity of fresh vegetables is being exported to China, Germany and Qatar. Globalisation has created anopportunity to boom a vegetable market because of which international trade of fresh and processed vegetables is massively increasing (Dias, 2011). Globally, increase in 1% per capita income in developing countries is associated with increase in 0.5% in per capita vegetable availability (Schreinemachers et al., 2018).

Commercial vegetable production is booming in many regions and countries worldwide. Arising global demand of vegetables, due to the increasing health awareness, increasing income, changing lifestyle and urbanisation, is further expected in future. To expand the quantity and increase the quality and safety of vegetable production, innovative technology, knowledge and enhancement of market competitiveness is important. There is clearly the opportunity to develop large number of vegetables based small enterprises in Nepal. In order to be benefited from these opportunities, there is a need for increasing the production of quality vegetables utilising innovative technologies, knowledge and enhancement of market competitiveness.

## Giving Chance to Traditional Ways via Innovations

Fresh and processed vegetables have a large domestic market in Nepal. The busy lifestyle of consumers today demand for quickly and easily prepared foods, while at the same time they want to eat healthily. The space between these two factors provides an opportunity for the improved processing and value addition within vegetable products. There is a high demand for the traditional products, whereas the market is equally growing for the new processed items. Most vegetable enterprises still operate on a traditional model. However, a modern enterprise should offer value-added and safely processed vegetables as complementary products and services responding to the local consumers' needs. Such an enterprise can create value by managing business partnerships with farmers, processing technology providers and consumers, which result in higher profits. There are some proved techniques that can be useful to improve the vegetables based enterprise. Here, some opportunities for innovation in vegetables retailing have been discussed.

### *1. Rethinking of Vegetable Processing*

Processing is a method for extending the life of vegetable products, at the same time preserving nutrition and improving food safety. Physical, chemical and biochemical techniques used for vegetable processing is summarized below in Table 21.1. Primary processing involves a minimal change to the physical, chemical and nutritional properties of food. For vegetables, it includes washing, cutting, mixing, freezing, coating and packaging of fresh produce rather than selling unprocessed and unpackaged vegetables (Fischer, 2009). Secondary processing involves the alteration of food from its natural state. For vegetables, secondary processing involves making slices, pulp, paste and drying, whereas tertiary processing involves cooking, canning, jamming, juicing, etc. that change vegetables into the other products (Fischer, 2009). These techniques create a

substantial benefit to the consumer saving time and adding benefits like taste, versatility and storage life. Figure 21.2 depicts the classification of vegetables processing routes.

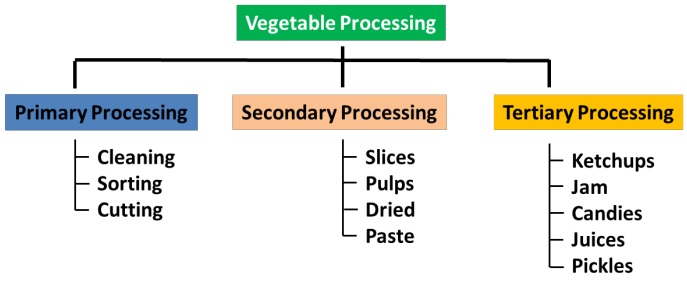



**Figure 21.2.** Schematic diagram illustrating the classification of vegetables processing.

**Table 21.1.** Summary of physical, chemical, and biochemical techniques used for vegetable processing.

| | |
|---|---|
| **Physical** | Heating |
| | Cooling, freezing, chilling, canning |
| | Lowering of water content (drying/dehydration, concentration) |
| | Sterilising filtration |
| | Irradiation |
| | Other physical means (high pressure, vacuum, inert gases) |
| **Chemical** | Salting |
| | Smoking |
| | Sugar addition |
| | Artificial acidification |
| | Ethyl alcohol addition |
| | Antiseptic substance action |
| **Biochemical** | Lactic fermentation (natural acidification) |
| | Alcoholic fermentation |

## *2. Category Management*

Grading and categorising the vegetables according to quality, size, types, geography and their characteristics would attract consumers and could improve marketing. For example, quality and size grading of vegetables and selling individual categorised to different customers at different prices.

## *3. Nutritional Labelling*

Certain vegetables could be promoted focusing on their nutritional availability and health benefits. Consumer may not be aware of the nutritional profile of specific vegetables. For example, certain exotic vegetables like broccoli, cabbage likewise certain traditional vegetables like *Ban tarul, Kalo bethe, Sano saro, Kalo neuro* (Joshi et al., 2007), and

many more which has a high markets value. In addition, nutritional and calorie information in the form of labels, booklets or leaflets could be provided.

## *4. Pure and Organic Form*

A significant number of consumers are seeking pure and organic vegetables which are associated with better taste and health. There is a high demand for such products which exceeds the supply providing a better margin for farmer and retailers.

## *5. Convenience Food*

High demand for readymade and healthy snacks is on rising these days. Products using vegetables such as nutritional bars, meal kits, and heat and eat meals (which can be heated at consumer's convenience and eat i.e. vegetable soup; hot and cold recipes with fresh vegetables i.e. salads) for the consumers who want to eat right away.

## *6. Preparation Ideas and Recipes*

Although, consumers are aware of health and taste who want to eat home cooked food, but they may not know how to prepare and cook meals incorporating vegetables. A vegetable entrepreneur can take the initiative to encourage consumers to make a meal and snacks of vegetables by providing preparation ideas and recipes. The recipes and ideas of preparing vegetable meals can be placed on the package or can provide a link that redirects the consumer about recipe and preparation steps.

## *7. Neglected and Underutilized Vegetables*

There are several neglected and underutilized vegetables that have no technical and financial investments in the development of the crops, although they have high potential for food, nutritional security and high adaptability to changing climate (Joshi et al., 2020). Indigenous species that have not been registered and researched extensively also fall in the category of neglected and underutilized vegetables. Some of the neglected and underutilized vegetables found in Nepal are *Ram phal* (alligator apple), *Karkale jhar* (monochoria), *Ban karela* (bitter melon), *Bhote paalungo* (bladder dock), *Dundu saag* (garlic chives), *Poi sag* (creeping spinach), *Saunp* (dill), *Fultarul* (edible canna), *Niuro* (fiddlehead fern), *Bihi* (African eggplant), *Jalukaa* (hitchhiker elephant ear), *Hiunde simi* (lablab bean), *Kundruk* (ivy gourd), *Pindaalu* (taro), etc (Joshi et al., 2019, 2020). Many species of vegetables fall in the category of future smart food as they provide food security with high nutritional value, health benefits and climate resilience, such as *Pindaalu* (taro), *Bakkula* (faba beans), *Tarul* (greater yam), *Iskush* (chayote), *Barella* (balsam apple), *Sahinjan* (drumstick), *Kubhindo* (ash gourd), *Chattel* (chathel gourd), *Methi* (fenugreek), *Saunp* (dill), *Bethe* (lamb's quarter), *Sim saag* (water cress), *Lunde* (green pigweed, green amaranth), *Jaringo* (sweet belladonna, Indian poke), etc. These vegetables have various medicinal benefits like to improve digestion, lower blood sugar levels, prevent certain types of cancers, protect the skin, boost vision health and contain immune-boosting nutrients. There are many more nutritional benefits of such smart vegetables (Timsina & Shivakoti, 2018). Hence, enterprises for growing this type of vegetables can also flourish once it can be commercialised.

### *8. Vegetable Wastes as Resource*

Many consumers are unaware of vegetable waste like peels, tops and other scraps, which can be used in some other ways. Vegetables suppliers and retailers can educate consumers about the use of waste and maximize the value of the products they buy. For example, vegetable scraps can be added to compost and fertilize the garden; similarly, vegetable peels and scraps can be used in making stocks and broth. Such information may encourage consumers to responsibly use and recycle vegetable waste.

Some of these product innovations would require investment in vegetable processing and storage equipment. Fresh vegetables that cannot be sold in time could be processed immediately, so can reduce wastage. Freshly processed and value-added vegetables have a considerably high price than the raw commodities. To make sustainable business, entrepreneur should engage in smart business partnership with producer, supplier, retailers, and consumers.

## Global Trends and Case Studies

According to the data published by Statista Research Department, 2020, the production of vegetables in the world was more than one billion metric tons per year. Out of that, over 834 million metric tons of fresh vegetable are produced in Asia (Web 1). Figure 21.3 shows the world's leading 10 producers of fresh vegetables in the year 2018. China was the leading producer with a production of around 549 million metric tons, followed by India. China has always been a large contributor to the world vegetable production (Dias & Ryder, 2011). Similarly, Figure 21.4 shows the global vegetable production by type in the year 2018. Among other, tomatoes were produced in high volume, approximately 182 million metric tons worldwide.

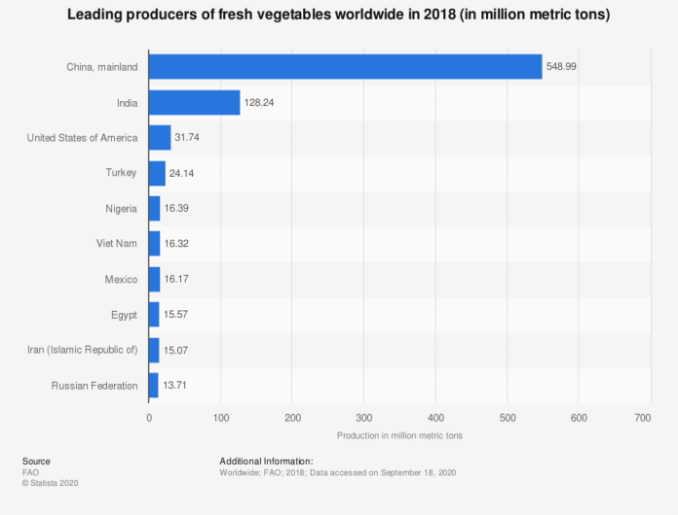



**Figure 21.3.** Diagram showing the world's leading producer of fresh vegetables (Research and Markets, 2021).

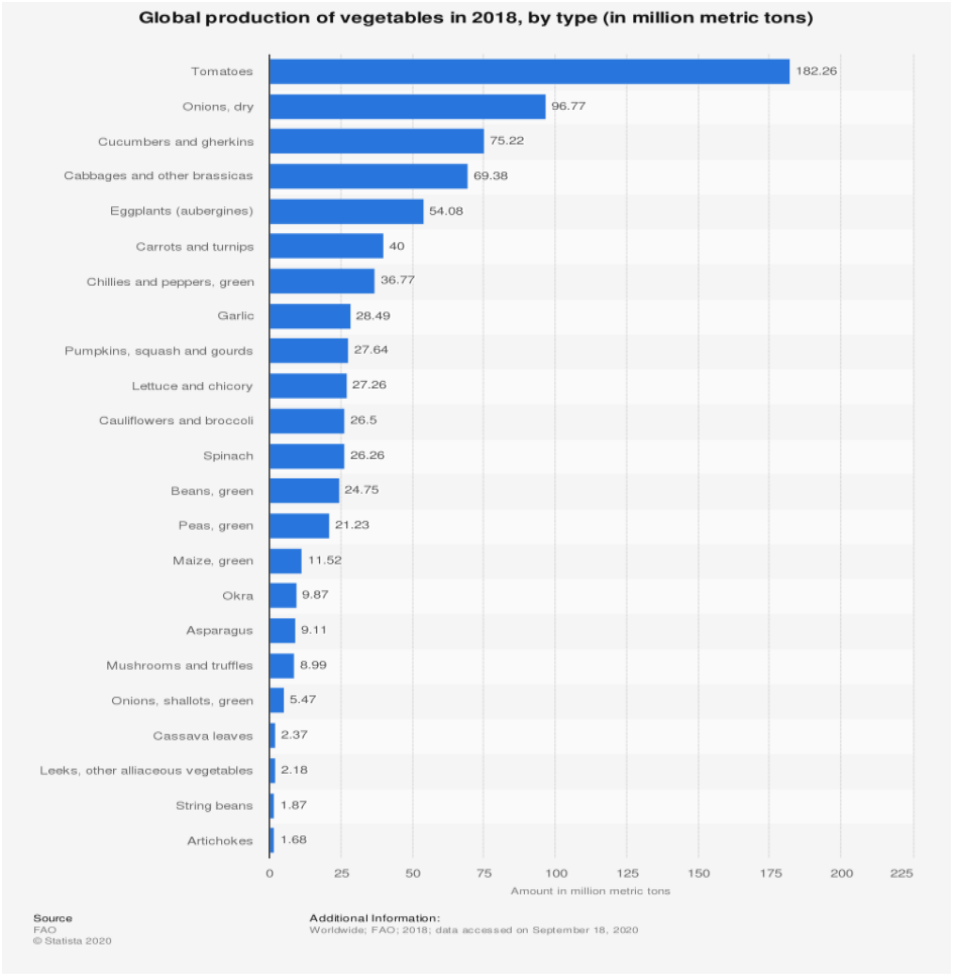



**Figure 21.4.** Diagram showing the global vegetable production by their type (Research and Markets, 2021).

According to the forecast made by Global Marketing Associates, the fruits and vegetable market is expected to reach 373.5 billion US$ by 2022. The market is divided to different products from fresh, dried, frozen to processed ones. The processed product accounts for around 35% of total revenue and expected to grow.

According to the report published on world vegetable market analysis, 47 million tons of vegetable were exported worldwide in 2018 with then increased in average annual rate of 1.7% from 2007 to 2018 (Research and Markets, 2021). Table 21.2 shows the highest global exporter of vegetables in the year 2018. The countries mentioned in Table 21.2, represents more than 70% of total exporters of vegetables globally in 2018.

**Table 21.2.** Vegetable exports by different countries in the year 2018.

| Country | Amount (Million tones) |
|---|---|
| Netherlands | 6.1 |
| Mexico | 5.8 |
| Spain | 5.1 |
| China | 4.3 |
| France | 3.5 |
| Germany | 2.7 |
| U. S. A. | 2.4 |
| Canada | 1.4 |
| Belgium | 1.3 |
| India | 1.2 |
| Egypt | 1.1 |

Source: (Research and Markets, 2021)

The World Health Organization (WHO) has the range of consumption of vegetables per person i.e., 200–250 g, but due to the per capita income varies with the country, the daily intake is below 250 g. Therefore, per capita income of the country is directly affecting the vegetable intake (Siddiq & Basher, 2019). Per capita vegetable consumption in Nepal was 114 kg compared to Europe at 115 kg and the US at 114 kg (Yuman et al., 2004).

With the import and export of quality vegetables, local vendors are also equally contributing for upgrading the socioeconomic status of some countries, which includes East Asia, Pacific and South Asian countries. Some of the countries are creating footmarks in vegetable harvest, production, consumption and trade; among which, Thailand, Malaysia, China, India, Korea, Indonesia, Philippines, Vietnam, etc. are considered as the leading countries.

Cultivation procedure, technology and research based vegetable production has been introduced in many of these countries where national and international people are getting an opportunity in farming sector, setting the rules and regulations for vegetable production, marketing, standardization, testing and research in vegetable farming. China is going through the production of green, organic food and pollution-free vegetables in their respective province (Tey et al., 2009). Malaysia, Thailand and Indonesia are the tourist attraction countries where food exploration is one of the magic tools. In Malaysia, the consumption of vegetables increases with a rise in their income, where the urban people demand a higher quality of vegetables than rural customers (Johnson et al., 2008). Thailand is another example of growing vegetable enterprise. The vegetable industry is a key asset for productivity improvement, export market development, income generation and livelihood improvement in Thailand.

## *1. A Case Study from Thailand*

The Thai industry is one of the top 10 asparagus exporters globally (Islam et al., 2017). The increase in grown by more than 10% per year from 2000 to 2005 is reported. With the focus on export markets in Japan, Taiwan and the UK, export volumes and value grew by around 30% annually. The industry that provides small scale farmers a reliable income is well organized and most of the farmers are in grower groups that have contracts with exporters. The industry is supported by government from tax incentives to foreign investment, research and development (R&D) and marketing. Table 21.3 shows asparagus production and export statistics of Thailand in the year 2000 to 2005.

**Table 21.3.** Asparagus production and export statistics of Thailand.

| Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Export quantity (1000 tons) | 3.83 | 7.43 | 8.02 | 6.98 | 11.96 | 15.76 |
| Export value (1000 US$) | 6,476.00 | 10,790.79 | 13,807.72 | 15,611.24 | 24,568.00 | 28,165.00 |

## *2. A Case Study from India*

The vegetable productivity in Meghalaya, India is very low due to high rainfall, moisture stress and poor soil nutrition. Protective cultivation using polyhouse technology helps farmers in regulating the factors and helps in providing quality off-seasonal products (Ghimire & Upreti, 2019). The production in protected condition was increased by 38% as compared to normal cultivation. This technology helps to increase production, minimize crop diseases and pests, and increase life span of crops with high growth rate. With this, net return and profitability also doubled. This technology has created job opportunities, income all-year round for local farmers, and higher income per unit of land.

## *3. A Case Study from Nepal*

There are limited but quite successful stories of vegetable based enterprises in Nepal. The enterprises are primarily based on the modification of the local knowledge and techniques. Many such enterprises rely on production and conservation of off-season vegetables for future uses. In this context, Nepal mid-hills are considered to be the potential areas for off-season vegetable farming. Still the production of the vegetable is limited which could not even fulfill the internal demand. According to a study conducted in Okhaldhunga district, the factors influencing the off-season vegetable production include education, training received and the adaptation of technology along with other factors (Kunwar et al., 2015). It has been generally demonstrated that the formal education and training opportunities for farmers create a favourable attitude for the new practices as the training aid in enhancing skills and confidence to adopt new approaches and technologies (Caswell et al., 2001). The production of off-season vegetables was found to increase by over 60% when the farmers were provided practical training. Table 21.4 shows some vegetables based enterprises established in Nepal.

**Table 21.4.** List of some Nepalese enterprises based on vegetable in Nepal.

| Name of Enterprises | Products/Services |
|---|---|
| Hajuri Khadya Udhyog | Different vegetables-based pickles |
| KHETI | Agri-foodtech digital platform |
| Mitho Organic Food Pvt. Ltd. | Organic vegetables |
| Himalayan Grace Pvt. Ltd. | Green vegetables and beans |
| Hamro Bari Organic Pvt. Ltd. | Organic vegetables |
| Madanpur Agricultural Center Pvt. Ltd. | Vegetables and fruits |
| Bholung Organic Farm Pvt. Ltd | Vegetables |
| Duch Star Farming | Vegetables and fruits |
| Ganesh Healing Garden | Vegetables and herbs |
| Golden Harvest Farm | Vegetables and fruits |
| Innovative Agro Solution Pvt. Ltd. | Vegetables seed |
| Palpasa Organic Vegetables Pvt. Ltd. | Organic vegetables and fruits |
| Kareshabari Organic Farming | Organic vegetables |
| Suncity Organic Agriculture Farming Industries | Organic vegetables |
| Ming Organic Farm Pvt. Ltd. | Vegetables |
| Agriculture Himalayan Pvt. Ltd. | Vegetables |
| Green Mountain Farmhouse | Organic manure |
| Srijana Organic Farm | Vegetables |
| Mehadi Vegetable Organic Farmhouse | Organic vegetables |
| Bichour Organic Farm Pvt. Ltd. | Vegetables |

Source: (Department of Industry, 2020)

## Challenges and Opportunities

### *1. General Analysis of Enterprises Opportunities*

Enterprises that supply food items based on vegetables are emerging steadily. The present scenario of vegetable enterprise is mostly in the form of small to medium scale business. In addition, commercial scale of vegetable enterprise is developing slowly due to the high demand in urban areas. Before the production and access to market, several critical farm inputs and processing inputs are required. From land to technology, seed to fertiliser, and from storage and processing to transportation and marketing has an equal opportunity to develop as an enterprise.

Seed production and marketing of around 30 species of vegetable and their 72 varieties are carried out in Nepal (Pokhrel, 2010). The major vegetable crops of Nepal are cultivated within terai region (Acharya, 2018). The study has shown that as much as 88% profit can be obtained for farmers on supplying produce to wholesale vegetable market (Rekhi et al., 1990).

Figure 21.5 represents the schematic diagram of vegetable trade chain with production and processing inputs and the prospect enterprises.

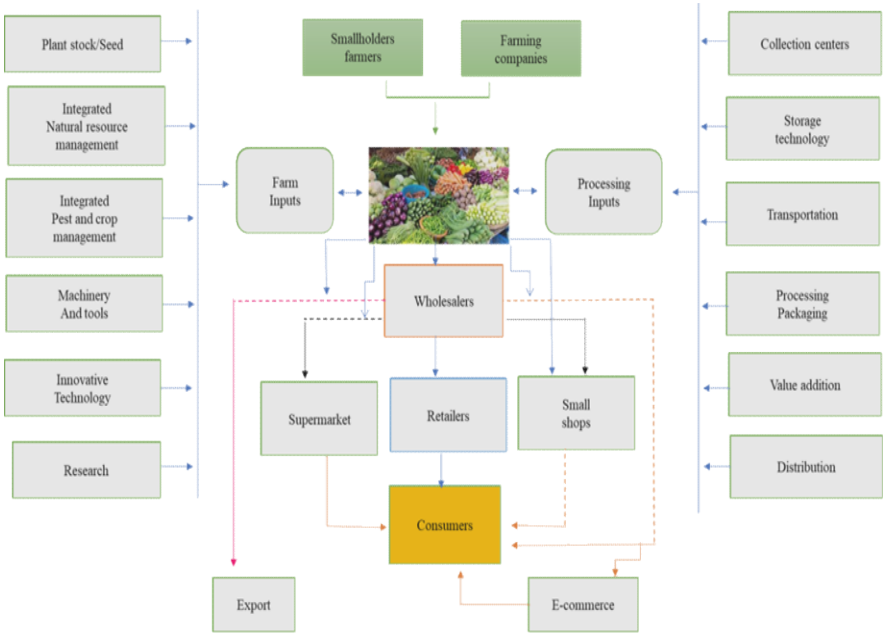



**Figure 21.5.** Schematic diagram showing the vegetable trade chain.

## *2. Pre-Harvest Issues*

### I. Seed/gene banks, seed distribution

Seed production is an important aspect in commercial vegetable production since the quality and nutrition of vegetables depend on their parent-line. Studies has shown that due to poor drying, management and storage practice, around 10–20% losses were observed in vegetable seeds from farm to market (Magar & Gauchan, 2016). Although, seed production is profitable, it also bears great risks since it requires proper storage, skilled manpower and longer production time (Magar & Gauchan, 2016). For instance, *Srijana* hybrid tomato seeds were first produced and registered in Nepal Agriculture Research Council (NARC). Later, the seeds were distributed to other private seed distributors or seed farmers, which became profitable in the long run. The dominant actor sharing in *Srijana* tomato seed production is private sector at around 85% of the total *Srijana* seed production, followed by non-governmental organization (10%), farmers group (3%) and governmental station/farm/centres (2%). Out of the total *Srijana* seeds produced, about 95% was consumed in domestic market, while 5% was exported to India (Maharjan, 2020). This indicates that there is a demand for good quality seeds in vegetable production. The seed production and distribution market are essential for a vegetable enterprise, which bears profit over time. It should also be noted that the farmers are dissatisfied with the profit observed due to the involvement of collection and selling companies that take higher share of the profit (Ward et al., 2020).

## II. Integrated natural resource management

The main natural resources required for farming are soil and water. Both possess the ability to hold nutrients that are required for the growth of plants. Soil not only holds the plants but also stores water and provides nourishments though nitrogen fixation. Hence, investigation on the quality of soil plays a vital role in cultivation of the type of vegetables.

Water is used during photosynthesis in green plants. So, the irrigation of land using water is essential for the growth of crops. The irrigation canals or channels are managed either by the farmers, local government bodies or both. Proper management of water bodies and channels is necessary as there might be overflow of water during monsoon and dry soil during summer.

Overall, the natural resource management is an important pre-requisite for agriculture and vegetable farming as it determines the type and quality of suitable vegetable production in the land.

## III. Pest control and fertilizers

While growing vegetables, it is equally necessary to provide the necessary nutrition and ward off any pests that might attack the vegetable plant. According to the policies in Nepal, chemical fertilizer and pesticides must be procured from international market as the private company are restricted to do so (Pokhrel, 2010). The government has brought subsidiaries to farmers in effect to make the chemicals affordable. However, there is a major problem like variable pricing of chemicals in different locations – the terai region has comparatively lower price of chemical fertilizers as compared to hilly region due to the additional charges incurred during transportation (Raut et al., 2011). Thus, a possible enterprise, that can survey, produce, and provide to the demand of chemical fertilizers and pesticides, is necessary.

## IV. Machinery, tools and innovative technology

At present, many types of machinery and tools are developed focusing on the production of vegetable crops. A ploughing machine has replaced the manual works of beating the soil. The seed plantation and water pipelines for irrigation have been motorized. After the harvest, cleaning also can be done using machinery. During the growth of vegetables, tools are required for weed and pest control. These tools and machinery are essential for enhancing the production capacity of farmers such that their investment and returns are balanced.

Innovative technologies like utilizing green-house effect, vertical farming, precision agriculture, block chain, robotic systems, artificial intelligence, etc. are being developed to modernize the agriculture sector. The combination of green-house farming and indoor vertical farming has resulted in the harvest of off-seasoned vegetables in a small area of land. Precision agriculture enables farmers to increase efficiency and manage costs by controlling every variable of crop farming such as moisture levels, pest stress, soil conditions and micro-climates. The use of block chain in selling of vegetable and vegetable products gives rise to trace ability of items, secured transactions and

transparency in businesses. The use of Unmanned Aerial Vehicles (UAVs) and remote sensing technology can monitor plant health, soil condition, temperature, humidity and many other necessary data. More information on the plants can be easily available for better production of vegetables. The young generation of farmers can easily adapt to the new technologies, whereas the traditional farmers might find difficulty in implementing them.

## *3. Post-Harvest Issues*

### I. Cleaning, packaging and processing

After the harvest of the vegetables, the vegetables need to be cleaned either with water to remove the dirt and soil, or special cleaners to remove any type of chemicals that might be present due to the use of pesticides and fertilizers. After cleaning, they might need to be weighed or sorted and then packaged into pouches with the tags for their weight, contents, manufacture, expiry date, etc. In case of processed or preserved vegetables, there will be an added step of drying, fermentation or frying of vegetables. While packaging of vegetables and their products, factors like handling, storage, moisture, shelf-life, etc. should be considered.

### II. Storage and transportation

The vegetable products should be stored properly before transportation from farms or industries to the market. In case of fresh produce, they should be stored in cool temperature during transport. For the same reason, fresh vegetables can only be transported for short distance and time before the degradation of its freshness. Transportation costs depend on the distance of the production or collection point to the marketplace, wages and cost of the fuel. The storage, collection and transportation can be done by intermediators as well as the farmers themselves (Raut et al., 2011).

### III. Marketing and market access

Market is the last step in the vegetable enterprise, so that the products can reach the interested consumers. The packaged products, especially the indigenous vegetable products, must be marketed for the possible consumers through proper communication channels via advertisements. These specialized products can only enter the markets if given a proper market access by local markets and groceries to fully benefit from these products. At present, the organic vegetables and their products are being marketed mainly by young entrepreneurs in online advertising medium and stores in urban areas. The farmlands near the urban areas have benefitted due to the ease of access to marketplaces in cities (Raut et al., 2011). If there is access to market for the vegetables and products produced in remote areas, it will be beneficial to the farmers in uplifting their economic status steadily.

## Conclusion

Research related to vegetables and nutrients can show the types of nutrients in vegetables, and presence of healing properties, harmful chemicals or microorganisms. The research on the seeds of vegetation is significant for producing a good quality vegetable with least infestation and high nutritional value. Furthermore, the research on the soil and water of

farms shows the nutrients available and infestation so that required fertilizers and pesticides are added as per the requirement. Similarly, research works on processed vegetables that can be developed as enterprises, are necessary. The research and incubation centres that help to transform entrepreneur's business ideas are needed to attract a young mind and are essential in our context, which eventually promote entrepreneurship, job creation and economic development. Research centres like Research Centre for Applied Science and Technology (RECAST), National Innovation Center (NIC), etc. are working and promoting such entrepreneurs' research idea collaboratively.

The wide geographical diversity of Nepal has enabled the production of large variety of vegetables which create new opportunities for small and middle sized enterprises. The following challenges should be addressed in order to turn the opportunities to sustainable businesses and hence support nation's aspiration of prosperity.

***Infrastructures*:** One of the major limitations in vegetable farming and marketing is the under-developed infrastructures of irrigation, transportation and communication. Water is the most important resource for vegetation after soil, and irrigation of fields during vegetation season is necessary. Thus, a good channel of irrigable water should be provided to the farmlands.

***Transportation*:** Transportation is essential for the transfer of vegetables from producers to market and purchase of utilities for farming. Transportation is particularly cumbersome during monsoon season as the roads and bridges are sometimes even washed away due to flooding. A robust network of road transport is thus another essential backbone for flourishing vegetable farming and marketing.

***Innovative approaches*:** A significant limitation in vegetable based enterprise is the traditional way of farming, and use of inefficient resources and methods of farming. There is a need to emphasize in introduction of technical knowledge, training, exposure, knowledge gap and extension service for the effective use of resources for vegetable production.

***Technology utilization*:** The introduction of advanced technologies for commercial farming is also crucial to cut down the price of vegetables in local market. This enables a competitive market with the products from foreign countries like India and China. If the local vegetables can be fresh, qualitative and inexpensive than imported ones, the consumers would certainly purchase local products.

**Abbreviations:** NARC = Nepal Agriculture Research Council; NIC = National Innovation Center; RECAST = Research Centre for Applied Science and Technology; WHO = World Health Organization.

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## Author's Biography



Asmita Khanal has obtained her Master's Degree in Biotechnology from Sikkim Manipal University of Health, Medical and Technological Sciences. She is currently a Researcher affiliated to Research Center for Applied Science and Technology (RECAST), and a part-time faculty member at the Department of Zoology, Amrit Science Campus (ASCOL). Her research is centered on food science and technology, functional food, encapsulation, nanotechnology, and probiotics.



Prasamsha Panta is a Ph. D. scholar at Central Department of Biotechnology, Tribhuvan University, Nepal. She is currently working on targeted drug delivery system for rheumatoid arthritis using nanomedicine approach. She has collected research experience on anticancer study, regenerative medicine and natural polymer mediated drug delivery systems.



Dr. Raksha Dangol has obtained Ph. D. from Nanyang Technological University, Singapore. She is currently working as a Post-Doctoral Research Fellow in collaboration with Research Centre for Applied Science and Technology (RECAST), Tribhuwan University (TU) and National Innovation Center (NIC). Her research work focuses on synthesis and characterization of nanomaterials for energy storage applications as well as the study and exploration of the traditional nanotechnologies in Nepal.



Prof. Dr. Rameshwar Adhikari studied chemistry in Tribhuvan University (TU), Kathmandu, and graduated from Martin Luther University Halle-Wittenberg, Germany. He is Fellow of International Union of Pure and Applied Chemistry (IUPAC) and Alexander von Humboldt Foundation, and recipient of POLYCHAR International Materials Science Prize, Technology Award of Nepal Academy of Science and Technology (NAST). He has published 140+ research papers in peer reviewed journals and 8 books. He has supervised 15 Ph. D. students (6 completed). He has served as visiting Professor at Rouen University (France), Mahatma Gandhi University (India), Kyoto Institute of Technology (Japan) and as Executive Director at RECAST/TU (2017-2020). His research areas and interest include electron microscopy and scanning probe techniques, nano- and biomedical materials, polymers, traditional knowledge and technologies.



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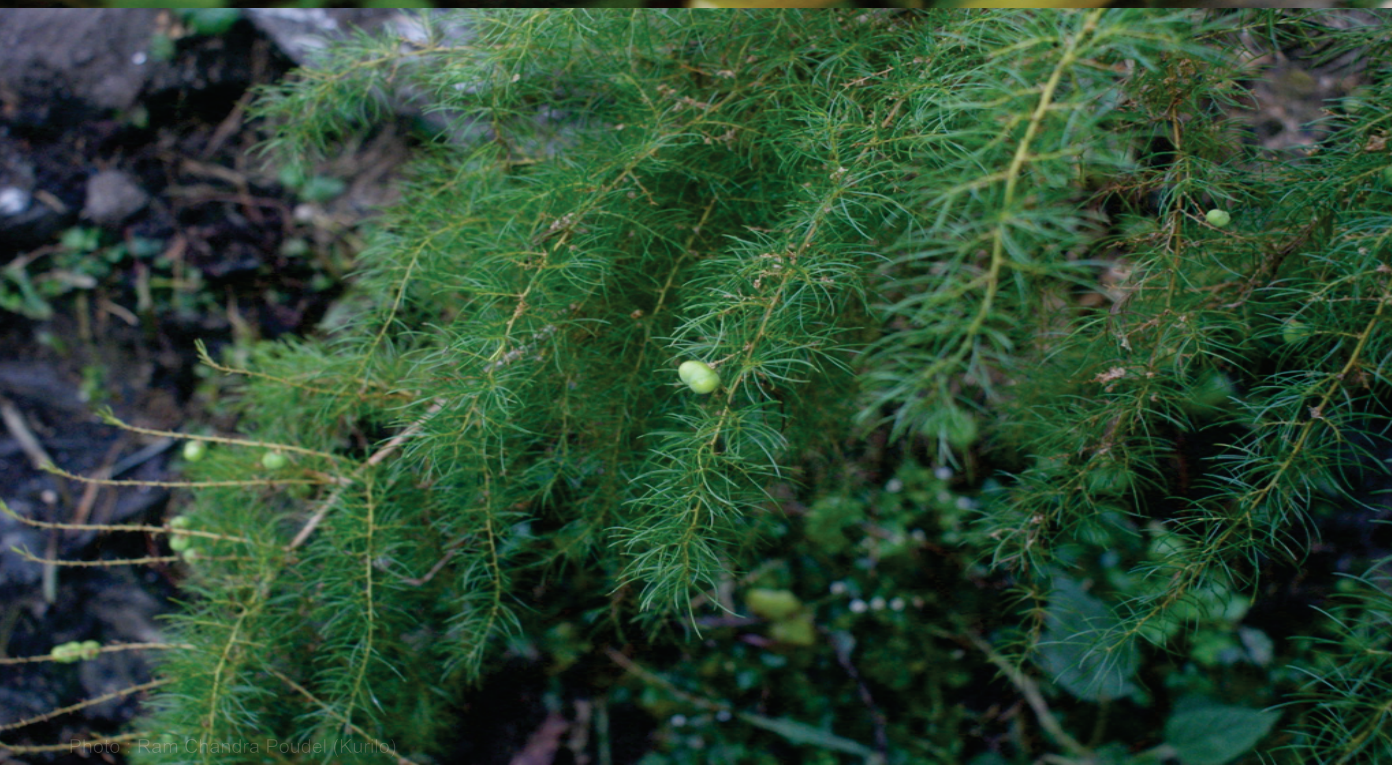


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