Morphological and Physicochemical Properties of Underexploited Leafy Vegetables of Meghalaya

Thesis

Submitted to

NAGALAND UNIVERSITY

In partial fulfillment for the Degree
of
DOCTOR OF PHILOSOPHY
in

HORTICULTURE
By

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2015

DEDICATED TO MY BELOVED FAMILY

DECLARATION

I, Juri Buragohain hereby declare that the subject matter of this Thesis is the record of work done by me, that the contents of this Thesis did not form the basis of the award of any previous Degree to me or to the best of my knowledge to anybody else, and that the Thesis has not been submitted by me for any research degree to any other Universities/Institute.

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ACKNOWLEDEGEMENT

First and foremost I take the privilege to express my deep sense of gratitude, indebtness and profound appreciation to my major advisor Dr. V. B. Singh, Professor, Department of Horticulture, SASRD, Nagaland University, Medziphema for his valuable guidance, keen interest, constructive criticism and innovative suggestions throughout the entire period of investigation and preparation of menuscript.

I express my gratitude to Dr. Bidyut C. Deka, Joint Director, ICAR Research Complex for NEH Region, Jharnapani for providing me with all the necessary facilities and for his valuable guidance, precious suggestions and academic help during the entire period of investigation.

I would like to extend my sincere gratitude and indebtness to Dr. G.C. Munda, PS and Ex-Head, Division of Agronomy, ICAR Research Complex for NEH Region, Umiam for his precious guidance and encouragement throughout my study.

I acknowledge my gratefulness to Dr. Akali Sema, Head, Department of Horticulture, SASRD, Nagaland University, Medziphema for her sincere help and generous advice during the period ofstudy.

I also sincerely thank all the respected teachers, scientists and office staffs of the Department of Horticulture, SASRD, Nagaland University, Medziphema, Division of Horticulture, Division of Crop Production (Agronomy) ICAR Research Complex for NEH Region for their spontaneous help and encouragement during the tenure of the investigation.

I expresses my gratefulness to Kepelino, Monti, Roy sir, Mishra sir, Laskar da, Victor mama, Theja, Naro, Rita, Haren da, Das da, Lyngdoh mam, Khraw , Juri ba, Lahar da, Arun bhaiya, Vandana di, Manoj, Homesh, Soso, Lapyn, Bidya, Sabita and Goutam for their encouragement, affectionate company and endless help.

Last, but not the least the I expresses my heartfelt thanks for the inspiration and moral support given by my parents and my brothers and sister and other family and well wishers in completion of the study.

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LIST OF ABBREVIATIONS

%	: Per cent
A.O.A.C	: Association of Official Analytical Chemists
AVRDC	: Asian Vegetable Research and Development Center
CITES	: The Convention on International Trade in Endangered Species of Wild Fauna and Flora
DRA	: Daily Required Allowance
DAS	: Days After Sowing
et al.	: Et Allii (And others)
Fig.	: Figure
g	: Gram
GLVs	: Green Leafy Vegetables
G	: Garo
i.e.	: Idest (That is)
IUCN	: International Union for the Conservation of Nature
J	: Jaintia
K	: Khasi
mg	: Miligram
NHB	: National Horticultural Board
NARS	: National Agricultural Research System
TDF	: Total Dietary Fibre
IDF	: Insoluble Dietary Fibre
SDF	: Soluble Dietary Fibre
WAE	: Weeks After Emergence
WHO	: World Health Organisation

Chapter I

INTRODUCTION

Leafy vegetables are highly beneficial for the maintenance of good health and so, are considered as essential foods. They are the storehouse of useful minerals and vitamins at the cheapest price and are considered as the corner stone of health care system due to the presence of many helpful phytochemicals in alleviating some serious diseases (Avakaya – Gongura, 2008). They serve as an indispensable constituent of human diet supplying the body with minerals, vitamins and certain hormone precursors, in addition to protein and energy (Akubugwo *et al*., 2007). They also provide roughage and have an important role in the balanced diet. They contain more nutrition per calorie than any other food. They maintain the alkaline reserve in the body and are excellent sources of vitamins and minerals, rich in fibre, extremely low in fat and carbohydrates and are rich sources of proteins. They play an important role in disease metabolism and slowing down of degenerative diseases because of their high carotene, ascorbic acid, micro and macro mineral contents. When taken with cereals like rice, leafy vegetables improve their protein quality by providing the essential amino acid that is not present in the cereals. Because of these reasons, vegetables hold an important position in well-balanced diets and most of the nutrient requirement of the body can be met by increasing the consumption of fresh vegetables. Thus, leafy vegetables can play a great role in tackling malnutrition among the people. In addition to meeting nutrient intake levels, better consumption of fruits and vegetables is associated with reduced risk of cardiovascular disease and stroke (Gillman *et al*., 1995). In the modern system of disease control, the leafy vegetables containing strong antioxidant properties or phytochemicals, neutralize the injurious effects of free radicals as scavengers and thus help in specific body functions in reducing risk of incidence of many diseases (Avakaya – Gongura, 2008). These phytochemicals do more than just fight disease they improve total health. Improved body detoxification, healthier hormone balance and better protection against oxidation are among the benefits of green leafy foods. Besides, they can be eaten at any stage of maturity that suits the growing season.

In recent years, tremendous attention has been paid to increasing vegetable production in India. As a result, the country has emerged as the second largest producer of vegetables next only to China with a production of 162.19 million tons from an area of 9.21 million hectares and an average productivity of 17.60 tons/hectare (NHB, 2013) and the area under vegetable crops in the state of Meghalaya was 40.50 thousand hectares; with a production of 403.40 thousand tones and productivity of 10 t/ha (NHB, 2013).

Meghalaya is one of the biodiversity rich states of India in terms of vegetation and flora. Varied altitude, topography, status of soil and climatic conditions favour high species richness. (Sawain *et al*., 2007). The people of Meghalaya consume different types of leafy vegetables which either grow in wild or are semi-cultivated. Wide geographical and climatic diversity provides a repository of many indigenous leafy vegetables which are regarded as valuable medicinal properties in the region. These leafy vegetables often grow naturally and are easier to grow and resistant to pest and diseases. These vegetables play an important role in the life of rural people in various angles; they make an important contribution to the diet and form an important part of food and nutritional security of tribal population in the state. In addition to their role in nutrition, these vegetables are also found to have medicinal properties. They contain different phytoceuticals like – terpenes, phytosterols, thiols, etc., which provide health benefits beyond their traditional and nutritional value (Das *et al*., 2004). The northeast as a whole is recognized as a primary centre of origin (Vavilov, 1926) of 152 species of cultivated plants, where several groups of tribals are still practising a life style which enables them to utilize plants as vegetables, medicinal and other economic uses without causing disturbance to the valuable species. The topography, altitude and rainfall pattern have made this region floristically rich and diverse. Tropical leafy vegetables such as *Amaranthus*, *Spinacia*, *Basella*, *Pisum*, *Raphanus*, *Corchorus*, *Cucurbita*, *Lagenaria*, *Melia*, *Lathyrus*, *Chenopodium*, *Enhydra*, *Moringa*, *Nymphaea*, *Ipomoea* and ferns like *Diplazium*, *Pteridium* are dominantly used in plains of the region, while temperate ones like *Brassica*, *Colocasia*, *Hibiscus*, *Sechium*, *Fagopyrum*, *Tetragonia*, *Tetrastigma*, *Lactuca*, *Sauropus*, *Houttuynia*, *Corydalis*, *Phytolacca*, *Clerodendron*, *Eryngium* and *Sonchus* are commonly used in the region (Hore, 2004). Most of the cultivated species are grown during winter in plains; while in the hills major species grow luxuriantly in monsoon season. Species of *Amaranthus*, *Raphnus*, *Brassica*, *Spinacia*, *Basella*, *Cucurbita*, *Pisum* are preferred over others in plains, while in the hills *Brassica juncea* var. *cuneifolia* is most sought after vegetable especially in Meghalaya, Nagaland, Arunachal Pradesh and Mizoram states. The leaves of *Hibiscus subdariffa* are a delicacy to the Garo tribes. Similarly, the tender twigs of *Clerodendron colebrookianum* are often used by the Mizos. The leaves of *Houttuynia*, *Sechium*, *Tetragonia* and *Corydalis*, are used by the Khasi tribe. The hill people of Meghalaya and Arunachal Pradesh relish the apical leaves of *Sauropus androgynus*. Both the plain and hil tribes equally relish leaves of *Mentha*, *Coriandrum* and *Eryngium* as raw, thrashed or cooked conditions. Some important leafy vegetables found and consumed in Meghalaya include *Houttuynia cordata* (Thunb.), *Centella asiatica* (L.), *Colocasia esculenta* (L.), *Commelina benghalensis* (L.), *Eryngium foetidium* (L.), *Amaranthus viridis* (L.), *Diplazium esculentum* (Retz.) Sw., *Brassica juncea* (L.) etc. Many of these vegetables are cooked as traditional delicacies. For instance, the fresh immature fronds of *Diplazium esculentum* are wiped with a cloth to remove the red petiolar hairs and boiled. Boiled fronds are cut and fried in cooking oil with spices such as seeds of *Cleome viscosa* L. (Misra *et al*., 2008). The tender shoot of *Fagopyrum cymosum* are cooked and eaten as vegetables and the young leaves are cooked with dry fish and eaten by local people (Kayang, 2007).

Relished as raw as well as cooked, these underexploited vegetables have vast potential outside the region also. However, research and development regarding these vegetables have been neglected. Many valuable species are also on the verge of extinction. Given the amazing health benefits of these foods, this is unfortunate. Since there is a search for novel, high quality, functional and inexpensive foods among the consumers in the global market, edible underexploited plants as rich bioresource of the region can supplement such need in the diet. The study of these commonly consumed leafy vegetables is important not only to identify the potential sources which could be utilized as alternative food but also to select promising types for domestication. So these species need to be conserved and emphasis should be given on growing these species on a large scale to be able to be supplied to other parts of the country. Large-scale production of these indigenous vegetables would also help in reducing the seasonal fluctuations in vegetable production. Currently, nearly 25% of the horticultural produce is lost due to poor post-harvest management. With improved harvesting facilities, better packaging and storage, these losses could be greatly minimized. Hence, the present study is an endeavor to identify and explore some of the underexploited leafy vegetables of Meghalaya with the following objectives:

1. Collection of different underexploited leafy vegetables of Meghalaya and their necessary introduction in the Experimental field.
2. Evaluation of morphological and physicochemical characters of the collected vegetables.
3. Standardization of maturity indices of the collected vegetables.

Chapter II

REVIEW OF LITERATURE

Leafy vegetables are those plant species of which the leafy parts, including leaves, young, succulent stems etc., are used as vegetables. Leafy vegetables have been used through history to date (Vorster *et al.,* 2005). Of late, leafy vegetables have received considerable attention as a simple and economical means of providing vitamins and minerals and are classified as protective foods. In the state of Meghalaya of the Northeastern region of India, a number of underexploited as well as cultivated leafy vegetables are consumed with relish by the local people and even some of them are considered as great delicacies.

Since no detailed study has been done on these plants, hence, a brief review of research work related to the present investigation is presented in this chapter.

2.1 Underexploited Leafy Vegetables

2.1.1 World Scenario

Abasse *et al.* (2007) carried out a survey to assess the importance of indigenous leafy vegetables in both the diets and the economy of the rural sector of Niger and to identify constraints and challenges leading to identification of research priorities. They identified twenty two plant species used as leafy vegetables and selected the five most important indigenous leafy vegetables in Niger which were: *Moringa oleifera*, *Corchorus* spp., *Senna obtusifolia*, *Hibiscus sabdariffa,* and *Adansonia digitata*.

An experiment was conducted (Knisley and Nyomora, 2007) to analyze the role of indigenous leafy greens in the diet and agriculture of the Sandawe, a former hunting and gathering ethnic group located in Kondoa District, Tanzania, that began transitioning to an agricultural subsistence base approximately 100 years ago. Availability and dietary importance of indigenous vegetables were determined by surveying transects through areas of human activity, identifying and weighing harvested greens, observing the preparation of greens, and compiling food logs. This research illustrated the importance of quantitative studies of indigenous leafy vegetables as well as the role of cultural norms and individual preference as they relate to the maintenance of biodiversity.

Dogan *et al*. (2004) surveyed 121 wild edible plants used as food in Anatolia. The results of this study show that the plants may be boiled, fried in fat, and eaten raw or as rolled vegetables. They may also be consumed as pickles, fruits, sweets and spices, and drunk as cold and hot drinks. Out of the studied vegetables, thirty species (8 genera) were identified as belonging to the Lamiaceae family, 15 species (15 genera) belong to the Asteraceae family, 13 species (5 genera) belong to the Rosaceae family, 8 species (7 genera) belong to the Brassicaceae family, 6 species (3 genera) belong to the Orchidaceae family and 5 species (5 genera) belong to the Apiaceae family.

Allemann (2007) conducted an experiment to integrate three indigenous vegetables, i.e., amaranths, cucurbits and *Plectranthus esculentus*, into the farming system in the Mamabolo community in Limpopo province of South Africa. It was found that although the community knew most of the species, some of them had been "lost", because of lack of knowledge about their use among the young generation. The project's procedures were presented, together with the problems encountered and lessons learned. It was reported that the established model could be followed for introducing new crops at the community level.

An investigation was carried out to document the contribution of traditional food crops to food security in Nhema communal area, Midlands Province, Zimbabwe (Maroyi, 2012). A total of 23 plant species were identified as important traditional food crops in Nhema communal area. Traditional food crops in Nhema communal area were mainly used as leafy vegetables (40%), followed by edible seeds (20%), cereals (17%), edible fruits (13%), edible stems (7%) and edible tubers (3%).

The contribution of wild and semi-wild food plants to overall household diet was assessed in Mutunda and Kiryandongo, sub-counties of Bunyoro-Kitara Kingdom, Uganda (Agea *et al*., 2011). About 62 wild and semi-wild food plants belonging to 31 botanical families were reported as commonly being consumed in the study area. Their consumption comprised a major part of the dietary intake of the poor households. Many are almost available throughout the year for gathering with exception of a few species that are gathered mainly in the rainy or dry seasons.

Dansi *et al*. (2008) reported 187 plant species belonging to 141 genera and 52 families which were used as traditional leafy vegetables in agro-ecological zones of Benin. Among these, 47 (25.13%) were cultivated and 140 (74.87%) were gathered from the wild. Herbs (64.78%) were the most numerous followed by shrubs (19.78%) and trees (15.50%). Of the species reported, 18 of national importance were found among which *Solanum macrocarpon*, *Corchorus olitorius*, *Amaranthus cruentus* and *Gymnanthemum amygdalinum* ranked first. The perceived nutritional and medicinal (curative, regulative, and stimulative) properties of the species as well as their cultural significance were documented. Some traditional leafy vegetables were known and consumed by all or many ethnic groups while many others were simply ethnospecific or used by only a few people. They concluded that given the large quantity of evidence of the importance of the traditional leafy vegetables, there should be a systematic effort to improve their understanding and their uses to reduce if not alleviate rural poverty and malnutrition in Benin.

In recognition of the potential of indigenous vegetables to contribute towards poverty and malnutrition alleviation and the diversification of the agricultural environment, AVRDC - The World Vegetable Center has undertaken germplasm exploration, collecting, regeneration, characterization and preservation of germplasm of vegetables indigenous to the Southeast Asian region for more than a decade. The AVRDC has assembled more than 55,000 accessions of seed, leafy and fruit vegetable germplasm which includes about 12,000 accessions of about 200 species originated from nine countries in Southeast Asia. Exploration and germplasm collection were undertaken in Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam. Species and site priorities were based on a consultative process participated in by representatives from the national agricultural research system (NARS). Characterization was done using a standard set of descriptors. Accessions with potential for promotion were identified. The importance of linking conservation with utilization was recognized and activities to promote utilization among farmers, traders, women, children and consumers in general were undertaken. In situ conservation in farmer's fields was done through mainstreaming conservation of agrobiodiversity in production systems, school gardens, and women training in home gardening schemes, conservation, seed production and nutrition. In-country training and special purpose training at its headquarters were provided by AVRDC to staff of NARS. AVRDC continues to be committed to the assembly and preservation of a genetically diverse vegetable germplasm collection including vegetables indigenous to South Asia, Southeast Asia, Africa and other regions where such germplasm are endangered from genetic erosion and where they can play an important role in diversification of production systems and improved nutrition (Engle and Faustino, 2007).

Böhme and Pinker, 2007, gave an overview about indigenous leafy vegetables, solanaceous, cucurbits and legumes with high nutritional value and economical potential in Southeast Asia particularly Vietnam. They collected information about indigenous vegetables in these regions and made attempts to select and cultivate few of these species. Based on the investigations they started to develop a database providing information about the native vegetables used in Southeast Asia. They found that there is a lack in evaluation and breeding of different vegetable genotypes leading to a lack of species and cultivars for intensive and sustainable production; and concluded that introducing indigenous vegetables in production systems could also reduce the high risk for genetic erosion in the actual high diversity and could use the genetic potential of the landraces.

Survey and documentation of the diversity of the indigenous semi-temperate vegetables in the Cordillera region in Philippines were undertaken through a participatory approach with the local communities (Lirio *et al*., 2007). Forty-seven plants species belonging to 21 families were reported to be eaten as vegetables, utilizing mostly the tops or young shoots. Of the 21 families, a greater number (19.15%) belonged to Asteraceae, followed by Solanaceae (10.64%), Amaranthaceae (8.51%), Brassicaceae (6.38%) and Passifloraceae (6.38%). Other than use as food, 51% of the indigenous vegetables surveyed have medicinal values as well.

Rahim *et al.* (2007) reported different aspects of research results of different organizations and future prospects of growing more indigenous vegetables in the hunger prone (Monga) areas of Bangladesh by adjusting existing cropping pattern and homestead planting. Indigenous vegetables like Moringa, sword bean, country bean (*Dolichos* spp.), *Luffa*, aroids (*Colocasia*, *Amorphophallus*, *Alocasia*, *Xanthosoma*), cucurbits, yam (*Dioscorea*), leafy vegetables etc. can easily be grown in the homestead and in the crop field which supplemented the foods and employment opportunity to overcome Monga and to reduce poverty.

In a survey carried out in the Xiangxi region of western Hunan province, China, 335 taxa belonging to 87 families and 119 genera were found to be utilised as wild vegetables (Zou *et al.* 2010). Wild vegetables as the mainstay of human diet and Chinese traditional medicines have played an important role in the daily life and income of local ethnic groups for centuries. They examined candidate species for their prevalence and their potential to offer returns, for example in cereal production and tourism, and indicate horticultural management and processing technologies which may exploit wild vegetable availability.

The role of indigenous vegetables in national economy and poverty alleviation in Bangladesh was studied by Rahim *et al*. (2007). They found that indigenous vegetables can play an important role in alleviating the poor nutritional status of the people in Bangladesh. These vegetables offer scope for year-round production in the homesteads and hilly region of the country and it can create a number of job opportunities in the rural and suburban areas and in the complementary fields of business that arise from productions, such as marketing, processing and transportation.

2.1.2 Indian Scenario

The importance and use of native food plants used in diet by the tribes have been documented by Singh and Arora (1978), Arora and Nayar (1984), Haridasan *et al*. (1990).

Chadha, and Patel (2007) reported about the prospects of indigenous perennial plants as source of vegetables. They grouped the indigenous perennial plants that are used for vegetables into three broad categories: fruits used as vegetables, plant parts used as vegetables and traditional perennial vegetables. The important perennial plants whose plant parts are predominantly used for vegetable purposes are *Bambusa* spp., *Moringa oleifera*, *Murraya koenigi*, *Sauropus androgynus* and *Sesbania gradiflora*. Indigenous perennial plants that are traditionally cultivated only for vegetable purposes are *Basella alba*, *Coccinia indica*/*C. cordifolia*, *Momordica* *cochinchinensis*, *M. dioica* and *Trichosanthes dioica*. Even though the current exploitation of many plants by the rural and tribal populations is restricted in the areas of their origin, some of them have shown equal acceptability among the urban population. Many of the above plants are known for high nutritional and medicinal values.

According to Arunachalam *et al*. (2007) many of the traditional leaf vegetables remain underutilized in India. They reported the market potential, season of availability, common, vernacular and botanical name of 42 species of plants belonging to 28 families. These were either grown or gathered from wild growth from a range of habits and habitats and commonly marketed and used as leaf, tender shoot or flower vegetable in Jalpaiguri District of West Bengal.

An investigation was conducted in the temperate region of Kashmir valley to document the basics information of the lesser known food plants consumed by the local communities and to plan future possibilities for popularizing these valuable herbs (Akbar *et al.*, 2011). Some important plant species belonging to different families used by the inhabitants of the district for culinary purpose were reported. Apart from fresh use, the people of the area collect these herbs and dry them for use in the off season when there is non availability of vegetables due to severe and snowy winter. The local communities were found to be expert collectors of these herbs and used them for common culinary and ethnic medicinal purposes. The reported plants were found to possess enough potential if utilized and explored up to their maximum potential through specific breeding and laboratory techniques to meet the present nutritional needs and secure the future demands.

In view of changing of food habits of local communities of Uttarakhand Himalaya, a study was conducted by Mehta *et al.* (2010) to document the native plan genetic resources of food importance and traditional recipes. Both cultivated and wild edible plant species were documented in this study. Apart from the cultivated crop plant species, there were a large number of wild plant species identified by local inhabitants, which provided them vegetables and fruits round the year. They were not only helpful in supporting the livelihood, but addressed the economic needs by selling them in the local market. A total of 27 wild edible vegetables including leafy vegetables were documented in the Uttarakhand hills. These vegetables were used to prepare very special cuisines and were famous for their taste and nutritious values.

Kalia *et al*. (2007) reported different locally adapted indigenous vegetables in Himachal Pradesh which were consumed, traditionally based on age old indigenous knowledge of their nutritive and medicinal value, in different areas, which included leafy vegetables (*Amaranth*, *Chenopodium*, *Colocasia*, curry leaves, coriander, fenugreek, radish, zimmu, *Rumex*, *Nasturtium*, *Fagopyrum* etc.), flower buds and fruits (*Bauhinia*) (Kachnar), *Cordia* (lasora), chayote (launku) etc.), fern (*Diplazium*) and legumes (broad bean). They reported that these vegetables were rich in Beta-carotene, quality protein, calcium, iron, phosphorus, vitamin A, C and dietary fibre. Thus, they played a great role in tackling malnutrition. In the recent years, the local people of remote areas have started producing vegetables adapted to their climate and supplying to a larger section of society in a bid to fight poverty and hunger.

In remote rural settlements where vegetable cultivation is not practiced and market supplies are not organized, local inhabitants depend on indigenous vegetables, both cultivated in kitchen gardens and wild, for enriching the diversity of food. Knowledge of such foods is part of traditional knowledge which is largely transmitted through participation of individuals of households. Misra *et al.* (2008) surveyed a total of 123 households in six villages of Nanda Devi Biosphere Reserve buffer zone using a schedule to assess the knowledge, availability and consumption pattern of wild leafy vegetables. The diversity of wild leafy vegetables being used by the local inhabitants was found to consist of 21 species belonging to 14 genera and 11 families, which was far less than that being reported to be used by the communities from Western Ghats in India and some parts of Africa. Irrespective of social or economic status all households in the study villages had the knowledge and used wild leafy vegetables. The availability and use period varied for the different species. The study indicated that the knowledge is eroding due to changing social values and non participation of younger generation in collection and processing of such wild leafy vegetables.

An investigation was conducted to collect, identify and document information on the wild food plants traditionally used by the tribes in the Parambikulam Wildlife Sanctuary in Palakkad district of Kerala (Yesodharan and Sujana, 2007). They reported that eighty three species were used by the tribes as vegetables, wild fruits, beverages or in other preparations. Wild vegetables formed the largest group which included roots, tubers, young leaves and buds, inflorescence, unripe/ripe fruits and seeds. Out of 83 species, 82 belonged to Angiosperms (63 dicot and 19 monocot) and one species belonged to Gymnosperm. Among them 30 species are used as leafy vegetables, 31 species for fruits, 16 species for seeds and 10 species as food in the form of rhizomes/tubers/corms and 6 plants as food from stem/shoot. *Amaranthus spinosus* Linn., *Centella asiatica* (Linn.)Urban, *Euphorbia hirta* Linn. *Oxalis corniculata* Linn. and *Mollugo pentaphylla* Linn. were used by the tribals more extensively.

A documentation of plant species in the *Barind* region of Malda district of Paschimbanga which grow in wild, consumed as traditional and leafy vegetables by rural and tribal people, their mode of use, parts used and their price in the rural markets was done by Biswas and Das (2011). They identified 45 wild plant species belonging to 39 genera and 28 families used as leafy vegetables and consumed by rural and tribal people. It was also recorded from the survey in local village markets that of these 22 species were sold there in different seasons. Good number plants such as *Argemone mexicana*, *Azadirachta indica, Centella asiatica, Boerhavia diffusa, Baccopa monnieri*, *Enydra fluctuans, Hygrophila auriculata*, *Vitex negundo, Cissus quadrangularis, Ipomoea aquatica*, *Moringa oleifera, Paederia foetida* etc. were used as medicines too. Leaves of different stages of maturity, young shoot and petioles were used as vegetable. Many of the recorded leafy vegetables produced tasty food though all of these plants were collected only from their wild habitat. They emphasized the need to bring some of these plants under research and development and improve their acceptability among the common urban people which will increase the diversity in the vegetable market and the poor people can cultivate those plants easily and can earn their livelihood.

An investigation highlighting the plants used as leafy vegetable and wild fruits among the different local and tribal peoples in the remote areas of Maldah district in West Bengal was carried out by Chowdhury and Mukherjee (2012). A total of 84 Angiosperms belonging to 71 genera representing 46 families and 2 species of Pteridophytes belonging to 2 genera representing 2 families were enlisted from the district. Different part of those species like fresh green leaves, rhizomes, unripe fruits, young pseudo stem, petals, inflorescence, young twig, seeds, petiole etc were used as vegetable. Observation showed that species like *Aegle marmelos* (L.) Corr., *Amaranthus spinosus* L., *Boerhabia diffusa* L., *Enydra fluctuans* Lour, *Hygrophila auriculata* (Schumacher) Heine, *Leucas Indica* (L.) R. Br. *ex* Vatke, *Marsilea minuta* ,*Diplezium esculentum* (Retz.) Sw., *Ipomoea aquatica* Fossk., *Musa bulbisiana* Colla., *Sesbania grandiflora* (L.) Poir, *Paederia foetida* L. were consumed throughout the year and were very popular as leafy vegetable, fruits and flowers among the local and ethnic communities. Leaves and tender shoots were the most dominant plants part. Based on mode of utilization total 84 enlisted species were differentiated and it was found that different parts of 73.81 % plants were used as vegetables, followed by fruit or seeds (19.05 %), pickle (3.57 %), condiment (1.19 %) and fermented milky latex as alcohol (2.38 %) by ethnic and local villagers.

2.1.3 North Eastern Region of India

Arora (1981) listed more than 300 plant species out of the native flora of the region, which were used as edible ones. Out of these, more than 25 species provided tuberous rhizomes which were eaten either raw or boiled and other 50 species provided leaves and tender shoots which were used as vegetables, others were edible fruits. According to Peter and Devadas (1989), there were about 700 species belonging to 125 plant families, which contributed as leafy vegetables. 78 species were used in this region as leafy vegetables and out of these, 45 species occurred in wild habitat.

Kumar (2003) collected information on many lesser known leafy and other edible plants used by local tribal communities of northeast India. Most of these plants were collected by the locals from the wild and are lesser known outside the region. These plants are excellent candidates for developing valuable functional foods, nutraceuticals or providing valuable chemicals or genes of economic or other interests.

Hore (2004) described about the cultivated and wild leafy vegetables of North East India, which have rich food value and observed that there was genetic erosion among these leafy vegetables as the indigenous vegetables are replaced by the introduced species and there has been meager effort on the collection and conservation of leafy vegetables particularly in this region. He emphasized that attention should be given seriously on such plants having nutritive value, which can broaden the avenue for possible introduction and utilization extensively.

Sureja *et al*., 2007 described the details of botanical identity, plant parts used and mode of use of the underexploited annual and perennial vegetables of the Adi tribe of Arunachal Pradesh and outlined the scope for their promotion and research. The Adi tribe used plants like *Diplazium esculentum*, *Solanum torvum*, *S. spirale*, *S. indicum*, *Spilanthes oleracea*, *Amaranthus spinosus*, *A. tricolor*, *Brassica juncea* var. *rugosa*, *Chenopodium album*, *Eryngium foetidum*, *Fagopyrum esculentum*, *Xanthoxylum rhetsa*, *X. nitidum*, *Gynura crepidioides*, *Pouzolzia benettiana*, *Mormordica cochinchinensis*, *Bauhinia variegata*, *Manihot esculenta*, *Ipomoea batatas*, *Clerodendrum colebrookianum*, *Murraya koenigii*, *Houttuynia cordata*, *Urtica parviflora*, etc. as vegetables. Some of these vegetables were used to cure diseases like high blood pressure, diabetes, urinary and stomach disorders, bronchitis, diarrhoea, etc. They are sold in the local market and fetched good price.

Status and potential of wild edible plants of Arunachal Pradesh was studied by Angami *et al.* (2006). They observed that the indigenous communities continuously included wild edibles to their daily food intake and sales from the surplus added to their income and emphasized on the sustainable harvesting of wild edible plants which would help enhance and maintain the region's biodiversity. In the study, about 118 wild edible plant species were recorded. *Allium reballum*, *Alternanthera sessilis*, *Amaranthus viridis*, *Begonia roxburghii*, *Centella asiatica*, *Chenopodium album*, *Clerodendrum colebrookianum*, *Colocasia esculenta*, *Houttuynia cordata*, *Mentha arvensis*, *Oxalis corniculata*, *Paederia scandens*, *Passiflora edules*, *Plantago major*, *Polygonum alatum* etc were some of the plants used as leafy vegetables.

Wild edibles and other useful plants from the Sikkim Himalaya were reported by Sundriyal *et al*. (1998). Of the total 175 wild plants used for food, 64% were edible as fruits/seeds, 18% leafy vegetables and 10% flowers and flower buds. Other plants were used as medicines, fermented food and beverages, dyes, oil, and for household goods. Occurrence and distribution of some important taxa were presented. The need for *ex situ* (popularizing them in agro-forestry systems) and *in situ* (in natural habitats) conservation of these plants was emphasized.

Sundriyal *et al*. (2004), also described the botanical richness, elevational distribution and dietary use of the edible wild plant resources from the Sikkim Himalaya (Eastern Himalaya), many with promising potential. A total of 190 wild plant species were screened from the Sikkim Himalaya, belonging to 143 genera and 78 families and accounting for nearly 15% of total edible wild plants resources of India. Of the total, 65% were edible for their fruits, 22% for leaves/shoots, 7% for flowers and 3% for roots/ rhizomes. Nearly 91 wild edible species were recorded from low-hills, 70 from mid-hills and 28 species from high-hill areas. Within Sikkim state, the North and East districts represented maximum diversity of edible wild plants due to the wilderness and inaccessibility to most of the habitats. An average rural family annually consumed nearly 8 types of edible wild plants, and a few species provided over five meals in a season. Selected plants also formed a source of earning to a few families that sold them in local markets. It was suggested that the high diversity of edible plants needed to be conserved for future use. Some species may be grown in traditional agro-forestry systems and on marginal lands of otherwise low agricultural value. Such measures may help protect wild plant resources in their natural habitats.

Singh *et al*. (2012) discussed the diversity and problems relating to conservation and enhancement of underutilized vegetable crop species in North-East India with special reference to Manipur. The indigenous leafy vegetables used in the region were *Chenopodium album*, *Ipomea reptans*, *Amaranthus viridis*, *A. lividus*, *A. spinosus*, *Basella rubra, B. Alba*, *Rumex vesicarius*, *Brassica juncea*, *Malva verticillata* etc. They emphasized the need for identifying the regional demand for vegetable crops, underutilized species for collection, particularly, for high yield, quality, resistance to diseases and pests, tolerance to frost and acidity.

A survey of wild edible plants used by the Zou tribe was undertaken by Gangte *et al.* (2013) in Manipur. It was revealed that 84 wild edible plants belonging to 36 families were being used by the Zou's. Out of these 84 species, 70 species were used as vegetables and food, 13 species were used as spices and condiments and 1 species *Dioscorea sativa* was used as famine food. The most common part of the plant consumed was leaves with 29 species (34.5%), tender shoots with 18 species (21.4%), fruits with 14 species (16.6%), rhizome, corm and tuber with 9 species (10.7%), inflorescence with 8 species (9.5%), pods with 7 species (8.3%), seeds with

6 species (7.14%), petioles with 3 species (3.5%) and fruit cover (rind), bark, frond and root with 1 species (1.19%) each. The study also found that maximum of the plant species belonged to Cucurbitaceae and Arecaceae with 7 species each, Papilionaceae and Solanaceae with 6 species each, Paoceae with 5 species, Mimosaceae with 4 species, Zingiberaceae, Rutaceae, Lamiaceae and Dioscoreaceae with 3 species each. Theaceae, Convolvulaceae, Liliaceae, Amarantheceae, Asteraceae, Malvaceae, Lauraceae, Moraceae, Musaceae and Euphorbiacea with 2 species each.

Patiri and Borah (2007) reported 350 species of Angiosperms belonging 215 Genera under 95 Families; 2 species of Gymnoperms and 12 Pteridophytes as wild edible plants of Assam. Families were arranged as per Bentham and Hooker's system with recent modifications adopted by BSI. Valid botanical names were followed by vernacular names in Assamese and other local languages. A brief description of habit and habitat of the plants were given, mentioning flowering and fruiting seasons with a note on their uses as food by natives.

Brahmaputra valley of Assam is very unique in its plant bioresources and is inhabited by different communities. Besides the cultivated crops, they are also dependent on various wild plants, which are used for consumption as well as in ethnomedicine. Barua *et al.* (2007) reported 38 wild edible plants of Majuli Island and Darrang district. Most of these plants were found to be used for culinary purposes as well as in medicines. The culinary preparations were delicacies and some of them were specially prepared during the major festivals. The availability of these plant or their parts coincided with the onset of rainy season, i.e. from March to September.

Kar and Borthakur (2008) documented 57 species of wild plants used as vegetable by the Karbi tribe of Karbi- Anglong district, Assam, out of which 21 were leafy vegetables. The scientific names of the plants, method of use demand and form of use of these vegetables were included. They also highlighted the medicinal value, market price and shelf-life of the vegetables after harvest. The conservation of the indigenous wealth through cultivation and further follow up investigation on these plants for chemical analysis was also emphasized.

The ethno botany with particular reference to biodiversity conservation of the important wild edible, medicinal and threatened plant species in Assam was reported by Sarma *et al.* (2010)**.** They found that the people living in remote/forest area still depended upon to a great extent on the indigenous system of medicine/cultivation. Out of 3895 plant species nearly 7.34% were used as wild vegetables, fruits and ethno--medicines. In over all, 286 edible wild plant species estimated belong to 93 families and 192 genera were hitherto unknown or less known to the world. Of these, 150 species were reported to be used in traditional system of medicine. The estimates revealed that as many as 27 species were in the list of red data book, CITES and IUCN red list threat categories due to over exploitations and these plants need a strong conservation and protection management.

Pegu *et al.* (2013) reported the list of wild edible plants in Poba reserved forest in Dhemaji district of Assam and their importance to local communities. A total of 122 wild edible plants belonging to 89 genera under 52 families and 2 varieties were reported. The report also included two fern species namely *Cyclosorus extensa* and *Diplazium esculentum*. Twenty six species were found to have single use (i.e., dietary use) while other species had more than one uses such as medicine, animal feed and source of cash income and livelihoods.

The use of wild vegetable by the local indigenous people living in the fringe areas of Chirang Reserve Forest was reported by Dutta (2012). He found that 98 plant species belonging to 52 families and 83 genera were used as vegetables by these communities. Out of the plant documented 93 species belonged to angiosperm, 1 gymnosperm and other 4 species were pteridophytes. Of the angiosperms 19 species belonged to monocotyledons and 74 species belonged to dicotyledons. Majority of the vegetable were eaten fresh. Out of the documented plant species, leaves or young shoot of 58 species, fruits of 7, flowers of 6, seeds of 5 and roots of 3 species were used as vegetables. Most of the vegetables used were collected from Chirang Reserve Forest. These vegetables were either consumed raw or cooked and helped to compensate the day to day calorie requirement of the people.

2.1.4 Meghalaya

Documentation of tribal knowledge on wild edible plants of Meghalaya was carried out by Kayang (2007). He discussed the various aspects of the wild plants used by Khasi, Jaintia and Garo tribes of Meghalaya as these plants resources are genetically important for future agricultural research. The present study recorded 110 wild growing plants, which were eaten whole or in part by the local people. The plant parts, viz. roots, tubers, stems, leaves, flowers, fruits and seeds were used. Some important plants used as vegetables by the local people included *Adhatoda vasica* Ness, *Centella asiatica* Linn., *Eryngium foetidum* Linn., *Fagopyrum dibotrys* D. Don., *Houttuynia cordata* Thunb., *Oxalis corniculata* Linn., *Rumex nepalensis* Spr., and *Diplazium esculentum* (Retz.) Sw. etc.

The people of Meghalaya are very close to nature, and forests are one of the important natural resources in the state. The tribes of the state largely depend on forests for their livelihood and have acquired a vast knowledge about plant wealth and utilization of forest products. Sawian *et al.* (2007) reported about the traditional knowledge about wild edible plants used by tribal people of Meghalaya. During the investigation, a total of 249 species of wild belonging to 153 genera and 82 families were reported. Among them 129 were trees, 54 shrubs, 37 herbs and 29 climbers. The majority of the species were fruit bearing (125). Some edible plants had great economic value and were highly linked with socio-economic development of tribal communities of the state. A few such species may be introduced in agro-forestry systems, which could be potential genetic resources for tree breeding programme in other areas of the country and also to provide edible plant resources to the communities in addition to creating photosynthetic pool to counter environmental degradation.

Tribals in Meghalaya not only cultivate variety of crops but also domesticate quite a lot of wild plant species in their courtyard, orchards, kitchen garden, flower garden and sedentary agricultural fields. A study was carried out to explore the wild plant species domesticated by Khasis, Garos and Jaintias of Meghalaya (Chetri, 2006). A total number of 62 plant species belonging to 59 genera under 44 families were found to be ethnically domesticated in Khasi, Garo and Jaintia hills of Meghalaya for different utilitarian purposes in day to day life of the tribal people. *Allium hookeri* Thwaites, *Chenopodium album* L., *Eryngium foetidum* L., *Houttunyia cordata* Thunb., *Mentha arvensis* L., *Nasturtium officinale* Br. etc were some important leafy vegetables domesticated by the local people.

In south Meghalaya, farmers maintain a variety of economically important plant species in arecanut agroforestry systems. Tynsong and Tiwari (2010) investigated plant species composition of arecanut agroforests of south Meghalaya and encountered 160 plants, which included 83 tree species, 22 shrub species, 41 herb species and 14 climber species. The study revealed that arecanut agroforests provided cash income, medicine, timber, fuelwood and edibles for household consumption as well as for sale.

Jaiswal (2010) reported the culture and ethno-botany of Jaintia tribal community of Meghalaya. Jaintia tribal community, the original inhabitants of Jaintia Hills district of Meghalaya have a fascinating culture and tradition based on a close relationship with the nature. Plants and plant products play an important role in Jaintia life and thus are an integral part of Jaintia culture. In this report the knowledge of Jaintia people about various plant species that grow in the region and the way these plant species are used as edible plants, indicators of agricultural seasons and in the treatment of some common ailments were reported. Among these species, mention may be made of *Houttuynia cordata* Thunb., *Codonopsis parviflora* Benth., *Fagopyrum dibotrys* (D. Don.), *Rumex nepalensis* Spr. etc., which were used as leafy vegetables by the community.

Singh *et al*., (2012) investigated the wild edible plants used by the Garo tribes in the Nokrek Biosphere Reserve, Meghalaya. They reported 71 wild edible plant species under 61 genera and 42 families being taken by Garo tribes as food; of which they consumed rhizomes, corms and tubers of 8 species; barks of 1 species; stem piths, tender shoots and fronds of 9 species; leaves and twigs of 21 species; flowers/ flower-buds and inflorescence of 2 species; fruits/ pods of 25 species; seeds, nuts, skin, kernels of 3 plant species; whole parts of 2 plant species. Some important species used as leafy vegetables include *Bauhinia purpurea* L., *Begonia roxburghii* (Miq.) A.D.C., *Commelina benghalensis* (L.) Schott, *Ficus hispida* L.f., *Houttuynia cordata* Thunb., *Oxalis corniculata* L. , *Polygonum nepalense* Meisner, *Pteridium aquilinum* (L.) Kuhn etc.

2.2. Maturity Stages of Leafy Vegetables

The maturity stage of a conventional vegetable is universally defined and a crop is normally harvested and consumed at a known stage of plant development, irrespective of environmental conditions for plant growth (Guarino, 1997). Unlike conventional vegetables, there is little documented information about the age of plant development to define harvest maturity for wild or indigenous leafy vegetables. Hence data on their nutritional value is likely to vary widely, due to influences of plant age and the environmental conditions during plant growth (Jansen *et al*. 2004, Hands 2000).

Data on the nutritional content of conventional vegetables can be reasonably associated with a specific stage of plant development, but information about the age of plant development to define harvest maturity for wild or indigenous leafy vegetables including amaranths is scanty. A field experiment was conducted in order to assess the, P, K, Ca, Na, Cu and Zn content at different harvest stages of amaranth (Makobo *etal*. 2010). Amaranths were harvested at 3, 4, 5, 6, 7 and 8 weeks after emergence (WAE). A significant difference was observed in the time these different mineral nutrients reached highest levels. At 3 WAE Ca and Zn, at 4 WAE P, at 6 WAE K and at 7 WAE Na and Cu reached their highest levels. Protein level significantly decreased from 50.8 to 43.47% during the 8 weeks. Regardless of the differences in reaching their highest levels which stretched from 3 to 7 WAE, it was observed that when Ca and Zn reached their highest level at 3 WAE, other minerals despite being low in their concentration could still meet the Daily Required Allowance (DRA) for humans.

The physical characteristics, nutrient contents and triterpene compounds of *Centella asiatica* var. Nyonya were investigated at three different stages of maturity: 50, 60 and 70 days after ratooning (Rosalizan *et al*., 2008). Physical characteristics of *C. asiatica* at each stage of maturity showed no statistical differences in whole plant length, leaf width, root length and culm length. Moisture content was slightly higher (92%) when harvested at 50 days after ratooning, but the value decreased significantly to 88–89% when harvested at 60 and 70 days. The leaf colour intensity (C* values) was low in young plants but increased significantly as plants grew older. There was significant change in total soluble solids as the maturity period increased. The highest levels of chlorophyll and titratable acidity, and lower level of pH were observed at 60 days of harvest, while ascorbic acid content decreased significantly with advance in maturity. The plant contained significant amount of Na, K, Mg, Fe, Zn, P and Ca. With advance in maturity, the K and Ca levels increased significantly. Different levels of triterpene compounds were observed at different maturity stages. The content of asiatic acid was not significantly different at all stages of maturity. However, the levels of madecassic acid, asiaticoside and madecassoside were significantly different with advance in maturity. These compounds were higher when harvested at 60 days and decreased significantly thereafter. Thus, for the ratoon crop, it was recommended to harvest the plant at 60 days after ratooning since most of the bioactive compounds were observed to be highest at this stage of maturity.

Micromineral contents were estimated in some commonly consumed green leafy vegetables in India: *Koyyathotakura* and *Peddathotakura* (varieties of *Amaranthus* species); *Erragogu* and *Tellagogu* (varieties of *Hibiscus* species) *Gangabayalakura* (*Portulaca olerecea*) and *palak* (*Spinacea olerecea*) at three different stages of maturity (Khader and Rama, 1998). Varietal differences were also observed. The results of the study showed that as the plant matured from stage I (15 days) to stage II (30 days), iron and manganese contents increased whereas zinc and copper contents decreased as the plant matured. Varietal differences were also observed at different stages of maturity. The results also indicated that the consumption of green leafy vegetables at stage I and stage II potentially provided the greatest amount of a mineral.

Khader and Rama (2003) also analysed the macro mineral contents in commonly consumed green leafy vegetables in India, namely: *Koyyathotakura* and *Peddathotakura* (varieties of *Amaranthus* species); *Erragogu* and *Tellagogu* (variety of *Hibiscus* species); *Gangabayalakura* (*Portulaca olerecea*) and *Palak* (*Spinacea olerecea*) at three different stages of maturity. The results of the study showed that as the plant matured from stage I (15 days) to stage II (30 days) calcium and magnesium content increased. In contrast, phosphorus content decreased as the plant matured. The results also indicated that the consumption of green leafy vegetables at stage I (15 days) and stage II (30 days) potentially provide the greatest amount of minerals.

A study was conducted by Saha *et al*. (2003) to optimize the time of sowing and stage of harvest of red amaranth during winter season to obtain higher yield without loss of palatability. It was observed that in November sowing, highest palatability (1.59) was achieved when harvested at 15 DAS. Harvesting at 20 days after sowing (DAS) was found to be suitable for November sowing considering economic yield as well as palatability. The December sowing plants had moderate palatability with leaf-stem ration 1.38. On the other hand, in January sowing when harvested at 30 DAS expressed acceptable leaf-stem ration (1.71). Therefore, considering yield and optimum palatability, it was reported that harvesting of the crop should be done at 25 DAS in December sowing and 30 DAS in January sowing.

Punna and Paruchuri (2004) conducted a study to generate data on total (TDF), insoluble (IDF) and soluble (SDF) dietary fiber contents of green leafy vegetables (GLVs) and to assess the effect of leaf maturity and cooking on these parameters. Sixteen GLVs namely, Agathi (*Sesbania grandiflora*), Ponnagantikura (*Alternanthera sessillis*), Amaranth (*Amaranthus gangeticus*), Basella (*Basella rubra*), Cabbage (*Brassica oleracea*), Colocasia (*Colocasia antiquorum*), Coriander (*Coriandrum sativum*), Curry leaves (*Murraya koenigil*), Drumstick (*Moringa olefera*), Fenugreek (*Trigonella foenum graecum*), Gogu (*Hibiscus cannabinus*), Mint (*Mentha spicata*), Gangavoil (*Portulaca oleracea*), Chukka (*Rumex vesicarius*), Spinach (*Spinacia oleracea*) and Tender tamarind leaves (*Tarmarindus indica*) were analysed for TDF, IDF and SDF. Among the GLVs analysed, the TDF and IDF contents were the lowest (2.5 g% and 1.6 g%) in Basella and were the highest (16.3 g% and 13.4 g%) in curry leaves. The SDF content ranged from 0.7 g% in spinach to 2.9 g% in curry leaves. The SDF as a percentage of the TDF ranged from 11.3% in tender tamarind leaves to 36.0% in Basella, but the majority of GLVs had around 25% of the TDF as SDF. Significant variation was observed between inter-species and intra-species in TDF, IDF and SDF contents of all the GLVs. As the leaf matured from tender to mature and to coarse stage, the TDF and IDF contents of Amaranth, Basella, *Hibiscus*, *Rumex* and Spinach increased significantly. The SDF content significantly increased from tender to mature stage in all five GLVs, but there was no further increase from mature to coarse stage except in *Rumex*, where a significant increase (25%) was observed. Processing/cooking of GLVs had no significant effect on their TDF, IDF and SDF contents.

An experiment was conducted by Kanthaswamy (2006) to understand the mean performance of seventy four amaranthus genotypes at five stage of harvest along with the extend of variability of different quantitative and quality characters in relation to yield. The yield increases were attributed to augmentation of yield components like plant height, leaf length, leaf breadth, petiole length, number of leaves per plant, branches per plant, stem girth. An overall analysis of the growth pattern and weight of leaves and component characters indicated that the optimum stage for harvest was between stage S2 to S3, i.e. 30 to 45 days after sowing. Among the different growth stages, the iron content was found to be high at S3 stage. Quality parameter especially calcium, protein and crude fibre content of the genotypes showed higher values at S3 stage and thereupon it started to decline. The anti nutritional factor like oxalate showed increasing trend up to S3 stage and declined thereupon.

Agbo *et al.* (2010) conducted a research in Côte d'Ivoire on the maturity stages of six leafy vegetables (lagos spinach, jute mallow, roselle, spinach, black nightshade and amaranth) which were grown during 2 months at the Agronomic Research Station of Anguededou (Abidjan). They were analysed each weeks for pH, proteins, sugars, fibers, vitamin C, β-carotene, minerals and oxalic acid content. The results revealed that roselle was the most acid leafy vegetable and had the highest oxalic acid content. Protein level decreased during leafy vegetables growth. Total sugars level was constant between the 2nd and 5th weeks. Lagos spinach had the most elevated fiber content at the 3rd week (37.17% for soluble fiber and 66.1% for insoluble fiber). Amaranth and black nightshade had the highest vitamin C content at 7th week (64.44 and 66.67 mg/100 g fresh weight respectively). Moreover, roselle had the highest β-carotene content (64.12 mg/100 g fresh weight, at the 5th week). Phosphorus content of amaranth and black nightshade was the highest at 6thweek with respectively 0.45 mg/100 g dry matter (DM) and 0.33 mg/100 g DM. Magnesium level was constant during leafy vegetables growth. Spinach and jute mallow had the highest iron content at the 5th week (70 and 88.8 mg/100 g DM). The most elevated calcium level was found in spinach (3.68 g/100 g DM at the 6thweek) and in lagos spinach (4.8 g/100 g DM at the 8th week). On the other hand, the lowest potassium content was found in roselle (1.84 g/100 g DM at the 8th week). They concluded that the propitious period for leafy vegetables consumption was between the 3rd and the 5th weeks of growth because nutrients levels were maximal.

An experiment was carried out during rainy season (from July to September) at the experimental station of the Agrhymet Regional Centre in Niamey (Niger) (Atta *et al*., 2010). The content of the micronutrients Fe, Mn, Cu and Zn in the leaves of three ecotypes of Roselle (A3, A7 and A9) at three growth stages; vegetative (stage I), flowering (stage II), and mature (stage III) was determined. Results indicated that at stage I, ecotype A3 had higher Fe content in leaves. In addition, A3 had also the highest Zn content in leaves at stage I. For all three ecotypes, Fe and Zn content in the leaves decreased significantly from stage I to stage II, then remained constant until stage III. For Fe, the decrease between stage I and II was 37% for A3 and 50%, respectively for A7 and A9. The corresponding decrease of Zn content was 30% for A7 and 50%, respectively, for A3 and A9. The Mn content in the leaves of Roselle was similar for the three ecotypes at stage I, thereafter it increased continuously during plant growth. From stage I to II, the increase was about 90%, 70% and 50%, respectively for A9, A7 and A3. From stage II to III, the increase in Mn content in the leaves was significantly ($p<0.05$) higher for A3 and A7, respectively 180% and 80%. At stages I and II, the highest Cu content was recorded for A3 and the lowest one for A7. During the whole cycle of plant growth, the Cu content in the leaves was relatively constant for A9. In contrast, Cu content in the leaves decreased for the remaining ecotypes. Therefore the vegetative stage corresponding to 25 days after sowing was recommended as optimal harvest time of Roselle to maximise on the nutrients.

Deveci and Uzun (2011) conducted a study to determine variations in total phenolic compound and chlorophyll contents in spinach (*Spinacia oleracea* var. *matador*) at three different growth stages like cotyledon, 5 true leaves and harvest maturity. They observed that among the growth stages of spinach grown in three different growth environments, amounts of total phenolic compound, total chlorophyll, chlorophyll a and chlorophyll b increased towards the harvest phase in which the most maturated and aged plant was achieved.

Aggrwal *et al*. (2013) conducted an experiment to study the changes in physical and biochemical properties of fenugreek (*Trigonella sp*. L.) leaf during different growth stages. Plant height, fresh weight, dry weight, number of primary branches, leaf area, number of leaves, increased significantly with advancement of age. The maximum plant height, fresh weight, dry weight was recorded in Rmt-1 at 60 DAS and minimum in Pusa Kasuri at 30 DAS. Maximum leaf area and number of primary branches was recorded in Pusa Kasuri at 60 DAS and minimum in Am-1 at 30 DAS. Maximum number of leaves and relative water content was recorded in Pusa Kasuri and minimum in Rmt-1. Maximum chlorophyll a content was recorded in Pusa Kasuri at 45 DAS and minimum in Rmt-1 at 60 DAS. Maximum chlorophyll b, total chlorophyll and carotenoid content were recorded in Pusa Kasuri at 45 DAS and minimum in Am-1 at 60 DAS.

2.3 Physicochemical Parameters of Leafy Vegetables

A study was undertaken by Yildirim *et al.* (2001) in order to investigate wild plant species locally consumed as food in Upper Coruh Valley, Turkey. The plant species were collected in the late winter and spring, and their taxonomic identifications were made. The plants identified were *Plantago minor* L., *Polygonum bistorta* L., *Astrodaucus orientalis* L., *Camelina rumelica* Boehm., *Lathyrus tuberosus* L., *Galium rotundifolium* L., *Chenopodium album* L. and *Sisymbrium officinale* L. Analysis were carried out to evaluate the nutritional values of the plant parts. The highest dry matter, ascorbic acid, nitrogen, protein, phosphorus and potassium contents were determined to be 20.87g/100g, 161.25mg/100g, 1.08g/100g, 6.75g/100 g, 66.09mg/100g and 1544.38mg/100g in *L. tuberosus*, respectively. *A. orientalis* had the highest iron (7.12mg/100g), manganese (0.90 mg/100g) and copper (0.47mg/100g) contents. *C. album* was the richest in magnesium and sodium contents. Calcium was abundant in all species. The maximum amount of zinc was found to be 1.57mg/100g in *C. rumelica*.

Seventy edible wild forest green leafy vegetables (GLVs) collected and consumed by tribals of Andhra Pradesh, India were analyzed by Rajyalakshmi *et al.* (2001) for total carotenoides (TC) and beta carotene (BC) contents using high performance liquid chromatography (HPLC). The vitamin A activity expressed as retinol equivalents (RE) was calculated based on *in vivo* conversion factor given by

WHO. The results of the study indicated that thirty-six GLVs were found to have high vitamin A activity (0.87 to 2.34 RE) with TC and BC contents ranging from 12.22 to 36.13 and 5.21 to 14.05 mg %, respectively; thirty GLVs had moderate vitamin A activity (0.36–0.8 RE) with TC and BC contents ranging from 10.60 to 31.33 and 2.19 to 4.78 mg %. Four GLVs contained low vitamin A activity (0.07–0.32 RE); – TC and BC contents ranging from 5.12 to 13.13 and 0.40 to 1.94, respectively. The percent beta carotene in total carotenoids among the three groups of the GLVs varied from 19.41 to 73.02, 11.11 to 46.21 and 5.98 to 37.11, respectively.

A total of 38 green leafy vegetables from selected regions of south Karnataka were identified and analyzed for their nutrient content by Sheela *et al*. (2004). The iron content of the vegetables ranged between 3.68 to 37.34 mg/100g; the highest iron content was observed in Nelabasale greens, *Portulaca oleracea* (37.34 mg). Calcium content ranged from 73 to 400 mg/100g. Chilikere greens, *Oxalis acetosella* (400 mg) had maximum calcium content. The highest ascorbic acid content was found in Knol Khol greens, *Brassica oleracea*.

Gupta *et al* (2005) analysed the chemical composition of 13 locally available underutilized green leafy vegetables (GLVs). Moisture, ash and ether extract of the greens were in the range of 73–95g/100g, 0.77–3.54g/100g and 0.2–0.9g/100 g, respectively. Four GLVs had high iron content (13.15–17.72 mg/100g) while the rest had lower levels (2.62– 9.86 mg/100g). Calcium content varied largely between the greens ranging from 41 mg/100g in *Polygala erioptera* to 506 mg/100g in *Digera arvensis*, whereas phosphorous ranged from 16 to 63 mg/100g. Ascorbic acid was higher in *Delonix elata* (295 mg/100g) and *Polygala erioptera* (85 mg/100g) and lower in others (3–46 mg/100g). Thiamine was found to be less than 0.1 mg/100g in six greens and 0.1–0.33 mg/100 g in others. Total carotene content ranged between 10 and 35 mg/100 g in all with exceptionally high amount in *Cocculus hirsutus* (67 mg/100g) and *Delonix elata* (60 mg/100g). Beta-carotene was 13– 25% of total carotene in all greens. Oxalate content was below 100 mg/100g in five greens and less than 1400 mg/100g in the remaining GLVs. Tannin content ranged between 61 and 205 mg/100g in all GLVs with the exception of *Coleus aromaticus* (15 mg/100g) and *Delonix elata* (1330 mg/100g).

Rai *et al*., (2005) studied the proximate composition and nutritive value of some common edible wild plants sold in the local markets of Sikkim, which included wild leafy vegetables like, *Nasturtium officinale* Brown (water cress), *Huttuynia cordata* Thunb, *Urtica dioca* (singing nettle), *Ficus benjamina* Linn, *Aconogonum molle* (D. Don) and found them to be of high nutritive value. They observed that these uncultivated wild plants supplemented the need of cultivated vegetables and contribute in food security of the region. The antioxidant and other bioactive compounds of these wild edible plants should be studied so that they can find place in global markets.

Shukla *et al.* (2006) reported the proximate mineral composition in 30 strains of *A. tricolor* along with some suggestions for qualitative improvement of the foliage yield with reference to minerals. Vegetable amaranth was found to be a rich source of minerals like calcium (1.7±0.04 g/100g), iron (1233.8±50.02 mg/kg), and zinc (791.7±28.98 mg/kg). The heritability estimates were high for most of the traits, with potassium and calcium showing high values, while comparatively lower values were recorded for magnesium and nickel. Nickel was the only mineral that showed positive correlation with all the minerals, as well as with leaf size and foliage yield. Zinc showed strong positive relationship with iron (0.66**) and manganese (0.74**), and was the only mineral exhibiting significant positive association with foliage yield.

Twenty seven wild green edibles from Meghalaya were selected on the basis of rapid rural appraisal and analyzed for the contents of the micronutrients by Murugkar (2006). Wild edibles rich in calcium (mg%) included *F.cunea* (665.8), *P.major* (427.8) and *B.roxhburghii* (336.5). *C.diffusa* (11.6 mg%) and *O.corniculata* (16.7 mg %) were rich in iron and wild edibles rich in β-carotene (mg %) included *S. acmella* (6105.7), *S.oleoraceus* (4051.6), *F.cymosum* (2708.4) and *F.cunea* (2537.9). They observed that these leaves could form an important part in combating dietary deficiencies of vitamin A, iron and calcium, which are the primary causes night blindness and other vitamin A related deficiencies, anemia and osteoporosis especially among women and children in India. Due to the therapeutic value these leaves could form a part of low cost nutritional therapy that has been advocated by the Indian government to combat these serious deficiencies.

Odhaya *et al*. (2007) reported the preliminary nutritional data for traditional leafy vegetables collected in Kwa Zulu-Natal, South Africa, including their content of mineral elements (Ca, P, Na, Zn, Mg, Mn and Fe) and antioxidant levels. Twenty vegetables were studied: *Amaranthus dubius*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Asystasia gangetica*, *Bidens pilosa*, *Centella asiatica*, *Ceratotheca triloba*, *Chenopodium album*, *Cleome monophylla*, *Cucumis metuliferus*, *Emex australis*, *Galinsoga parviflora*, *Justicia flava*, *Momordica balsamina*, *Oxygonum sinuatum*, *Physalis viscosa*, *Portulaca oleracea*, *Senna occidentalis*, *Solanum nodiflorum* and *Wahlenbergia undulata*. The results of this study provided evidence that these local traditional vegetables, which do not require formal cultivation, could be important contributors to improving the nutritional content of rural and urban people. From this study, it was determined that twelve leafy vegetables, namely

A. dubius, *A. gangetica*, *A. hybridus*, *A. spinosus*, *C. metuliferus*, *C. monophylla*, *C. triloba*, *G. parviflora*, *J. flava*, *M. balsamina*, *P. viscosa* and *W. undulata* provided mineral concentrations exceeding 1% of plant dry weight which were much higher than typical mineral concentrations in conventional edible leafy vegetables; they were thus recommended for future commercial cultivation. High levels of antioxidant activity (96%) were noticed in *J. flava* and *P. oleraceae*.

Ujowundu *et al.* (2008) evaluated aqueous leaf extracts of *Boerhavia diffusa* and *Commelina nudiflora* for nutritional and anti-nutritional compositions. The results showed that both vegetables contained saponins, alkaloids and flavonoids. The proximate and vitamin compositions of *B. diffusa* and *C. nudiflora* included mainly moisture (82.22% and 88.63%), carbohydrate (10.56% and 5.67%), vitamin C (44.80 and 41 .60mg/00g dry weight), vitamin B3 (97.00 and 66.20mg/l00g) and vitamin B2 (22.00 and 8.70mg/00g) respectively. The mineral contents of the defatted leaf extracts were found to be Na (162.50 and 75.55mg/100g), Ca (174.09 and 240.00mg/100g) and Mg (8.68 and 6.63mg/100g) for *B. diffusa* and *C. nudiflora* respectively. Iodine was detected at 0.002mg/100g in *B. diflusa* leaf extract only. The proximate, vitamin and mineral compositions obtained suggested that the leaves, as cheap sources of vitamins C, B3 and B2, as well as other macro-and micro-nutrients, can be incorporated into human and animal diet to meet their recommended daily allowances. The content of flavonoids and vitamin C in the leaf extracts also suggested possible anti-oxidant effects of these leafy vegetables.

A study was conducted to evaluate the acceptability of various indigenous vegetables in Embu district collected from Western Kenya (Magoti *et al*., 2008). *Solanum nigrum* (Black Night shade), *Corchorus olitolius* (Jews Mallow), *Cleome gynandra* (Spider plant), *Crotalaria brevidens* (Sun hemp), *Vigna unguiculata* (Cow peas) and *Brassica carinata* (African kale) were grown on-station. Visual and sensory properties were conducted where the participants developed criteria to evaluate the acceptability of the vegetables. Thirty-six respondents participated in the study conducted at KARI Embu. Results revealed that a high proportion of respondents ranked them highly in terms of smell, appearance, colour, taste, softness and palatability. All the sensorial properties of these African leafy vegetables were ranked above average (good or very good). The demand for seed by participants to plant in their farms was a clear evidence of high acceptance. Demonstration of the production of the various ALV was therefore recommended on farm to enhance their adoption amongst the smallholder farmers in the region

Mbugua *et al*. (2008) conducted an investigation in Lari, Kiambu West district Central Kenya to participatorily characterize and evaluate selected African leafy vegetables with smallscale farmers. A total of 31 accessions of spiderplants (*Cleome gynandra*), amaranths (*Amaranthus* sp.) and African nightshades (*Solanum* sp.) were participatorily characterized by four farmer groups comprising over 80 members. The following traits were evaluated: Number of leaves per plant, leaf colour, branches/plant and organoleptic test. Most farmers preferred highly leafed and branched genotypes with dark green leaves. In organoleptic test, there was a wide variation among all accessions evaluated.

Variability of few nutritionally important minerals (calcium, iron, magnesium, phosphorus, and potassium) in fifteen leafy green vegetables widely consumed in Assam was determined by Borah *et al*. (2009). The mineral composition in terms of ash, Ca, Mg, Fe, K, and P revealed that these traditional vegetables were sufficiently rich in mineral content. The ash content varied from 6.21 g% in *P. chinense* to 8.6 g% in *Amaranthus spinosus*. The mineral contents in these fifteen vegetables showed that calcium was the most abundant macroelement present, ranging from 875 mg/g (*A. spinosus*) to 396 mg/g (*Oldenlandia corymbosa*).This was followed closely by magnesium, which was present in the amount ranging from 621 mg/g (*A. spinosus*) to 215 mg/g (*A. sessilis*). The Ca content was found to be higher than Mg in all the vegetables studied. Phosphorus was present in the amount ranging from 62mg/g (*Cassia occidentalis* and *Eclipta prostrata*) to 48 mg/g (*P. chinense*).Potassium content was highest in *Centrella asiatica* (18 mg/g) and lowest in *Eryngium foetidum* (11.26 mg/g). Trace element iron was found highest at 25.42 mg/g (*A. sessilis*) and lowest amount at 18.21 mg/g (*P. chinense*).

Mensah *et al*. (2008) carried out a systematic survey of green leafy vegetables from Edo State of Nigeria to evaluate their frequency of use in local meals. Twelve common ones out of the twenty nine green leafy vegetables were selected for further evaluation to determine their nutritional and medicinal values. Fresh leaves were shredded and sun dried before milling into vegetable powder and then taken for qualitative and quantitative phytochemical analysis. The vegetables were a major source of ascorbic acid and the mean values ranged from 100 to 421.6 mg/100 g with the *Amaranthus* (408 mg100-1g) and Ce*losia (*421 mg100-1g) species containing higher quantities. *Amaranthus* and *Talinum* recorded high mineral contents. The crude protein ranged from 3.8 to 27.7 g/100 g and carbohydrate contents ranged from 2.9 to 47.9 g/100 g. The analysis further showed presence of alkaloids, inulins, saponins and tannins which are known components of herbs used in traditional medicine.

Wild vegetables play an important role in the diet of inhabitants of different parts of the world. Some of the wild vegetables of South Africa are *Chenopodium album*, *Sonchus asper*, *Solanum nigrum* and *Urtica urens*. The leaves of these plants were analysed for their nutritive value, antinutritive components and polyphenolic contents (Afolayan and Jimoh, 2009). The protein contents of their leaves ranged between 13.25% and 26.44%, while the fibre and mineral (ash) contents were 16.08-23.08% and 13.0-27.75%, respectively. *U. urens* contained the highest concentrations of calcium, potassium, phosphorus and zinc. A high level of iron was observed in *S. asper*. These values were found to be comparable with or higher than those of commonly used vegetables such as spinach, lettuce and cabbage. The total phenolic contents ranged between 4.58 and 10.53 mg/g. In terms of anti-nutritional principles, all the vegetables had comparatively lower concentrations of phytate, alkaloids and saponins. Considering the amount of available mineral elements in the vegetables, these plants could be valuable and important contributors to the diets of the people in South Africa.

To identify the potential of green leafy vegetables (GLVs) as antioxidants, methanolic extracts of Amaranthus sp., *Centella asiatica*, *Murraya koenigii* and *Trigonella foenum graecum* were studied for their antioxidant activity in different systems at multiple concentrations (Gupta and Prakash, 2009). Total antioxidant activity assessed by phosphor-molybdenum method, free radical scavenging activity by 1,1-diphenly-2-picryl hydrazyl (DPPH), reducing power and ferrous ion chelating activity were determined. The GLVs were analyzed for ascorbic acid, total and β-carotene and total polyphenol contents. The ascorbic acid, total carotene, β-carotene and total phenolic content (tannic acid equivalents) of the GLVs ranged between 15.18–101.36 mg/100g, 34.78–64.51 mg/100g, 4.23–8.84 mg/100g and 150.0–387.50 mg/100g respectively. The extracts were found to have significantly different levels of antioxidant activities in the systems tested. The total antioxidant activity was highest in *Murraya koenigii* (2,691.78 µmol of ascorbic acid/g sample) and least in *Centella asiatica* (623.78 µmol of ascorbic acid/g sample). The extract concentration causing 50% inhibition of DPPH (IC50) was determined (*M. koenigii* < *C. asiatica* < *Amaranthus* sp. < *T. foenum graecum*). The maximum DPPH scavenging activity and reducing power was exhibited by *Murraya koenigii*. Multiple regression analysis showed that the relationship of total antioxidant activity, free radical scavenging activity, and reducing power with polyphenol and total and β-carotene was highly significant.

The mineral (calcium, magnesium, iron, potassium and phosphorus) contents and chemical composition of carbohydrate, protein, fat found in 15 traditional vegetable species collected from different parts of North-east India were analysed by Baruah and Borah (2009). The results of this study could contribute to the knowledge on vitamin contents in these vegetables. The amounts of ascorbic acid found in some species were much higher than the amount present in many conventional vegetables.

Jain *et al*. (2010) evaluated some parameters regarding nutritive value of leaves of *Oxalis corniculata*. L. used as alternative vegetable during emergency by some tribes of central India. The leaves were found to be rich in moisture (82.42±0.5%), total carbohydrate (24.67±0.4%), crude protein (22.28± 0.5%), crude lipid (23.7±0.5%), sodium (1.12±0.02%), potassium (2.17±0.31%), calcium (2.5±0.08%), nitrogen (3.56±0.70%) and magnesium (0.25±0.03%).

The nutritional quality of some cultivated and wild species of *Amaranthus* L. were analysed by Srivastava (2011). Fresh leaves were analyzed for protein and carbohydrate content and oven dried leaves for Fe, Ca, K and Na contents. Protein content varied from 6.10-9.00g/100g of fresh leaves. The amount of carbohydrate in fresh leaves of all four species varied from 9.75g-21.29g. Among the species, *A. spinosus* showed higher amount of carbohydrate (21.29g) which is almost two folds higher than *A. tricolor* (9.75g). Results showed that *A. viridis* had higher accumulation (54 mg/100g) of Na. Overall K amount in the dry leaves of the four species varied between 2230-3900 mg/100 g of dry leaves and it was almost 2 fold differences between values of lowest and highest accumulation. The variation in amount of Ca was 38 fold higher, *A. spinosus* from the minimum amount (*A. blitum*). Fe content in dry leaves was maximum in *A. viridis* (15 mg/100g of dry wt.) followed by *A. spinosus* (13.28 mg/100g), *A. tricolor* (10 mg/100g) and *A. blitum* (9 mg/100g). Wild species were found to contain more amount of Fe than cultivated species. The results of this study indicated a nutritive potential for the Amaranthus leaves, therefore, domestication of this plant was suggested along with assessment of its chemical and nutritional properties.

The native uses of ethnobotanical species identification and chemical analyses of different edible parts of wild plant species consumed by the local people inhabiting in the tribal areas of Bilaspur district, situated in the eastern part of Chhattisgarh was done by Vishwakarma and Dubey (2011). Total seventy wild edible plant species were identified and recorded. Out of seventy plants species 25 were chemically analyzed The results of nutritional composition showed that the leaves had high moisture content from 93.45 ± 0.182% to 56.96 ± 0.255% which was highest in the leaves of *Carthemus tinctorius* and lowest in *Cissus quadrangularis*. Crude protein contents in the samples varied from 1.2 ± 0.602% to 17.84 ± 0.892%. *Ipomoea aquatica* showed the highest value of 17.84 ± 0.892%. Leaves of *Amaranthus virdis, Chenopodium album, Centella asiatica, Commelina benghalensis, Moringa oleifera* were also found to be very good sources of protein. Out of 25 vegetables, crude lipid content ranged from 0.72 ± 0.409% to 30.02 ± 0.461. The lowest value of crude lipid was found in *Aegle marmelos* 0.77 ± 0.046% which was low as compared to the previously reported value of 2.66% in *Momordica* species. Energy in terms of calorific value was found to be in the normal range of 134.6 kcal/100 gm to 431.6 kcal/100 gm. Iron content in these samples ranged from 21 ppm to 869 ppm. All the values were statistically analyzed and compared with previously reported values.

The leaves of Fagopyrum cymosum, *Ficus clavata*, *Ficus geniculata*, *Ficus pomfera*, *Gentiana pedicellata* and the seeds of *Gynocardia odorata*, of different botanical families grown in Meghalaya used as wild edible plants by the local people were analysed for their nutritional composition (Seal, 2011). For different plant species the crude fat content ranged between 1.13±0.07-1.51±0.03%. The crude protein content was found to be high in leaves of *F. cymosum* (25.49 ± 0.10%), *F. clavata* (25.01±0.07%) and in the leaves of *F. geniculata* (23.26± 0.07%) while the available carbohydrate content was highest in the leaves of *G. pedicellata* (72.94±0.27%) and very good amount in *F. pomfera* and *F. cyrnosurn*. The nutritive value ranged from 368.53±0.40-452.73±0.08 kcal /100g in the various wild edible plants. Among the various macronutrients estimated in the plant samples of different wild edible plants potassium was present in the highest quantity (9.60±0.11-37.71±0.07 mg/g) followed by calcium (8.9±0.10-1 7.66±0.13 mg/g) and sodium (0.66±0.01-1.15±0.05 mg/g). Micronutrients, such as iron, zinc, copper, manganese and chromium were analyzed in the different plant specimens. The results indicated that these wild edible plants under investigation could be a good supplement for protein, carbohydrate, sodium and potassium and were richer than that of the commercial vegetables and could be used for nutritional purpose.

Asaolu *et al*. (2012) carried out proximate analysis and mineral composition of some Nigerian leafy vegetables: bitter leaf (*Veronia amygdalina* L), India spinach (*Basella alba* L), bush buck (*Gongronema latifolium*), scent leaf (*Ocimium grastissimum*), Smooth amaranth (*Amaranthus hybridus*), Roselle plant (*Hibiscus sabdariffa*) and fluted pumpkin (*Telfaria occidentali*) using standard analytical procedures. The moisture content of the samples ranged between 10.0-12.08 %, crude protein, crude fibre, crude fat, ash contents and carbohydrate ranged between: 46.56 and 66.60, 4.02 and 12.08, 3.51 and 14.02, 5.02 and 15.55, 1.16 and 15.79 % dry matter (DM). Mineral element analysis showed that the leafy vegetables contained high levels of calcium (63.36-110.16), magnesium (27.51-288.65), sodium (15.01-88.00) and potassium (16.85-168.96) and low levels of copper (nd-3.14), nickel (2.32-

18.16) and manganese (2.54-10.06) mg/100g respectively. The study showed that the leafy vegetables examined contained high levels of crude protein with low fat content and crude fibre.

Ng *et al*. (2012) evaluated the nutritional profile and antioxidative properties of selected tropical wild vegetables. Five underutilized wild vegetables namely *Limnophila aromaticoides*, *Ceratopetris thalictroides*, *Crassocephalum crepidioides*, *Etlingera elatoir* and *Monochoria vaginalis* were analyzed for nutritional values, phenolic components and antioxidant activities. These wild greens were found to have high fibre (11.3-19.8 g/100g) and ash (13.0-17.6 g/100g) contents as compared to commercialized species, *Brassica juncea*. The iron content of *Monochoria vaginalis* was four times higher than *Brassica juncea* (33.1 mg/g dry weight). *Crassocephalum crepidioides* demonstrated remarkable lipid peroxidation inhibition (90.4%). The phenolic content of *Etlingera elatoir* was two times higher than *Brassica juncea*. So, these wild vegetables could be potentially used in alleviating micronutrients deficiency especially for the rural populace and as a potent source of natural antioxidants.

In one investigation biochemical evaluation of 20 leafy vegetables was done by Sharma and Kumar (2013). The phytochemical analysis of all the studied plants revealed carbohydrates, proteins, fats and fibers as nutritional components, whereas the presence of alkaloids, flavonoids, saponins, tannins, terpenoids, cardiac glycosides and phlobatanins, supported therapeutic properties. They concluded that the consumption of such important plant resources should be encouraged and popularized as these could be beneficial resources for prevention, management and treatment of chronic diseases of the modern age.

Saikia and Deka (2013) examined the macroelements (Na, K, Ca, Mg and P) and trace elements (Fe, Zn, Cu, Mn, Cr and Ni) content of fresh and cooked vegetables of twenty one wild vegetables traditionally consumed in North-East India. All the examined vegetables were found to be rich source of macroelements as well as trace minerals. Calcium was the most abundant macroelement ranging from 125.7 mg/100g to 543.2 mg/100g, while Iron was found to be the most abundant microelement in the examined vegetables which ranged between 6.97 mg/100g to 22.7 mg/100g.

The major nutritional components as well as calorific values were estimated for nine non- conventional wild leafy vegetables traditionally used by various tribal communities of Nagaland was evaluated by Gogoi *et al*. (2014). Different plant types were covered in the study viz herbs - *Eryngium foetidum, Polygonum microcephalum*; shrubs - *Gentum gnemon*, *Rhynhotechum ellipticum*, *Zanthoxylum oxyphylum*, *Zanthoxylum acanthopodium*, *Skimmia arborescens*, *Lycianthus pachypetala* and trees - *Rhus semialata*. Crude protein contents were very impressive in the range of 11.65% in *S. arborescens* to 28.54% in *E. foetidum*. All the species were very rich in total mineral in the form of ash content which varied from 7.0% in *P. microcephalum* to 19.69% in *S. arborescens*. Crude fibre was found in high amount and varied from 12.50% in *Z. oxyphylum* to 26.59% in *G. gnemon*. Total carbohydrate and lipid content were comparatively low with limited variability. Calorific value exhibited wide variability n the range of 98.21 K cal/100 gm in *S. arborescens* to 168.44 K cal/100 gm in *G. gnemon*.

A study was conducted to evaluate nutritional properties of certain traditional medicinally important edible leafy vegetables of Assam, India (Gogoi and Kalita, 2014). Nutritive value and mineral composition of *Alternanthera sessilis*, *Drymaria cordata*, *Eclipta alba*, *Houttuynia cordata* and *Leucas plukenetii*, which were basically used as medicine of different ailments, were determined. Proximate analysis revealed high amount of carbohydrate content ranging from 38.46 - 66.54%. Moisture content was found to be highest in *Eclipta alba* (89.1%) while protein was higher in *Houttuynia cordata* (19.68%). Fat content was relatively less and fiber content ranged from 9.4 - 23.52%. These vegetables were found to be rich sources of macroelements as well as trace minerals. Potassium was the most abundant macroelement ranging from 6240.0-14570.0 mg/kg, followed by sodium, calcium and magnesium. Among the trace elements Iron was highest (252.8-712.9 mg/kg), followed by zinc, manganese and copper. The results demonstrated that these 5 selected underutilized medicinal plants have great nutritional significance.

Patricia *et al*. (2014) analyzed the physicochemical and nutritive properties of the leafy vegetables consumed in Northern Côte d'Ivoire (*Amaranthus hybridus*, *Andasonia digitata*, *Ceiba patendra*, *Hibiscus sabdariffa* and *Vigna unguiculata*). The results obtained were as follows: moisture (69.93 - 87.40%), crude proteins (13.12 -

22.26%), crude fibre (12.11 - 33.00%), ash (7.25 - 26.79%), carbohydrates (26.19 - 59.99%), crude lipids (1.17 - 4.90%) and food energy (134.87 - 312.92 kcal/100g). The mineral element contents were high with remarkable amount of K (848.3 - 3970 mg/100g), Ca (1331.15 - 4680 mg/100g), Mg (345.55 - 2110 mg/100g), P (343.53 – 1320 mg/100g) and Fe (30.71 - 90.00 mg/100g). The Ca/P ratio was desirable and ranged from 2.75 to 9.99. These leafy vegetables also contained appreciable levels of vitamin C (30.00 - 60.01 mg/100g) and polyphenols (134.07 - 294.83 mg/100g). The studied leafy vegetables highlighted antioxidant activity varying from 69.05 to 80.21%. All these results indicated that the studied leafy vegetables if consumed in sufficient amount would contribute greatly to the nutritional requirement for human health and to the food security of Ivorian population.

Chapter III

MATERIALS AND METHODS

The present investigation entitled “Morphological and Physicochemical properties of underexploited leafy vegetables of Meghalaya” was carried out in the Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya and the Department of Horticulture, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland. Twenty five underexploited leafy vegetables were collected from different parts of Meghalaya and they were propagated in the research Farm of the Division. The collected vegetables were analysed for their morphological and physicochemical parameters at different stages of maturity.

3.1 About the Investigation

3.2 Experiment I: Collection of different underexploited leafy vegetables of Meghalaya

In the present Experiment, planting materials of underexploited leafy vegetables were collected from different parts of Meghalaya. Among the collected vegetables, twenty five were selected and were propagated in the research Farm of the Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya.

Area covered: All the parts of Meghalaya comprising of Khasi, Garo and Jaintia Hills.

Area/office visited: Farmers’ field/Village markets/District Agriculture Office.

Materials collected: Seeds/other planting materials.

Season: Both Rabi and Kharif

Number of trips undertaken: 4

3.3 Experiment II: Evaluation of morphological and physicochemical characters of the collected vegetables

In the second experiment, the selected vegetables were analysed for their morphological and physicochemical parameters.

Plot size: 2m x 2m, No. of replications: 3

3.4 Experiment III: Standardization of maturity indices of the collected vegetables

In this experiment, maturity indices of the selected leafy vegetables were standardized based on their morphological and physicochemical parameters. The vegetables were harvested at six different stages of maturity i.e., 2 WAE (Weeks After Emergence), 4 WAE, 6 WAE, 8 WAE, 10 WAE and 12 WAE and the different parameters were analysed.

Plot size: 2m x 2m.

No. of replications: 3

3.5 Observations recorded for Experiment II and III

3.5.1 Morphological parameters

a) Whether annual or perennial

b) Days taken from leaf emergence to maturity

c) Plant height

d) Plant biomass

e) Number of leaves

f) Leaf area index

g) Leaf weight (fresh and dry)

h) Leaf color

i) Leaf texture

j) Leaf shape

k) Number of harvests

l) Yield/harvest

m) Ratooning effect if any

3.5.2 Physicochemical parameters

a) Vitamin C content

b) Minerals content (Ca, Mg, Mn, Fe etc)

c) Chlorophyll content

d) Fibre content

e) Antioxidant phytochemicals (β – carotene, phenolics etc)

f) Acidity %

g) Moisture content

h) Cooking quality

i) Shelf life

3.6 Methods for estimating the morphological and physicochemical parameters for Experiment II and III

3.6.1 Morphological parameters

3.6.1.1 Whether annual or perennial

Annual/perennial nature of the leafy vegetables was recorded.

3.6.1.2 Days taken from leaf emergence to maturity

The average number of days taken from leaf emergence to maturity was recorded for the different stages of maturity.

3.6.1.3 Plant height (cm)

The average heights of the plants at different growth stages were recorded for ten randomly sampled plants for each plot.

3.6.1.4 Plant biomass (g/plant)

The mean total weights of the plants (average of 10 plants for each plot) were evaluated at different growth periods.

3.6.1.5 Number of leaves

The total number of leaves per plant for each maturity stage was analysed for five plants and the average values were calculated.

3.6.1.6 Leaf area index

Leaf area index of the destructive plant samples was calculated following the graph paper method. Maximum length and maximum width of the leaf lamina of ten plants per plot was taken. The factor obtained was multiplied to the maximum length and width of each leaf and average was taken for calculating leaf area per plant. The average leaf area per plant was expressed in cm^2. Finally the leaf area index was estimated by dividing leaf area per plant to the ground area covered by the plants.

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf Area per plant (cm}^2\text{)}}{\text{Spacing (cm}^2\text{)}}$$

3.6.1.7 Leaf weight (fresh and dry) (g/plant)

Leaf fresh weight (average of five plants) was measured immediately after harvesting. The samples were then dried at 55°C in a hot air oven. After 48 hours, dry weight was measured.

3.6.1.8 Leaf color

Leaf color of the leafy vegetables was analyzed using the Hunter Colorimeter. The color difference meter was calibrated using a white standard. Leaves were placed directly over the 2.54-cm diameter aperture for reading and 3 values were recorded: ‘L’ for lightness on a scale of 0 to black to 100 for white; ‘a’ associated with positive values for red and negative for green; and ‘b’ a value more negative for yellower and more positive for bluer samples.

3.6.1.9 Leaf texture

Leaf textural quality was evaluated by manual appreciation based on a 5 – 1 scale.

Numbers	Rating
5	Firm and crunchy
4	Moderately firm
3	Tender
2	Soft
1	Very soft

3.6.1.10 Leaf shape

`Leaf shape was determined according to the shape of the leaf lamina.

3.6.1.11 Number of harvests

The crops were harvested at different stages and the total number of harvests was recorded for each maturity stage.

3.6.1.12 Yield/harvest (g/m^2)

Leaf yield was recorded for each harvest and was expressed in g/m^2

3.6.1.13 Ratooning effect if any

The plants were evaluated for any ratooning effect.

3.6.2 Physicochemical parameters

3.6.2.1 Vitamin C content

The 2, 6 dichlorophenol dye method was used for determining the vitamin C content of the vegetables (AOAC 1980). Five gram of sample was extracted with 25 ml of 4% oxalic acid and filtered. Five ml of aliquot was taken with 5 ml of 4% oxalic acid and titrated against the standard 2, 6-dichlorophenol indophenols dye to a pink end point which persisted for at least 15 seconds. Amount of vitamin C was calculated and expressed as mg per 100 g by the formulae:

$$\text{Vitamin C (mg/100g)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{wt./volume of sample taken for estimation}}$$

3.6.2.2 Minerals content

3.6.2.2.1 Calcium and Magnesium

The calcium and magnesium contents were determined by Complexometric Titration method of the samples after digestion with di–acid (Nitro–perchloric) mixture (Baruah and Barthakur,1997).

For Calcium, 5 ml of the aliquot was mixed with 25 ml of distilled water and 10 ml of 15% NaOH. After that 3 – 5 drops of indicator (Patton's and Reeder's Reagent) was added and the sample was titrated against EDTA 0.01 N solution to a violet colour end point. Percent Calcium in the sample was calculated as:

$$\text{Calcium (\%)} = \frac{\text{Titre value} \times \text{Normality of EDTA} \times \text{volume of sample} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{weight of sample}}$$

For magnesium, 5 ml of the aliquot was mixed with 25 ml of distilled water and 10 ml of buffer solution and then titrated against EDTA 0.01N after adding 3 – 5 drops of EBT indicator. The end point was of ink blue colour. Percent Calcium in the sample was calculated as:

$$\text{Magnesium (\%)} = \frac{\text{Titer value (for Ca + Mg - Ca)} \times \text{Normality of EDTA} \times \text{volume of sample} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{weight of sample}}$$

3.6.2.2.2 Iron and Manganese

The Iron and Manganese contents in the samples were determined with the help of atomic absorption spectrophotometer (AOAC, 1990). The filtrate from the di-acid digested sample was fed in to the atomic absorption spectrophotometer. 1.2 *N* HCl solution is used as reagent blank. For standard curve different volumes (15 ml and 30 ml for Fe and 5 ml and 10 ml for Mn respectively) were pipetted out from the100 ppm working stock solutions of Fe and Mn and diluted to volume with 1.2 *N* HCI solution to give different concentrations (3 ppm and 6 ppm for Fe and 1 ppm and 2 ppm for Mn respectively). The concentration of Iron or Manganese in the sample is calculated as:

$$\text{Fe or Mn (ppm)} = \text{ppm in reading x 100}$$

$$\text{Fe or Mn (mg/100g)} = \frac{\text{Fe or Mn (ppm)}}{10}$$

3.6.2.2.3 Crude Protein

Determination of crude protein content was calculated from the nitrogen content as determined by the micro-Kjeldahl method (AOAC, 1995). 0.5 g sample was digested with conc. Sulphuric acid in the presence of catalysts (K_2SO_4:$CuSO_4 2H_2O$:Se powder @ 50:!0:1). The liberated ammonia gas is distilled with 40% Sodium hydroxide solution and is absorbed in known amount of boric acid (25ml). The solution was then back titrated with standard Sulphuric acid of 0.1N. Amount of total nitrogen in the samples was calculated as:

$$\text{N (ppm)} = \frac{\text{Titer Value x 0.014 x } 10^6 \text{ x strength of acid}}{\text{Weight of sample}}$$

$$\text{N (\%)} = \frac{\text{N (ppm)}}{10^4}$$

$$\text{Crude protein (\%)} = \text{N (\%)} \times 6.25$$

3.6.2.2.4 Total Phosphorus

The total phosphorus content of the samples was estimated by the Vanadomolydophosphoric Yellow Colour method (Bray and Kurtz 1945). 20 ml of vanadomolybdate reagent is added to 10 ml of the di-acid digested sample and then volume is made up to 50 ml with water. The intensity of yellow colour was measured in a UV – VIS spectrophotometer at 450 nm. The percentage of total phosphorus in the solution is calculated from the standard curve prepared using standard P solution of different concentrations.

$$\text{P (ppm)} = \text{ppm of P as read from the standard curve} \times \text{total dilutions}$$

$$\text{P (\%)} = \frac{\text{P (ppm)}}{10^4}$$

3.6.2.2.5 Total Potassium

The total potassium in the di – acid digested samples was determined with a Flame photometer (Jackson 1973). The filtered extract was fed in the flame photometer and the total K readings were taken. Amount of total potassium in the samples was calculated as:

$$\text{K (ppm)} = \text{Reading from the instrument} \times \text{total dilutions}$$

$$\text{K(\%)} = \frac{\text{K (ppm)}}{10^4}$$

3.6.2.3 Chlorophyll content

The total chlorophyll in the samples was estimated by extracting 1g of sample using acetone in a pestle and mortar and then filtering the pigment (Witham *et al*., 1971).The volume was made upto 100 ml with acetone and the absorbance was measured in a UV VIS Spectrophotometer at 652 nm. Total chlorophyll was calculated as:

$$\text{Total chlorophyll (mg/g)} = \frac{\text{OD reading at 652 nm x 1000 x Volume made up}}{\text{34.5 x 1000 x Weight of the sample}}$$

3.6.2.4 Fibre content

The crude fibre content in the samples was estimated by AOAC method (1984). 5g of sample was digested with 200 ml of 1.25 % H_2SO_4 for 30 minutes. The contents were then decanted and the material was filtered through Whatman No. 1 filter paper. The residue was washed with boiling water until the washings were completely acid free. The acid free residue was then treated with 200 ml of 1.25% NaOH and boiled for 30 minutes. After decanting the layer, the material was filtered. The residue was then made alkali free by repeated washing with hot water followed by 80% ethanol and finally with petroleum ether. The sample was then dried in an oven at 100°C for 5 hours and weighed (W_e). Finally the material was transferred to a silica crucible , heated in a muffle furnace at 600°C for 3 hours, cooled in a desiccator and weighed (W_a). The crude fibre content in the sample was calculated as:

$$\begin{array}{c}\text{Crude fibre}\\ \text{(\% dry wt.)}\end{array} = \frac{W_e - W_a \text{ x } 100}{\text{Wt. of sample}}$$

3.6.2.5 Antioxidant phytochemicals (β – carotene, phenolics etc)

3.6.2.5.1 β- Carotene

β- Carotene content of the samples was determined by using the colorimetric method of Srivastava and Kumar (2002). 5g of the sample was extracted with 10 – 15 ml acetone and the supernatant was decanted into a beaker. The process was repeated twice. The combined supernatant was transferred to a separating funnel and 10–15 ml of petroleum ether were added and mixed thoroughly. After discarding the lower layer the upper layer was collected in a 100 ml volumetric flask and the volume was made up with petroleum ether. The OD was recorded at 452 nm and β-carotene was expressed as mg/100 g of sample by the following formula:

$$\underset{(mg/100g)}{\beta\text{-carotene}} = \frac{\text{Optical Density x } 13.9 \text{ x } 10^4 \text{ x } 100}{\text{Weight of the sample x } 560 \text{ x } 1000}$$

3.6.2.5.2 Total Phenols

The total phenol content in the samples was determined by using Folin-ciocalteu assay, following the method of (Bray and Thorpe, 1954). 0.5 gm sample was extracted with 80% (v/v) ethanol and then centrifuged at 10000 rpm for 20 minutes. The pooled supernatants were evaporated to dryness and residue was dissolved in 5 ml of distilled water. Aliquots of the extracts (0.2 and 2.0 ml) were pipetted out and the volume was made up to 3 ml with distilled water. Then 0.5 ml of Folin-ciocalteu reagent and after 30 minutes, 2 ml of 20% (w/v) Na_2CO_3solution are added, mixed thoroughly and kept in a boiling water bath for one minute, cooled and absorbance was measured at 650 nm in a UV-VIS Spectrophotometer against a reagent blank. Standard curve was prepared using different concentrations of catechol. The total phenol content in the samples was calculated by the following formulae:

$$\underset{(ppm)}{\text{Total Phenols}} = \frac{\text{Value from the standard curve x volume made up x volume of extract}}{\text{Volume of aliquot taken x wt. of sample}}$$

$$\underset{(mg/100g)}{\text{Total phenols}} = \frac{\text{Total Phenols (ppm)}}{10}$$

3.6.2.6 Acidity

Percentage tritratable acidity was determined by AOAC method (1980). 10 ml of the sample extract was titrated against 0.1N sodium hydroxide using phenolphthalein as an indicator. Acidity as citric acid was calculated by using the following formulae:

$$\text{\% acidity (as citric acid)} = \frac{\text{Titre value x normality of alkali x 64 x volume made up x 100}}{\text{Volume of sample taken for estimation x weight of sample x 1000}}$$

3.6.2.7 Moisture content

The moisture content of the vegetables was determined by the oven dry method by drying the samples at 60°C till constant weight of the sample was obtained (Rangana 1997).

3.6.2.8 Cooking quality

For cooking quality, fresh leaves were harvested; 200g of the leaves were separated from stalks and washed under running tap water, followed by distilled water. The leaves were then cut into small pieces of 1.0 - 1.5 cm and steam cooked for 15 min. The cooked vegetables were evaluated for cooking quality by manual appreciation method done by a panel of 9 trained people based on a 5 – 1 scale. The rating was based on appearance, taste, color, texture, flavor and overall acceptability. The scoring was as follows:

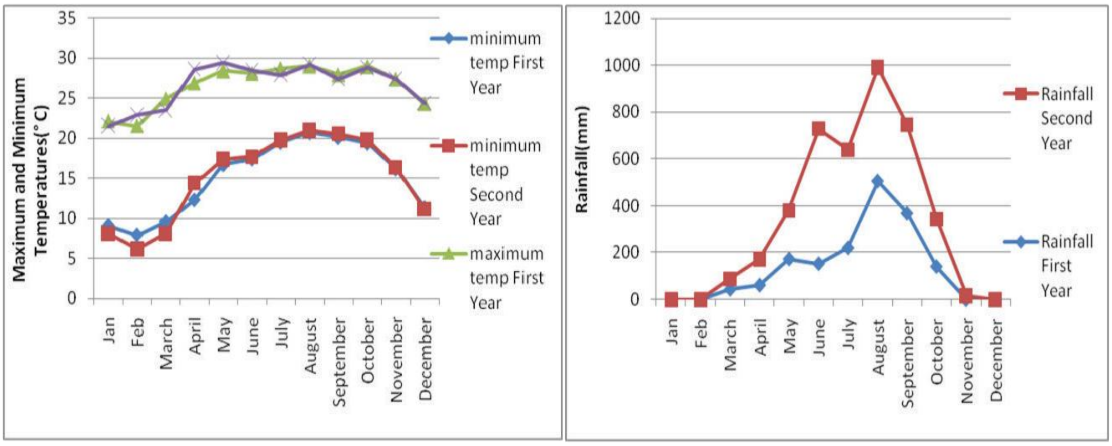
Numbers	Rating
5	Excellent
4	Very good
3	Good
2	Fair
1	Poor

3.6.2.9 Shelf life

Shelf life of the vegetables in days was assessed on the basis of acceptance and edibility from the day of harvest. 200g of fresh leaves were harvested at each stage of maturity and kept on plastic trays at room temperature. The samples were analysed by visual observations like colour change, freshness, texture, shrinkage, rotting etc. More than 50% decay/yellowing/shrinkage of leaves was considered as the critical limit for shelf life termination.

3.7 Meteorological parameters

The meteorological data during the experiment are presented in Figures 1 and 2.



(* First Year = 2010, Second Year = 2011)

Source: (ICAR Research Complex for NEH Region, Umiam, Meghalaya)

Figs. 1 and 2 Meteorological data during the experiment

3.8 Statistical analysis

The data obtained during the period of investigation was analysed through Completely Randomized Design by analysis of variance method. The significance of different sources of variation was tested by error mean square using Snedecor and

Cochran 'F' test of probability at 0.05 per cent level (Panse and Sukhatme, 1978).

If the variance was found to be significant, the standard error of the mean S.Ed(±) was calculated by using the following expression:

$$S.Ed = \sqrt{\frac{2 \times \text{Error mean square}}{\text{Total number of replications}}}$$

Chapter IV

EXPERIMENTAL FINDINGS

The present study consisted of three Experiments i.e. Experiment I, Experiment II and Experiment III. Experiment I consisted of collection of underexploited leafy vegetables from different locations of Meghalaya, which were propagated in the research Farm of the Division of Horticulture, Experiment II consisted of evaluation of morphological and physicochemical characters of the collected vegetables and Experiment III consisted of standardization of maturity indices of the collected vegetables. The salient findings of the present investigation are discussed together with logistic views under the following heads-

4. I Experiment I: Collection of different underexploited leafy vegetables of Meghalaya

For Experiment I, planting materials of underexploited vegetables were collected from different parts of Meghalaya. Among the collected vegetables, twenty five were selected on the basis of preference and survival rate and were propagated in the research Farm of the Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya.

4.1.1 Brief description of the selected vegetables:

1. Common Name: Pennywort, Indian Pennywort

Local Name: Mansyiar (K), Manimuni (G)

Botanical Name: *Centella asiatica* (L.)

Family: Apiaceae

Spacing used: 30 x 15 cm^2

Collected From: Lower Sangsanggre,
West Garo Hills, Meghalaya

Fig 3. *Centella asiatica* plants

Centella asiatica is a small herbaceous tropical perennial plant that can be grown as an annual in temperate gardens. It is indigenous to the warmer regions of both the hemispheres, including Asia, Africa, Australia, southern United States of America, Central America and South America.

It is used as a vegetable in many cuisines; being most commonly used as a green salad vegetable. It is also used as a cooked vegetable and as a medicinal herb in Ayurvedic medicine, traditional African medicine, and traditional Chinese medicine.

Centella asiatica is a slender trailing herb, rooting at the nodes. The plant has long- stalked, green, reniform leaves with rounded apices which have smooth texture with palmately netted veins. The rootstock consists of rhizomes, growing vertically down and stolons which grow horizontally, interconnecting one plant to another. The flowers are pinkish to red in color, born in small, rounded bunches (umbels) near the surface of the soil. *Centella asiatica* grows in tropical swampy areas. The plant spreads by producing new plants on above-ground runners. The new plants can be separated from the parent plant once they have produced roots.

2. Common Name: Common Plantain

Local Name: Skorblang (K, J)

Botanical Name: *Plantago major*

Family: Plantaginaceae

Spacing used: 30 x 20 cm^2

Collected From: Smit, East Khasi Hills Meghalaya

Fig 4. *Plantago major* plants

Plantago major is a herbaceous perennial plant native to most of Europe and northern and central Asia.

Plantago major is one of the most abundant and widely distributed medicinal crops in the world. It is also a highly nutritious wild edible that is high in calcium and vitamins A, C, and K. The young, tender leaves can be eaten raw, and the older, stringier leaves can be boiled in stews and eaten.

The plant has a rosette of leaves 15–30 cm in diameter. Each leaf is oval-shaped, 5 - 20 cm long and 4 - 9 cm broad, rarely upto 30 cm long and 17 cm broad, with an acute apex and a smooth margin; there are five to nine conspicuous veins. The flowers are small, greenish-brown with purple stamens, produced in a dense spike 5 - 15 cm long on top of a stem 13 - 15 cm tall (rarely to 70 cm tall). Greater Plantain is a common garden weed. It can be found on roadsides, grassland, waste and cultivated grounds. It can be found it compacted and soggy sites where other plants may not thrive. It succeeds in any soil and prefers a sunny position. Plantain is wind-pollinated, and propagates primarily by seeds, which are held on the long, narrow spikes which rise well above the foliage.

3. Common Name: Chameleon Plant, Rainbow Plant

Local Name: Jamyrdoh (K, J)

Botanical Name: *Houttuynia cordata* (Thunb.)

Family: Sauraceae

Spacing used: 30 x 20 cm^2

Collected From: Lawsohtun, East Khasi Hills Meghalaya

Fig 5. *Houttuynia cordata* plants

Houttuynia cordata is a herbaceous perennial plant growing to between 20 and 80 cm. The plant is native to Japan, Korea, southern China, and Southeast Asia. It is grown as a leaf vegetable for its tender young shoots and leaves eaten raw or cooked as a pot-herb. The whole plant is also used in folk medicine for diuresis and detoxification and herbal medicine for its antiviral, antibacterial and antileukemic activities.

Houttuynia is a rhizomatous plant spreading indefinitely and often vigorously by rhizomes. The proximal part of the stem is trailing and produces adventitious roots, while the distal part of the stem grows vertically. The leaves are alternate, broadly heart-shaped, 4 - 9 cm long and 3 - 8 cm broad. Flowers, growing usually in summer, are greenish- yellow, borne on a terminal spike 2 - 3 cm long with 4 - 6 large white basal bracts. The plant grows well in moist to wet soil and even slightly submerged in water in partial or full sun. It is propagated by seeds or division or semi-ripe cuttings of young basal shoots.

4. Common Name: Perennial Buckwheat

Local Name: Jarain (K, J)

Botanical Name: *Fagopyrum cymosum* (Meissn.)

Family: Polygonaceae

Spacing used: 30 x 30 cm^2

Collected From: Jowai, West Jaintia Hills, Meghalaya

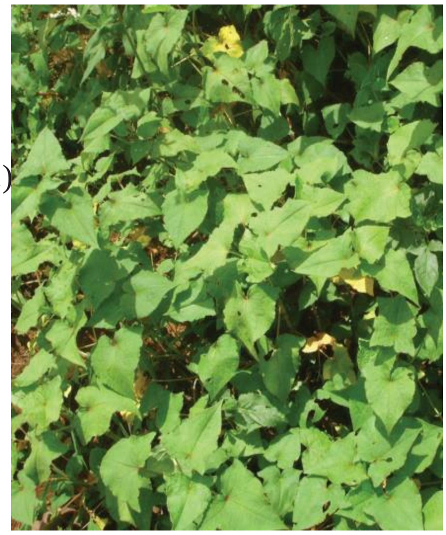


Fig 6. *Fagopyrum cymosum* plants

Perennial Buckwheat is a perennial plant growing up to 2 m. The plant is indigenous to the warmer regions of both the hemispheres, including Asia, Africa, Australia, southern United States of America, Central America and South America.

Leaves are taken raw or cooked, boiled or steamed and used like spinach. It is also used in folk medicine. The whole plant is anodyne, anthelmintic, antiphlogistic, carminative, depurative and febrifuge. It stimulates blood circulation.

Perennial Buckwheat is a tall, sparsely velvety, branched herb. Leaves are broadly triangular, arrow-shaped or heart-shaped, long-pointed, carried on 1.5 - 7 cm long stalks - upper stalks are short and the lower ones long. Stems are subterranean, thick and fleshy, with globular enlargements. Flowers are borne one-sided on the long recurved branches of the inflorescence. The plant is found growing mostly along side ditches on shady damp and fertile soil. A very tolerant and easily grown plant, it prefers dry sandy soils but succeeds in most conditions including poor, heavy or acid soils and even sub-soils. It is propagated by seeds or division.

5. Common Name:	Spiny coriander, long coriander
Local Name:	Dhania Khlaw (K,J), Etucha(G)
Botanical Name:	*Eryngium foetidum* (L.)
Family:	Apiaceae
Spacing used:	30 x 15 cm^2
Collected From:	Sonidan, Ri Bhoi Meghalaya

Fig 7. *Eryngium foetidium* plants

Eryngium foetidum is a tropical perennial and annual herb in the family Apiaceae. It is native to Mexico and South America and is mostly grown in tropical Africa, South Asia, warmer southern parts of Europe and Pacific Islands.

Long coriander has a typical aromatic flavor and is used for garnishing, marinating, flavouring and seasoning of cuisines in different parts of the world. It is also used in traditional medicine for treating burns, ear ache, fevers, hypertension, constipation, fits, asthma, stomachache, worms, infertility complications, snake bites, diarrhea, and malaria etc.

The plant length ranges from 10 to 30 cm along with 5 - 8 leaves/plant. The leaf margin is serrated and the fleshy and waxy oblanceolate or lanceolate leaves form a basal rosette. Inflorescence dichotomously branched and flowers densely crowded in simple umbels of oblong heads sessile on a whorl of radiating bracts. It grows naturally in shaded- moist forest soils, Jhum lands and along moist shaded pathways where heavy soils predominate. The plants are easily propagated by seeds (germinates in 20–25 days) in spring or suckers during monsoon.

6. Common Name:	Benghal dayflower or tropical spiderwort
Local Name:	Bat – pied (K)
Botanical Name:	*Commelina benghalensis* (L.)
Family:	Commelinaceae
Spacing used:	30 x 30 cm^2
Collected From:	Garobadha, West Garo Hills, Meghalaya

Fig 8. *Commelina benghalensis* plants

Commelina benghalensis is a creeping annual or perennial herb, native to tropical Asia and Africa.

The leaves of Benghal dayflower are harvested from the wild for local consumption, in many areas they are viewed as a famine food and only eaten in times of scarcity. The plant also has local medicinal uses and is the source of a dye.

Commelina benghalensis is a herbaceous perennial plant, with long, creeping, succulent stems that can be 60 - 90cm long; and ascending, jointed branches, rooting where the nodes touch the ground. The plant can become annual in areas with colder winters or long dry seasons. Leaves are usually shortly stalked and oblique-based, broad with purple or white hairs or narrow with white hairs on sheath-margins. Flowers are produced in spathes often found in clusters, funnel shaped, on peduncles 1-3.5 mm in length. The plant grows best under conditions of highs soil moisture and fertility, in sunny or lightly shaded places, though it can also persist in loamy, sandy, or rocky soils. It can be propagated from seeds, stem cuttings and root cuttings.

7. Common Name: Nepalese Knotweed

Local Name: Bat – saw (K)

Botanical Name: *Polygonum alatum* (Buch. – Ham. Ex Spreng.)

Family: Polygonaceae

Spacing used: 30 x 30cm^2

Collected From: Baghmara, South Garo Hills Meghalaya

Fig 9. *Polygonum alatum* plants

Polygonum alatum is an annual, believed to have originated in the Himalayas but it is now quite widespread, across the Asian, African and American continents and in the Pacific.

The leaves and tender shoots of *Polygonum alalatum* are used as vegetable and as famine food. The plant is also used in leprosy and paralytic patients, skin diseases and boils (rhizome boiled/paste) by traditional healers of Khasi tribe of Meghalaya.

Polygonum alatum is a relatively short-lived annual, completing development within 4 - 5 months. The plant is an erect or procumbent annual; stems are slender, glabrous, internodes long. Leaves are alternate, ovate to elliptic, up to 5 cm long, often with a pair of dark blotches each side of the mid-rib. The individual flowers, 2 - 3 mm long, are usually pink, but sometimes white, with four perianth segments. Usually it grows in damp shaded situations. It prefers moist or wet soil. It can be propagated from seeds or division of rootstalk.

8. Common Name: Roselle

Local Name: Jarsong (K), Galda (G)

Botanical Name: *Hibiscus sabdariffa* (L.)

Family: Malvaceae

Spacing used: 50 x 50 cm^2

Collected From: Asanggre, West Garo Hills Meghalaya

Fig 10. *Hibiscus sabdariffa* plants

Hibiscus sabdariffa is a robust annual shrub growing up to 3.5 – 4.0 m tall. It is native to West Africa, cultivated throughout the tropics.

Young roselle shoots, leaves and calices are used as cooked vegetable or finely cut and used in sauce. Roselle has antispasmodic, anthelminthic and bactericidal properties. The plants are rich in anthocyanins, as well as protocatechuic acid.

Roselle is an erect, mostly branched, annual; stems variously colored dark green to red; leaves alternate, glabrous, long-petiolate, palmately divided into 3 - 7 lobes, with serrate margins; flowers large, short-peduncled, red to yellow with dark center; capsules 5 cm long, 5.3 cm wide; root a deep penetrating taproot. It prefers tropical climates with well-distributed yearly rainfall of 1500 - 2000 mm, from sea-level to about 600 m altitude. It tolerates a warm and humid climate but is more susceptible to damage from frost and fog. Roselle is propagated from seeds

.

9. Common Name: Edible fern

Local Name: Tarkhang (K)

Botanical Name: *Diplazium esculentum* (Retz.)Sw.

Family: Athyriaceae

Spacing used: 50 x 45cm^2

Collected From: Lower Sangsanggre, West Garo Hills, Meghalaya

Fig 11. *Diplazium esculentum* plants

Diplazium esculentum is a terrestrial, fern, native to Asia. It is the most commonly eaten vegetable/greens of all the fern found throughout Asia and Oceania.

The young uncurled leaves of the plant called fronds are boiled, fried or raw and eaten with or without other vegetables. It is a good source of protein and sometimes taken as a medicine. Rhizome and young leaves have medicinal properties.

Diplazium is a terrestrial, palustrial fern, up to 2.5 m tall. The rootstocks are stout. The trunk is erect, woody, thickened, and bears many black wiry roots. The leafstalk is about 70 cm long. Foliage is compound up to 1.7 m, with 12 - 16 leaflets, more narrow at the top, up to 40 cm long and 25 cm wide. Spores are found along the whole length of the veinlets. The crop is found growing on sandy soil in open, shady, moist, swampy places along watercourses in forests and bamboo tickets, sometimes forming extensive colonies. The plant can be propagated by spores, rhizomes and division. In nature it forms clonal colonies by vegetative reproduction from root buds.

10. Common Name: Taro

Local Name: Chrew (K,J), Matchitangong (G)

Botanical Name: *Colocasia esculenta* (L.)

Family: Araceae

Spacing used: 45 x 30cm^2

Collected From: Asanggre, West Garo Hills Meghalaya

Fig 12. *Colocasia esculenta* plants

Colocasia esculenta is a perennial herb native to India and southeastern Asia; found throughout the tropics and much of the subtropics.

The tender leaves and tubers are eaten as vegetable, especially with acidic fruit in various forms.

Colocasia is a tuberous- rhizomatous herb. Leaves are with stout petioles, sheathing below; lamina is peltate, ovate, cordate. Leaf and petiole are purple coloured. Flowers are monoecious; spathe yellow, on a stout axillary peduncle; spadix shorter than the spathe, male and female inflorescence with usually interposed, flat neuters. Fruit consists of small oblong berries. It is a very common herb found in wild in open and damp areas. It can be propagated from corms, crowns and petiole.

11. Common Name: Lilac Tassleflower

Local Name: Jangao (K)

Botanical Name: *Emilia sonchifolia* (L.) DC.

Family: Asteraceae

Spacing used: 20 x 15 cm^2

Collected From: Umwas, Ri Bhoi Meghalaya

Fig 13. *Emilia sonchifolia* plants

Emilia sonchifolia is a small, short-lived, herbaceous plant native to Central and South America, Eastern and southern Asia and western Pacific.

The stems and leaves are taken as vegetable. The plant has astringent, antipyretic, anti-infection, febrifuge, anti-inflammatory, diuretic and sudorific properties.

Emilia sonchifolia is an erect or ascending, variable, smooth or sparingly hairy, more or less branched plant 10 to 40 centimeters high. The greenish stems are round in cross-section and hairless or sparsely hairy. Its leaves (1.5 - 13 cm long) are arranged in a weak rosette and alternately arranged along the stems; the larger lower leaves are deeply- lobed while the smaller upper leaves are narrower and almost entire. Flowering heads are 12 to 24 millimeters in length and long-peduncled; the branches are usually dichotomous. It grows in open places, wastelands, cultivated lands, gardens, etc., in and about towns and settlements at low and medium altitude. It prefers well-drained moist soil. Propagation is done by seeds.

12. Common Name: Field Mint

Local Name: Pudina (K, J, G)

Botanical Name: *Mentha arvensis* (L.)

Family: Lamiaceae

Spacing used: 45 x 40 cm^2

Collected From: Baghmara, South Garo Hills Meghalaya

Fig 14. *Mentha arvensis* plants

Field Mint is a herbaceous creeping perennial plant. It is native to the temperate regions of Europe and western and central Asia, east to the Himalaya and eastern Siberia, and North America.

The leaves have a reasonably strong minty flavour with a slight bitterness, and are used as flavouring in salads or cooked foods. The entire plant is antibacterial, antifibrile. It yields an essential oil and menthol.

The plant grows to 10 - 60 cm tall. The leaves are lanceolate-oblong, sharply toothed; in opposite pairs, simple, 2 - 6.5 cm long and 1 - 2 cm broad, hairy, and with a coarsely serrated margin; petiole is small about 5mm. The flowers are pale purple (occasionally white or pink), in clusters on the stem, each flower 3 - 4 mm long. It can grow in semi-shade (light woodland) or no shade and prefers dry or moist soil. It does not produce seed and propagation is through vegetative means only (stolons).

13. Common Name: Brazilian Cress

Local Name: Ja- sat (K), Mahong (G)

Botanical Name: *Spilanthes acmella* (L.)

Family: Asteraceae

Spacing used: 30 x 30 cm^2

Collected From: Umsaw, Ri Bhoi Meghalaya

Fig 15. *Spilanthes acmella* plants

Spilanthes acmella is native to Brazil and Africa. It grows both as an annual and a perennial.

The fresh leaves are eaten and used sparingly as cress as an additive to salads; they are even combined with chillies to offset the burn. The plants contain spilanthol which acts as an anaesthetic/analgesic. They also show anti-inflammatory, antibacterial, and antifungal properties. The entire plant (root, stem, leaf and flower) is medicinally active.

Spilanthes acmella is a tender annual grows up to 40cm, with soft branching stems that are swollen at the nodes with a sort of flare into the leaves and peduncles or emerging stems; stems are initially flushed red or purple, later more green and less pubscent; leaves are opposite, ovate-lanceolate, with wavy margins; flowers are bright yellow in terminal heads. Flowers process a tingling sensation while chewing. Seeds many, small compressed and brown colored. It is easily grown in most any good well drained garden soil in a full to partial sun exposure. It is propagated by seeds.

14. Common Name: Creeping wood sorrel

Local Name: Kynbat Dkhiew (K)

Botanical Name: *Oxalis corniculata* (L.)

Family: Oxiladaceae

Spacing used: 20 x 15 cm^2

Collected From: Lawsohtun, East Khasi Hills, Meghalaya

Fig 16. *Oxalis corniculata* plants

Oxalis corniculata grows as an annual in cooler regions but is perennial in warmer zones. Its place of origin is unknown, but it is considered an Old World plant occurring also in the temperate and tropical regions of North, Central and South America and the West Indies.

It is often used as a vegetable. Leaves are added to salads, cooked as a potherb with other milder flavoured greens or used to give a sour flavour to other foods. The whole plant is anthelmintic, ntiphlogistic, astringent, depurative, diuretic, emmenagogue, febrifuge, lithontripic, stomachic and styptic.

The plant is a small variable, prostrate, creeping herb, somewhat pubescent with long, scattered hairs, the stems creeping, up to 50 centimeters in length, usually rooting at the nodes. Leaves are trifoliate, with three small heart-shaped leaflets, their petioles 5 centimeters long or less, sessile. Leaflets are obcordate, 0.5 to 1.5 centimeters long and stalkless. At noontime, the leaflets droop like folded umbrellas. At night, the leaflets close and fold together. Flowers are yellow, one to several on each peduncle, subumbellately disposed, nearly 1 centimeter long. It commonly grows in arable land and waste places, open grasslands, etc., from sea level to an altitude of 2,200 meters. It spreads rapidly by seed and underground bulbils and rooting from nodes.

15. Common Name: Malabar spinach/ Indian spinach

Local Name: Palng – saw (K)

Botanical Name: *Basella rubra* (L.)

Family: Basellaceae

Spacing used: 40 x 35 cm^2

Collected From: Garobadha, West Garo Hills Meghalaya

Fig 17. *Basella rubra* plants

The Malabar-spinach is an herbaceous perennial vine native to the Indian Subcontinent, southeast Asia and New Guinea. Today it is cultivated extensively as a green vegetable in South-East Asia, Africa and India.

Malabar-spinach is eaten raw, in simple salads, or cooked. This vegetable is a good source of vitamin A, carotene, carbohydrates, starch, mineral salts like calcium, magnesium and iron as well as vitamins B_1, B_2 and E. The leaves contain several active components including flavonoids exhibit antioxidative, antiproliferative and anti- inflammatory properties in biological system.

Malabar spinach is a copious perennial climber which branches out widely growing upto 3 - 20 feet. Stems are thick and tender; the leaves are almost circular to ovate, alternate and short petioled. They are thick, rugose, succulent and coloured from green to purple with a hunt of red. Flowers are tiny white or pink, hermaphrodite; their cup shape calyx has five stamens attached to the spathe from the base. The plant prefers moist, warm climate zones. It can be grown from seeds or cuttings.

16. Common Name:	Alligator Weed
Local Name:	Jhurjhunput (K), Gri – Sob(G)
Botanical Name:	*Alternanthera philoxeroides (Mar.) Grisep.*
Family:	Amaranthaceae
Spacing used:	30 x 20 cm^2
Collected From:	Sonidan, Ri Bhoi Meghalaya

Fig 18. ***Alternanthera philoxeroid*** **plants**

Alternanthera philoxeroides is a perennial succulent plant which originated in South America. It can now be found elsewhere in South America, and also on the continents of North America, Australia, and Asia, and on a number of adjacent islands.

The plant has been reported to be used as a leafy vegetable by people in different parts of the world. It is also usd as a medicinal plant for cold, clearing heat and cooling blood, detoxicating and disinhibiting urine. The plant is anti-viral, antibacterial, and hepatic-protective.

Alligator weed is a summer perennial that typically grows to around 1 - 2 m and whose fleshy, succulent horizontal stems (called stolons) can reach 10 m. The stems are long, branched, and hollow. It can grow horizontally and float on the surface of the water, forming rafts, or form matted clumps which grow onto banks. Leaves are simple, elliptic, and have smooth margins; opposite in pairs or whorls, with a distinctive midrib, and range in size from 5 - 10 cm. Flowers are whitish, papery ball-shaped growing on stalks. Alligator weed can grow in a variety of habitats, including dry land, but is usually found in water. Reproduction in *Alternanthera philoxeroides* is predominantly through vegetative means. Vegetative growth occurs at the apical stem buds and axillary stem and root buds and the plant spreads through fragmentation.

17. Common Name: Bush Passion fruit,

Local Name: Sohbrap (K)

Botanical Name: *Passiflora edulis* (Sims.)

Family: Passifloracea

Spacing used: 50 x 50 cm^2

Collected From: Jowai, West Jaintia Hills Meghalaya

Fig 19. *Passiflora edulis* plants

Passiflora edulis is a herbaceous perennial vine native to Brazil, Paraguay and northern Argentina. It has been introduced to tropical regions around the world such as South East Asia and Hawaii.

Apart from the fruits, young leaves and plant tips of *Passiflora edulis* are also edible. Dry leaves are used in tea in Vietnamese folk medicine to relieve sleeping problems. Passion fruit oil is extracted from the seeds. It has varied applications in cosmetics manufacturing and for uses as a human or animal food.

The passion fruit vine is a shallow-rooted, woody, perennial, climbing by means of tendrils. The alternate, evergreen leaves, deeply three-lobed when mature, are finely toothed, 3 to 8 in (7.5 - 20 cm). A single, fragrant flower, 2 to 3 in (5 - 7.5 cm) wide, is borne at each node on the new growth. The plant occurs in wet areas or those areas where there is a pronounced damp season. It is common in plantations, rough pastures, roadsides and wasteland. Propagation can be done from seeds or from cuttings. The seed of *P. edulis* can be easily collected, and the dried seeds used for germination purpose. In *P. edulis* the cuttings with two to three growing points each can be used for propagation directly.

18. Common Name:	Hooker chives,
Local Name:	Ja – ut (K)
Botanical Name:	*Allium hookeri* (Thw.)
Family:	Liliaceae
Spacing used:	30 x 20 cm^2
Collected From:	Smit, East Khasi Hills Meghalaya

Fig 20. *Allium hookeri* plants

Allium hookeri is a perennial plant native to India, Sri Lanka, Myanmar (Burma), Bhutan and southwestern China. It is distributed in Eastern Himalayas, Tibet, South West China, North Eastern India, North Thailand, Sri Lanka.

The plant is used to garnish the cooking. The leaves and bulb can be eaten raw or cooked. The raw flowers can be used as a garnish on salads. The juice of the plant is used as a moth repellent. The whole plant is said to repel insects.

Hooker Chives is a bulbous herb with thick, fleshy roots. Bulbs are clustered and cylindric. Leaves are linear, shorter than or nearly equaling the flowering scape, 0.5 - 1 cm wide mid-vein distinct. Flowers are borne in hemispheric to spherical, many flowered umbels. The plant grows in forests, forest margins, moist places and meadows at elevations from 1400 - 4200 metres. It is propagated by division.

19. Common Name: Dock, sorrel

Local Name: Jarben (K)

Botanical Name: *Rumex nepalensis* (L.)

Family: Polygonaceae

Spacing used: 45 x 40 cm^2

Collected From: Jowai, West Jaintia Hills Meghalaya

Fig 21. *Rumex nepalensis* plants

Rumex nepalensis is a perennial herb, originating in from the northern temperate regions and widespread throughout Africa and the Mediterranean to eastern Asia.

Tender young leaves and shoots - cooked as a vegetable, roots are used as a rhubarb substitute. The herb is also considered as a medicine for cough and headache, as a laxative, antidote and depurative.

Rumex nepalensis is a stout, erect, rhizomatous perennial herb growing up to 1- 2 m tall, with green or pale brown stems. Leaves are alternate, simple; lower leaves long- petiolate, upper leaves shortly petiolate; blade of lower leaves oblong-ovate, 20 - 33 cm × 12 - 20 cm, base cordate, margins undulate-denticulate, crispy or flat, puberulous beneath, blade of cauline and upper leaves broadly ovate-lanceolate, base cordate to rounded or subtruncate. Inflorescence is a panicle with spreading branches, almost leafless, with somewhat remote whorls of flowers. Flowers are unisexual, usually pendulous. Fruits are sharply trigonous, ovoid nuts 3 - 5 mm × 2 - 2.5 mm, glossy brown. *Rumex nepalensis* occurs as a weed in disturbed habitats, and in moorland, grassland and bush land at 700 - 4000 m altitude. It grows well in most soils but prefers a deep fertile moderately heavy soil that is humus-rich, moisture-retentive but well-drained and a position in full-sun or part shade. *Rumex* is mainly propagated by seed, and after establishment, by division.

20. Common Name: Slender Amaranth or Green Amaranth

Local Name: Jada saw (K)

Botanical Name: *Amaranthus viridis* (L.)

Family: Amaranthaceae

Spacing used: 35 x 30 cm^2

Collected From: Garobadha, West Garo Hills Meghalaya

Fig 22. *Amaranthus viridis* plants

Amaranthus viridis is an annual possibly of Asian origin, distributed in tropical and subtropical regions of the world, also penetrating far into temperate regions.

It is occasionally cultivated as a leafy vegetable. Leaves and young plants are eaten as a cooked vegetable. The plant is also a good cattle fodder and green manure. The leaves are diuretic and purgative, and are used in poultices (fresh or as dried powder) to treat inflammations, boils and abscesses, gonorrhoea, orchitis and haemorrhoids. *Amaranthus viridis* is used as a medicinal herb in traditional Ayurvedic medicine.

The plant is an erect or ascending annual or short-lived perennial herb up to 1 m tall; stem are slender, branched, angular, glabrous to sparsely pubescent in upper part with multicellular hairs. Leaves are alternate, simple; petiole up to 10 cm long; blade deltoid- ovate to rhomboid-oblong. Inflorescence consists of agglomerated cymes arranged in slender, axillary or mostly terminal spikes, frequently paniculate, in the lower part of the stem often in dense axillary clusters. It prefers a well-drained fertile soil in a sunny position. It is found growing on disturbed or cultivated land, often around habitations. It is propagated from seeds.

21. Common Name: Malabar Nut

Local Name: Devglamch (G)

Botanical Name: *Justicia adhatoda* (L.)

Family: Acanthaceae

Spacing used: 60 x 60 cm^2

Collected From: Lower Sangsanggre, West Garo Hills, Meghalaya

Fig 23. *Justicia adhatoda* plants

Justicia adhatoda is an evergreen, sub- herbacious medicinal plant native to Asia. The plant grows wild in abundance all over Nepal, India, and the Pothohar region of Pakistan.

Leaves as well as inflorescence are used as food. This shrub has a number of traditional medicinal uses. It has been used as an antispasmodic, bronchodilator, and mucolytic agent in asthma and other respiratory conditions. It has oxytocic properties and can be abortifacient. Several alkaloids are present in the leaves. The most important is vasicine, a quinazoline alkaloid responsible for the medicinal activity of the plant.

J. adhatoda is a tall dense evergreen shrub with thick branches growing up to 8feet. This is a many branched shrub. The leaves are opposite, elliptic lanceolate, acute with narrow base 10 to 15 centimeters in length, smooth-edged, and borne on short petioles. Flowers are white in a dense bracteate peduncled spike, solitary or terminal at the end of the branches. Malabar nut grows commonly in open plains. This shrub grows on the plains of India and in the lower Himalayans, up to a range of 1000 meters above sea level. This plant is also cultivated in other tropical areas. It grows well in low moisture areas and dry soils however, it grows best in shaded or semi-shaded areas, and it will tolerate dry soil. It can be propagated by seeds or vegetative cuttings.

22. Common Name: Pippali

Local Name: Pathishree (K)

Botanical Name: *Piper longum* (L.)

Family: Piperaceae

Spacing used: 45 x 40 cm^2

Collected From: Lower Sangsanggre, West Garo Hills Meghalaya

Fig 24. *Piper longum* plants

Piper longum is a perennial aromatic herb, trailing either on ground or climbing on trees. It is indigenous to North-eastern and Southern India and Sri Lanka.

Pippali is certainly one of the most widely used of all Ayurvedic herbs. It is one of the best herbs for enhancing digestion, assimilation and metabolism of the foods. It is also highly prized for its ability to enhance assimilation and potency of herbs in a synergistic formula.

Long pepper is a perennial long slender climber with woody roots, creeping and jointed stems with fleshy fruits embedded in the spikes. The leaves of this slender climber are numerous of about 6.3 - 9.0 cm, broadly ovate, oblong-oval, dark-green and lustrous yet partly dull. The flowers are both male and female as male flower stalk is about 1 to 3 inch long while female flower stalk is ½ to 1 inch long. The fruit is long measures upto 1inch in diameter and is green-yellow when young while it gets black when ripened. *Piper longum* grows well in sandy loamy soils, which are well drained. Soils with rich organic matter and good moisture holding capacity are good for its vigorous growth. It can be propagated through seeds, suckers or cuttings.

23. Common Name: Spinach Dock or Narrow-leaved Dock, Garden Sorrel

Local Name: Khatta sag (G)

Botanical Name: *Rumex acetosa* (L.)

Family: Polygonaceae

Spacing used: 45 x 40 cm^2

Collected From: Asanggre, West Garo Hills Meghalaya

Fig 25. *Rumex acetosa* plants

Rumex acetosa is a perennial herb native to Eurasia and is cultivated as a garden herb or leafy vegetable. It occurs in grassland habitats throughout Europe from the northern Mediterranean coast to the north of Scandinavia and in parts of Central Asia.

The leaves are eaten raw or cooked. They make a thirst-quenching on their own, or can be added to salads, used as a potherb or pureed and used in soups. The dried and fresh leaves of sorrel have medicinal value. The medicinal action of sorrel is refrigerant and diuretic, and it is employed as a cooling drink in all febrile disorders.

Sorrel is a slender plant about 60 cm high, with roots that run deep into the ground, as well as juicy stems and edible, oblong leaves. The lower leaves are 7 to 15cm in length, slightly arrowshaped at the base, with very long petioles. The upper ones are sessile, and frequently become crimson. A very easily grown and tolerant plant, it succeeds in most soils, preferring a moist moderately fertile well-drained soil in a sunny position. It is shade tolerant. Propagation is done by seeds and divisions.

24. Common Name: Indian mustard

Local Name: Laipatta (K, G)

Botanical Name: *Brassica juncea* (L.)

Family: Brassicaceae

Spacing used: 45 x 30 cm^2

Collected From: Jowai, West Jaintia Hills Meghalaya

Fig 26.*Brassica juncea* plants

Brassica juncea is a perennial herb grown as an annual or biennial with primary center of origin in Central Asia (northwest India). The principle growing countries are Bangladesh, Central Africa, China, India, Japan, Nepal, and Pakistan, as well as southern Russia north of the Caspian Sea.

Young tender leaves of mustard greens are used in salads or mixed with other salad greens. Older leaves with stems may be eaten fresh, canned or frozen, for potherbs, and to a limited extent in salads. Mustard greens are high in Vitamin A and C, and iron. They are reported to be anodyne, apertif, diuretic, emetic, rubefacient, and stimulant. Mustard is a folk remedy for arthritis, footache, lumbago, and rheumatism.

The plants are up to 1 m or more tall pubescent or rarely glabrous sometimes with fleshy taproots. Stems erect, branched above.; branches are long, erect or patent; lower leaves are petioled, green, sometimes with a whitish bloom, ovate to obovate, variously lobed with toothed, scalloped or frilled edges, lyrate-pinnatisect, with 1 - 2 lobes or leaflets on each side and a larger sparsely setose, terminal lobe; upper leaves subentire, short petioled, 30 - 60 mm long, 2 - 3.5 mm wide, constricted at intervals, sessile, attenuate into a tapering, seedless, short beak 5 - 10 mm long. Rooting depth is upto 90 - 120 cm. It is a hardy, cool-season vegetable, growing well at monthly average temperatures of 15 to 18°C. It is moderately tolerant of soil acidity, preferring a pH from 5.5 to 6.8. It is mainly propagated from seeds.

25. Common Name: White goosefoot

Local Name: Jada (K)

Botanical Name: *Chenopodium album* (L.)

Family: Chenopodiaceae

Spacing used: 45 x 35 cm^2

Collected From: Sonidan, Ri Bhoi Meghalaya

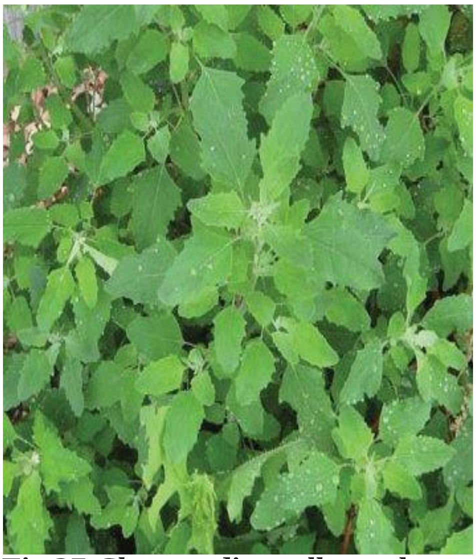


Fig 27.*Chenopodium album* plants

Chenopodium album is a fast-growing weedy annual plant native in eastern Asia It is widely introduced elsewhere, e.g., Africa, Australia, North America and Oceania and now occurs almost everywhere in soils rich in nitrogen, especially on wasteland.

The leaves and young shoots are eaten as a vegetable, either steamed in its entirety, or cooked like spinach. The plant is not employed in herbal medicine, though it does have some gentle medicinal properties and is a very nutritious and healthy addition to the diet. The leaves are anthelmintic, antiphlogistic, antirheumatic, and mildly laxative.

Chenopodium album plants tend to grow upright at first, reaching heights of 10 - 150 cm, but typically become recumbent after flowering (due to the weight of the foliage and seeds) unless supported by other plants. The leaves are alternate and can be varied in appearance. The first leaves, near the base of the plant, are toothed and roughly diamond- shaped, 3 - 7 cm long and 3 - 6 cm broad. The leaves on the upper part of the flowering stems are entire and lanceolate-rhomboid, 1 - 5 cm long and 0.4 - 2 cm broad; they are waxy-coated, unwettable and mealy in appearance, with a whitish coat on the underside. The small flowers are radially symmetrical and grow in small cymes on a dense branched inflorescence 10 - 40 cm long. White goosefoot grows in cultivated ground, especially on rich soils and old manure heaps. It prefers moist soil and can grow in very acid and very alkaline soils and propagated from seeds.

4.2 Experiment II & III: Evaluation of morphological and physicochemical characters of the collected vegetables and standardization of maturity indices of the collected vegetables

In the second and third experiments, the selected vegetables were analysed for their morphological and physicochemical parameters and their maturity indices were standardized based on their morphological and physicochemical parameters. The vegetables were harvested at six different stages of maturity i.e., 2 WAE, 4 WAE, 6 WAE, 8 WAE, 10 WAE and 12 WAE and the different parameters were analysed. The experiment was conducted for two consecutive years.

4.2.1 Morphological parameters

4.2.1.1 Whether annual or perennial

The annual or perennial natures of the collected vegetables are presented in Table
4.1. Among the 25 collected vegetables, 19 were found to be perennial and six vegetables, namely, *Polygonum alatum*, *Hibiscus sabdariffa*, *Emilia sonchifolia*, *Spilanthes acmella*, *Amaranthus viridis* and *Chenopodium album* were found to be annual.

Table 4.1 Annual/perennial nature of leafy vegetables under study

Sl. No.	Crop	Annual/Perennial
1.	*Centella asiatica*	Perennial
2.	*Plantago major*	Perennial
3.	*Houttuynia cordata*	Perennial
4.	*Fagopyrum cymosum*	Perennial
5.	*Eryngium foetidum*	Perennial
6.	*Commelina benghalensis*	Perennial
7.	*Polygonum alatum*	Annual
8.	*Hibiscus sabdariffa*	Annual
9.	*Diplazium esculentum*	Perennial
10.	*Colocasia esculenta*	Perennial
11.	*Emilia sonchifolia*	Annual
12.	*Mentha arvensis*	Perennial
13.	*Spilanthes acmella*	Annual
14.	*Oxalis corniculata*	Perennial
15.	*Basella rubra*	Perennial
16.	*Alternanthera philoxeroides*	Perennial
17.	*Passiflora edulis*	Perennial
18.	*Allium hookeri*	Perennial
19.	*Rumex nepalensis*	Perennial
20.	*Amaranthus viridis*	Annual
21.	*Justicia adhatoda*	Perennial
22.	*Piper longum*	Perennial
23.	*Rumex acetosa*	Perennial
24.	*Brassica juncea*	Perennial
25.	*Chenopodium album*	Annual

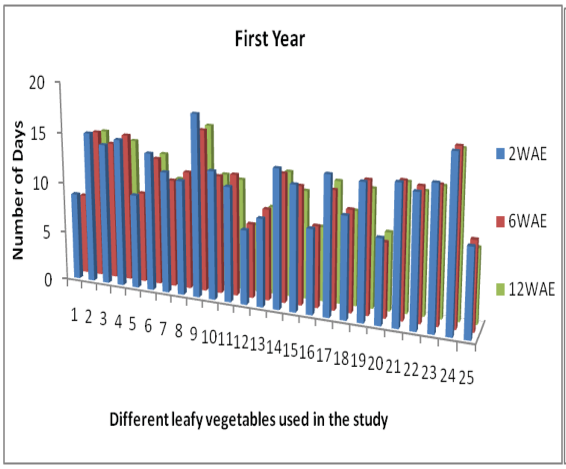
4.2.1.2 Days taken from leaf emergence to maturity

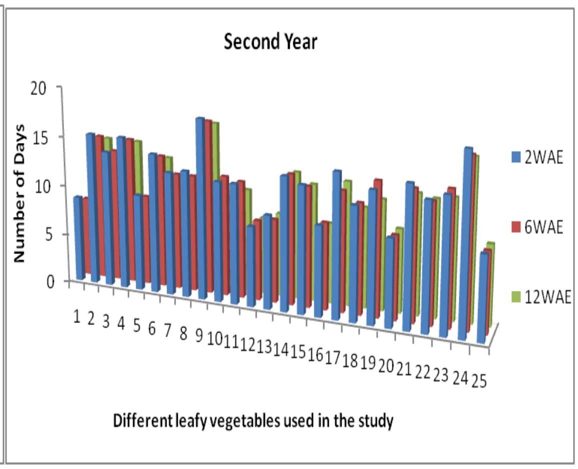
Data for days taken from leaf emergence to maturity are presented in Figures 28 and 29 and Table 4.2 which varied significantly among the different leafy vegetables.

Table 4.2: Days taken from leaf emergence to maturity of the leafy vegetables under study

Sl. No.	Crop	1st Year Week After Emergence						2nd Year Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	8.67	8.00	8.00	8.33	7.67	8.00	8.33	8.33	8.00	8.00	7.33	8.00
2.	*Plantago major*	15.00	14.67	14.67	14.33	14.00	14.33	15.33	14.67	14.67	14.33	14.00	14.00
3.	*Houttuynia cordata*	14.00	13.33	13.67	13.33	13.00	12.67	13.67	14.00	13.33	13.00	13.67	13.00
4.	*Fagopyrum cymosum*	14.67	14.33	14.67	14.00	13.67	13.67	15.33	15.00	14.67	14.33	14.33	14.00
5.	*Eryngium foetidum*	9.33	8.33	9.00	8.33	8.00	8.33	9.67	9.00	9.00	8.67	8.33	8.67
6.	*Commelina benghalensis*	13.67	13.33	12.67	13.33	13.00	12.67	14.00	13.00	13.33	13.33	12.67	12.67
7.	*Polygonum alatum*	12.00	12.67	10.67	11.33	11.33	10.33	12.33	12.00	11.67	12.00	11.67	11.00
8.	*Hibiscus sabdariffa*	11.33	12.00	11.67	11.00	10.67	10.33	12.67	11.67	11.67	12.00	11.00	11.33
9.	*Diplazium esculentum*	18.00	17.33	16.00	16.00	16.33	16.00	18.00	17.00	17.33	17.00	17.00	16.67
10.	*Colocasia esculenta*	12.67	11.33	11.67	10.33	10.67	11.33	12.00	12.33	12.00	11.00	11.00	10.00
11.	*Emilia sonchifolia*	11.33	11.33	12.00	11.33	11.67	11.00	12.00	11.33	11.67	11.00	11.33	10.33
12.	*Mentha arvensis*	7.33	7.00	7.33	6.67	7.00	6.67	8.00	7.67	8.00	7.33	7.00	7.67
13.	*Spilanthes acmella*	8.67	8.67	9.00	8.33	8.00	8.67	9.33	9.00	8.33	8.00	8.00	8.33
14.	*Oxalis corniculata*	13.67	12.33	12.67	12.00	12.67	12.33	13.33	13.33	13.00	12.67	12.33	12.67
15.	*Basella rubra*	12.33	12.33	11.67	11.33	11.67	10.67	12.67	12.00	12.00	12.33	11.33	11.67
16.	*Alternanthera philoxeroides*	8.33	8.67	8.00	8.00	7.67	7.33	9.00	8.33	8.67	8.33	8.00	8.00
17.	*Passiflora edulis*	13.67	13.00	11.67	12.00	11.67	12.00	14.33	13.33	12.00	12.33	12.00	12.33
18.	*Allium hookeri*	10.00	10.33	10.00	9.33	10.00	9.33	11.33	10.67	11.00	10.33	9.67	10.00
19.	*Rumex nepalensis*	13.33	12.67	13.00	12.67	12.00	11.67	13.00	13.00	13.33	13.00	12.33	11.00
20.	*Amaranthus viridis*	8.33	7.67	7.33	8.00	7.67	7.67	8.67	9.00	8.33	8.67	8.00	8.33
21.	*Justicia adhatoda*	13.67	12.33	13.33	13.00	13.00	12.67	14.00	13.33	13.00	13.33	12.33	12.00
22.	*Piper longum*	13.00	12.33	13.00	12.00	12.33	12.00	12.67	12.00	12.00	11.67	11.33	11.67
23.	*Rumex acetosa*	14.00	12.67	13.33	13.33	13.00	12.67	13.33	13.00	13.33	13.00	12.67	12.00
24.	*Brassica juncea*	17.00	17.33	17.00	16.67	16.00	16.33	17.67	17.00	16.67	16.33	16.00	16.00
25.	*Chenopodium album*	8.67	8.33	8.67	7.67	8.00	7.33	8.33	8.00	8.00	8.33	7.67	8.00
	SEM ±	0.39	0.54	0.46	0.52	0.44	0.42	0.32	0.27	0.30	0.35	0.33	0.37
	CD 5%	1.10	1.54	1.31	1.48	1.24	1.18	0.91	0.78	0.85	0.98	0.93	1.04

In general, *Diplazium esculentum* and *Brassica juncea* leaves took the more of days for attaining maturity; whereas *Mentha arvensis* and *Chenopodium album* leaves recorded the minimum number of days to attain maturity.





Figs. 28 & 29: Days taken from leaf emergence to maturity of the leafy vegetables under study

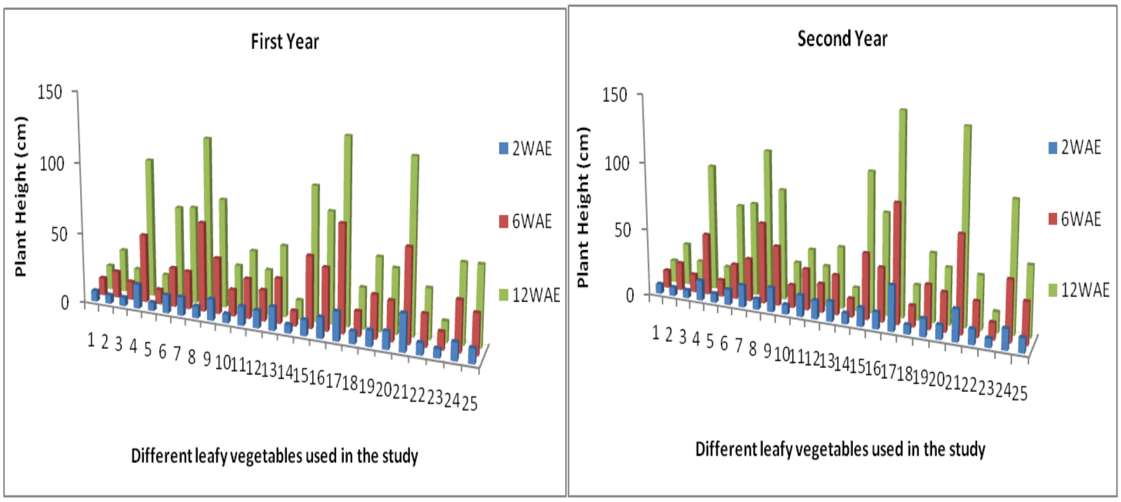
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1= *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*)

It was observed that leaves in the initial stages of growth took longer time to attain maturity than the later stages in both the years studied. *Diplazium esculentum* leaves at 2WAE during the first and second years of the experiment took the maximum number of days (18.00) to reach maturity, followed by *Brassica juncea* (17.67) at 2WAE during the second year; while *Mentha arvensis* leaves at 8 and 12WAE during the first year took the minimum number of days (6.67) to reach maturity.

4.2.1.3 Plant height

The plant heights of the crops at different stages of maturity are presented in Figures 30 and 31 and Table 4.3. Significant variations were observed in plant height among the different leafy vegetables studied during the experimentation period. The differences in plant height among the different vegetables are due to their genetic variations. Plant height was found to be high for for *Passiflora edulis*, *Justicia adhatoda*, *Hibiscus sabdariffa* and *Basella rubra*.

Plant height of the crops was found to increase with increasing age of the plants. *Passiflora edulis* recorded the maximum plant height of 148.65 cm at 12WAE in the second year of the experiment, followed by *Justicia adhatoda* recording a maximum plant height of 141.93 cm at 12WAE in the same year; whereas *Eryngium foetidum* recorded the lowest plant height of 5.81 cm at 2WAE during the first year.



Figs. 30 & 31: Plant height (cm) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

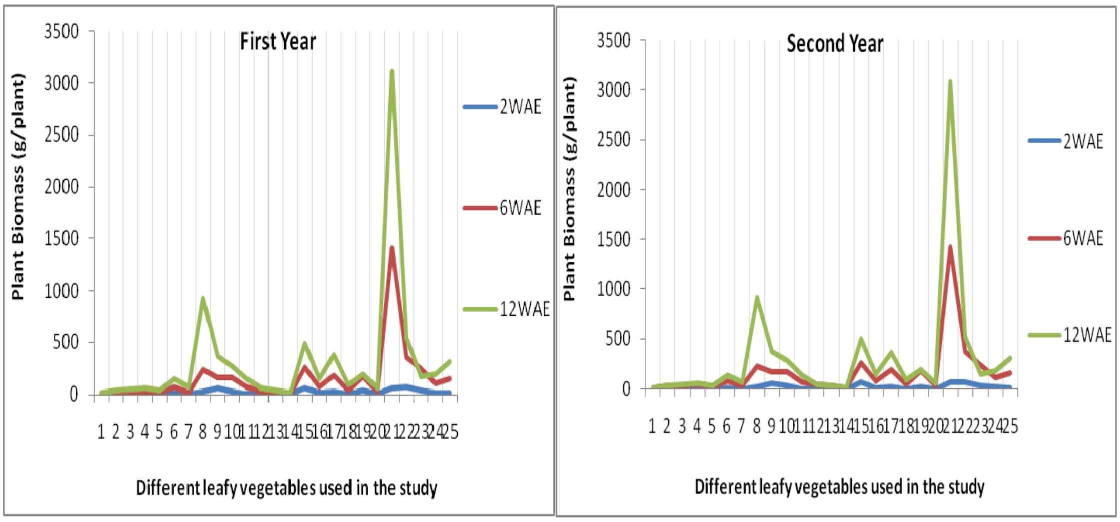
Table 4.3: Plant height (cm) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	7.60	10.33	12.35	14.07	15.93	17.20	7.22	10.50	13.22	14.35	16.17	16.63
2.	*Plantago major*	6.12	14.03	18.70	23.42	26.08	30.20	6.37	15.59	20.50	22.80	28.10	30.93
3.	*Houttuynia cordata*	6.02	10.10	12.83	15.20	16.87	17.80	5.95	9.72	13.30	17.08	18.02	19.18
4.	*Fagopyrum cymosum*	17.27	31.97	48.25	65.00	77.00	98.43	14.90	28.88	45.40	62.55	71.00	93.55
5.	*Eryngium foetidum*	5.81	9.15	10.42	14.70	15.12	16.69	6.75	8.95	12.27	15.42	16.05	18.02
6.	*Commelina benghalensis*	12.82	20.33	27.67	36.70	48.37	67.00	11.40	21.74	25.80	35.80	50.10	66.20
7.	*Polygonum alatum*	13.05	22.18	26.71	37.33	50.07	68.42	16.40	26.35	31.60	38.30	59.35	69.20
8.	*Hibiscus sabdariffa*	8.300	31.60	62.88	87.20	100.70	118.33	7.80	30.10	59.8	82.39	90.50	109.70
9.	*Diplazium esculentum*	15.00	29.00	39.30	48.80	60.90	76.80	18.00	33.50	44.15	55.25	65.40	82.10
10.	*Colocasia esculenta*	6.32	11.28	18.67	23.23	26.70	31.40	7.05	11.80	16.85	22.70	24.85	29.30
11.	*Emilia sonchifolia*	13.27	22.53	28.03	33.67	37.87	43.37	15.70	20.70	30.40	32.80	38.60	40.65
12.	*Mentha arvensis*	12.27	17.37	21.75	26.28	29.67	31.48	13.65	19.10	21.18	25.85	29.17	29.87
13.	*Spilanthes acmella*	16.57	25.93	31.51	38.03	46.00	50.05	14.80	22.50	29.27	36.40	39.95	45.60
14.	*Oxalis corniculata*	6.00	8.23	10.55	12.02	13.22	13.35	7.98	11.20	13.70	15.50	16.40	17.00
15.	*Basella rubra*	11.00	31.73	50.43	66.90	81.00	94.47	13.70	28.90	48.45	72.50	88.60	103.40
16.	*Alternanther philoxeroides*	14.73	31.67	44.03	54.35	67.67	78.33	12.35	27.55	39.75	52.35	64.60	75.15
17.	*Passiflora edulis*	20.45	54.10	75.45	98.75	117.95	130.23	33.40	64.10	87.45	107.6	129.65	148.65
18.	*Allium hookeri*	8.65	13.07	17.33	22.45	27.33	29.00	6.70	10.80	15.60	20.50	23.35	25.75
19.	*Rumex nepalensis*	11.13	20.97	30.50	37.98	44.15	51.67	13.05	21.77	32.37	35.13	46.32	50.65
20.	*Amaranthus viridis*	12.30	23.75	28.10	35.27	38.83	45.60	10.38	22.32	28.75	32.98	37.30	41.77
21.	*Justicia adhatoda*	26.2	47.13	65.67	85.5	110.17	121.58	23.55	50.48	71.37	96.48	127.2	141.93
22.	*Piper longum*	8.22	15.30	22.68	29.13	33.00	35.33	11.20	17.50	25.77	33.90	36.35	39.60
23.	*Rumex acetosa*	6.23	8.78	12.41	13.65	14.00	14.64	6.57	10.07	12.45	14.22	14.70	15.20
24.	*Brassica juncea*	12.5	24.56	35.52	43.50	51.18	55.83	15.22	29.70	44.50	65.40	73.80	95.75
25.	*Chenopodium album*	10.37	20.47	28.53	39.27	44.90	56.07	10.70	19.27	30.80	41.58	46.60	51.70
	SEM ±	1.55	2.20	2.40	2.42	2.97	2.77	1.62	2.03	2.23	2.29	2.32	2.34
	CD 5%	4.39	6.29	6.83	6.87	8.43	7.88	4.61	5.76	6.33	6.51	6.59	6.64

4.2.1.4 Plant biomass

Plant biomass (Figures 32, 33 and Table 4.4) of the different leafy vegetables studied varied significantly with *Justicia adhatoda*, *Hibiscus sabdariffa*, *Piper longum* and *Basella rubra* recording higher values for plant biomass.

For all the vegetables under study plant biomass increased with maturity and reached maximum at 12WAE. For the both the first and second years *Justicia adhatoda* recorded the maximum plant biomass of 3105.50 g/plant and 3085.97 g/plant respectively at 12 WAE, followed by *Hibiscus sabdariffa* (924.50 g/plant) at 12WAE during the first year; whereas *Oxalis corniculata* recorded the lowest plant biomass of 3.53 g/plant at 2WAE during the first year of the study.



Figs. 32 & 33: Plant Biomass (g/plant) of the leafy vegetables under study at different stages of maturity

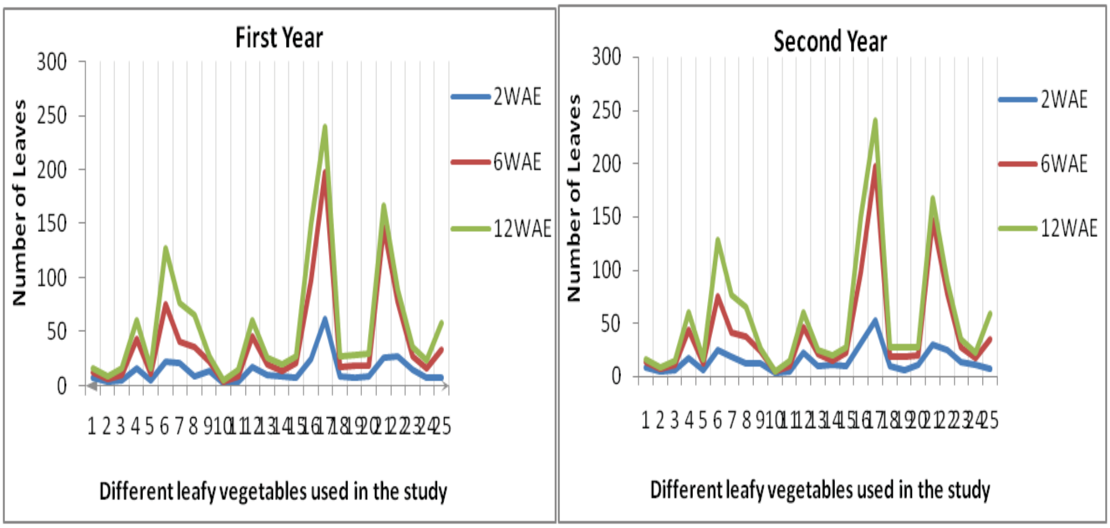
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.4: Plant biomass (g/plant) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	3.90	8.69	10.75	13.56	13.66	14.24	3.55	8.25	9.82	13.10	13.56	15.12
2.	*Plantago major*	9.82	15.36	23.34	25.34	31.33	34.78	10.67	17.23	27.51	25.87	30.58	32.80
3.	*Houttuynia cordata*	11.12	19.71	30.26	40.86	45.72	48.57	13.02	22.35	34.03	44.10	46.85	51.41
4.	*Fagopyrum cymosum*	15.00	24.32	37.15	50.56	57.63	59.65	14.52	19.86	39.23	46.19	50.38	56.82
5.	*Eryngium foetidum*	4.02	7.42	23.08	30.40	35.19	38.35	4.45	6.97	21.48	27.67	32.51	39.12
6.	*Commelina benghalensis*	12.78	46.52	76.54	95.52	120.75	144.47	13.42	50.34	72.43	99.91	124.35	136.50
7.	*Polygonum alatum*	9.25	15.34	25.16	42.10	56.32	72.57	8.25	13.57	27.87	38.13	50.36	66.94
8.	*Hibiscus sabdariffa*	25.00	101.25	239.74	500.25	750.23	924.50	30.35	90.85	227.08	526.32	800.45	912.92
9.	*Diplazium esculentum*	69.5	83.65	161.41	201.30	250.45	364.70	66.26	87.05	170.06	211.15	238..36	381.3
10.	*Colocasia esculenta*	30.93	78.40	168.00	215.24	243.20	269.70	33.92	82.72	164.30	242.56	251.47	280.68
11.	*Emilia sonchifolia*	6.64	35.28	72.84	82.35	132.23	145.54	5.83	38.02	68.43	85.48	142.45	141.97
12.	*Mentha arvensis*	11.35	21.84	35.65	42.24	50.85	55.54	13.20	24.30	38.43	43.04	52.78	53.23
13.	*Spilanthes acmella*	9.47	18.72	26.24	29.01	32.87	37.04	8.98	17.85	28.83	33.14	35.44	39.35
14.	*Oxalis corniculata*	3.53	8.62	10.47	13.07	15.00	16.62	3.86	8.89	11.22	15.34	17.50	18.06
15.	*Basella rubra*	64.86	194.32	256.64	325.20	404.45	487.68	70.90	202.3	262.03	330.62	414.10	500.12
16.	*Alternanthera philoxeroides*	14.48	38.64	81.36	98.75	118.23	145.67	16.06	34.40	72.70	102.98	123.80	147.29
17.	*Passiflora edulis*	28.96	110.26	182.45	285.65	356.40	378.62	23.59	94.60	190.57	292.67	336.42	360.69
18.	*Allium hookeri*	8.02	23.25	42.31	68.60	78.68	86.78	8.65	21.18	40.89	71.15	80.12	89.30
19.	*Rumex nepalensis*	34.56	88.52	170.25	245.67	318.65	190.38	29.88	83.77	176.34	218.67	350.20	197.73
20.	*Amaranthus viridis*	6.42	16.80	31.08	40.48	44.55	56.76	7.65	16.07	28.13	43.03	47.06	58.82
21.	*Justicia adhatoda*	64.35	650.54	1408.15	1775.16	2855.03	3105.5	74.21	610.8	1426.87	1805.5	2842.8	3085.97
22.	*Piper longum*	75.65	210.56	356.70	492.50	513.40	535.86	69.78	196.8	376.15	485.61	486.76	519.86
23.	*Rumex acetosa*	41.25	142.32	248.97	365.26	486.32	162.52	36.11	150.2	239.95	358.45	468.67	154.65
24.	*Brassica juncea*	17.59	46.33	105.63	128.76	140.40	183.68	23.45	49.21	111.6	134.24	143.05	190.07
25.	*Chenopodium album*	17.67	55.86	156.41	193.34	272.26	312.36	16.56	59.23	161.54	200.62	265.54	308.5
	SEM ±	1.11	2.76	2.60	3.14	3.47	5.49	1.43	2.85	4.00	3.58	3.93	8.47
	CD 5%	3.16	7.85	7.38	8.92	9.86	15.59	4.06	8.08	11.35	10.17	11.15	24.05

4.2.1.5 Number of leaves

Data for number of leaves of the leafy vegetables at different stages of maturity are presented in Figures 34, 35 and Table 4.5 which showed that leaf number varied significantly among the different leafy vegetables studied. *Passiflora edulis*, *Justicia adhatoda*, *Alternanthera philoxeroides*, *Commelina benghalensis* and *Piper longum* were found to have high leaf number/plant; while *Colocasia esculenta* and *Plantago major* recorded lower values for leaf number.



Figs. 34 & 35: Number of leaves/plant of the leafy vegetables under study at different stages of maturity

(Note: 1-25 represent the different leafy vegetables under study in the order: 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*)**.**

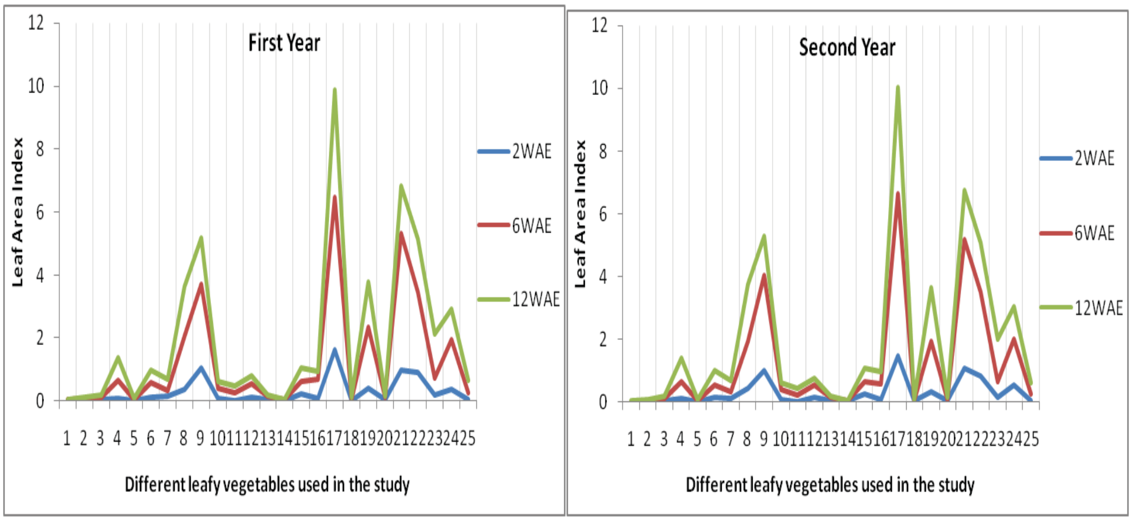
A progressive increase in leaf number was observed with increase in maturity of the vegetables with plants at 12WAE recording the highest number. For both the years of study, *Passiflora edulis* recorded the maximum leaf number/plant (255.33 and 240.00), followed by *Justicia adhatoda* (169.00 and 167.33) at12WAE; whereas *Colocasia esculenta* recorded the lowest leaf number/plant of 3.00 at 2WAE during the first year of the study.

Table 4.5: Number of leaves/plant (per plant) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	7.33	10.33	12.67	15.00	15.33	16.00	8.33	10.00	12.67	14.67	16.33	16.67
2.	*Plantago major*	4.67	5.67	6.00	7.67	8.00	9.00	5.00	6.00	6.67	7.33	8.00	8.67
3.	*Houttuynia cordata*	5.67	7.33	9.00	13.33	14.67	15.00	6.00	9.00	10.67	14.00	15.00	15.67
4.	*Fagopyrum cymosum*	16.00	28.33	41.67	52.33	58.33	60.33	17.00	25.00	43.00	49.67	56.33	60.33
5.	*Eryngium foetidum*	5.67	8.00	12.00	13.00	15.33	17.67	6.00	7.33	11.67	13.00	14.33	16.33
6.	*Commelina benghalensis*	22.67	45.67	78.00	98.33	114.33	125.00	25.00	51.00	75.00	106.33	118.00	128.00
7.	*Polygonum alatum*	21.33	25.00	40.33	63.00	75.00	81.67	18.67	23.33	41.00	58.67	70.67	76.33
8.	*Hibiscus sabdariffa*	9.33	27.00	38.67	48.00	56.33	63.00	11.67	25.33	36.33	46.33	59.67	65.00
9.	*Diplazium esculentum*	13.67	16.00	19.00	21.67	22.00	24.00	12.67	17.33	22.67	23.33	24.67	26.67
10.	*Colocasia esculenta*	3.00	3.33	4.00	4.00	4.67	5.00	3.33	4.00	4.00	4.67	5.00	5.00
11.	*Emilia sonchifolia*	4.67	7.33	10.00	11.00	13.33	16.00	4.33	8.00	9.33	12.00	14.33	15.00
12.	*Mentha arvensis*	18.33	28.00	43.67	48.67	54.33	61.33	22.67	31.00	46.00	53.67	57.00	60.33
13.	*Spilanthes acmella*	10.67	16.00	19.67	21.33	24.67	25.67	9.33	15.67	20.33	23.33	25.00	25.67
14.	*Oxalis corniculata*	9.33	12.00	13.00	15.00	16.67	17.33	10.67	12.67	14.33	17.00	19.33	20.33
15.	*Basella rubra*	8.00	14.33	18.67	21.00	24.00	25.67	10.00	16.33	21.67	23.33	26.00	27.67
16.	*Alternanthera philoxeroides*	25.67	67.00	112.67	126.33	142.33	148.33	31.33	63.67	98.00	132.67	145.33	150.00
17.	*Passiflora edulis*	62.00	141.00	188.00	218.00	245.67	255.33	53.00	120.67	197.33	224.33	230.67	240.00
18.	*Allium hookeri*	9.67	15.00	20.00	22.67	25.00	28.33	10.00	13.67	17.67	25.33	26.00	27.67
19.	*Rumex nepalensis*	7.33	17.67	21.67	23.00	24.67	27.67	6.33	16.00	19.00	23.33	25.67	28.00
20.	*Amaranthus viridis*	9.33	15.00	20.67	23.00	25.67	27.00	11.00	14.33	18.67	22.67	25.00	29.67
21.	*Justicia adhatoda*	26.33	110.33	144.67	155.33	163.00	169.00	30.00	88.67	147.00	158.33	161.33	167.33
22.	*Piper longum*	27.00	62.33	72.67	83.00	88.00	93.00	24.67	57.67	77.33	81.33	85.67	89.33
23.	*Rumex acetosa*	15.67	25.67	29.33	32.00	35.33	38.00	13.33	24.33	27.00	30.67	33.67	35.67
24.	*Brassica juncea*	7.33	11.67	15.00	18.00	20.00	22.00	10.67	13.00	16.67	19.33	20.67	23.00
25.	*Chenopodium album*	7.67	15.33	32.67	41.33	52.67	60.33	6.67	16.33	34.00	44.33	56.33	58.67
	SEM ±	1.50	3.25	2.37	2.94	3.12	3.18	1.86	2.74	3.81	3.78	3.55	3.84
	CD 5%	4.27	9.23	6.73	8.35	8.87	9.03	5.29	7.79	10.83	10.74	10.08	10.92

4.2.1.6 Leaf area index

The different leafy vegetables varied greatly with respect to their leaf area index (Figures 36, 37 and Table 4.6). Values for leaf area index were found to be high in *Passiflora edulis*, *Justicia adhatoda*, *Piper longum* and *Diplazium esculentum*; while lower leaf area index values were recorded in *Centella asiatica*, *Eryngium foetidum*, *Oxalis corniculata*, *Allium hookeri* and *Plantago major*. The leaf area index was found to increase with maturity for all the crops under study. Highest leaf area index (10.04) was recorded in *Passiflora edulis* at 12WAE during the second year of the experiment; which was followed by *Justicia adhatoda* with a leaf area index of 6.85 at 12WAE during the first year. Lowest leaf area index of 0.01 was recorded in *Plantago major* at 2WAE during the first year and *Emilia sonchifolia* at 2WAE during both the years of study.



Figs. 36 & 37: Leaf Area Index of the leafy vegetables under study at different stages of maturity

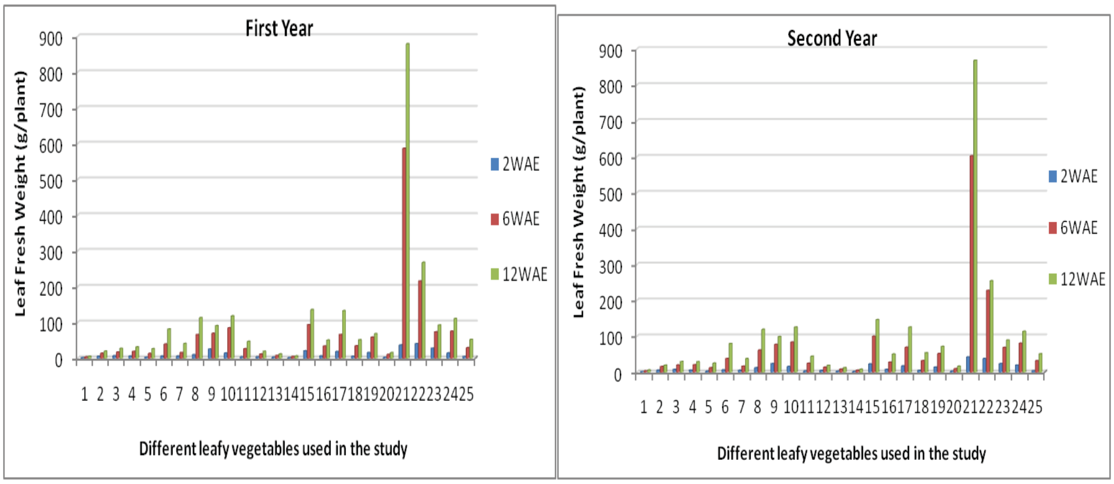
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.6: Leaf Area Index of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	0.02	0.03	0.04	0.04	0.05	0.06	0.02	0.02	0.03	0.04	0.05	0.07
2.	*Plantago major*	0.01	0.03	0.06	0.08	0.10	0.12	0.02	0.04	0.06	0.07	0.09	0.12
3.	*Houttuynia cordata*	0.04	0.08	0.11	0.16	0.19	0.20	0.05	0.10	0.13	0.17	0.20	0.22
4.	*Fagopyrum cymosum*	0.10	0.35	0.66	1.05	1.18	1.38	0.11	0.32	0.68	1.13	1.24	1.42
5.	*Eryngium foetidum*	0.02	0.03	0.05	0.06	0.07	0.08	0.02	0.03	0.06	0.06	0.07	0.09
6.	*Commelina benghalensis*	0.13	0.28	0.58	0.76	0.88	1.01	0.15	0.33	0.56	0.84	0.93	1.02
7.	*Polygonum alatum*	0.15	0.20	0.33	0.52	0.63	0.69	0.13	0.19	0.35	0.50	0.61	0.70
8.	*Hibiscus sabdariffa*	0.36	1.23	2.04	2.67	3.22	3.65	0.46	1.15	1.96	2.57	3.43	3.79
9.	*Diplazium esculentum*	1.05	2.16	3.71	4.28	4.67	5.18	1.02	2.21	4.06	4.46	4.74	5.32
10.	*Colocasia esculenta*	0.09	0.22	0.40	0.48	0.58	0.62	0.10	0.25	0.41	0.53	0.61	0.63
11.	*Emilia sonchifolia*	0.01	0.13	0.25	0.29	0.40	0.49	0.01	0.14	0.23	0.33	0.43	0.46
12.	*Mentha arvensis*	0.12	0.25	0.53	0.61	0.70	0.80	0.15	0.29	0.56	0.67	0.73	0.77
13.	*Spilanthes acmella*	0.05	0.10	0.15	0.18	0.21	0.22	0.04	0.09	0.16	0.19	0.22	0.23
14.	*Oxalis corniculata*	0.02	0.04	0.04	0.05	0.06	0.07	0.03	0.04	0.05	0.06	0.07	0.08
15.	*Basella rubra*	0.21	0.40	0.60	0.85	0.96	1.05	0.27	0.44	0.66	0.86	1.03	1.12
16.	*Alternanthera philoxeroides*	0.07	0.38	0.67	0.77	0.91	0.96	0.09	0.37	0.59	0.82	0.93	0.98
17.	*Passiflora edulis*	1.64	4.30	6.47	8.25	9.66	9.89	1.49	3.99	6.65	8.34	9.84	10.04
18.	*Allium hookeri*	0.02	0.04	0.05	0.07	0.09	0.12	0.03	0.05	0.06	0.06	0.08	0.11
19.	*Rumex nepalensis*	0.40	1.23	2.33	2.67	3.15	3.78	0.35	1.13	1.95	2.52	3.40	3.65
20.	*Amaranthus viridis*	0.04	0.08	0.12	0.13	0.15	0.17	0.05	0.07	0.11	0.14	0.16	0.18
21.	*Justicia adhatoda*	0.98	4.85	5.32	6.03	6.71	6.85	1.10	4.68	5.19	6.24	6.64	6.76
22.	*Piper longum*	0.90	2.95	3.47	4.56	4.99	5.14	0.83	2.82	3.51	4.72	5.02	5.09
23.	*Rumex acetosa*	0.20	0.46	0.72	1.01	1.36	2.14	0.17	0.45	0.67	0.97	1.29	2.04
24.	*Brassica juncea*	0.39	0.88	1.95	2.36	2.65	2.93	0.56	0.93	2.02	2.43	2.72	3.06
25.	*Chenopodium album*	0.03	0.11	0.27	0.42	0.57	0.67	0.03	0.12	0.28	0.45	0.61	0.64
	SEM ±	0.01	0.05	0.03	0.04	0.06	0.05	0.02	0.02	0.06	0.07	0.06	0.06
	CD 5%	0.02	0.15	0.08	0.12	0.17	0.14	0.04	0.06	0.17	0.21	0.18	0.17

4.2.1.7 Leaf weight (fresh and dry)

The fresh and dry leaf weights of the leafy vegetables are presented in Figures 38 & 39, 40 & 41 and Tables 4.7 & 4.8 respectively. It was observed that leaf weight was significantly affected by the type of vegetables. Higher values for fresh and dry leaf weights were observed in *Justicia adhatoda*, *Piper longum*, *Basella rubra* and *Colocasia esculenta* etc.; while lower values were recorded in *Centella asiatica* and *Oxalis corniculata*.



Figs. 38 & 39: Leaf Fresh Weight (g/plant) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

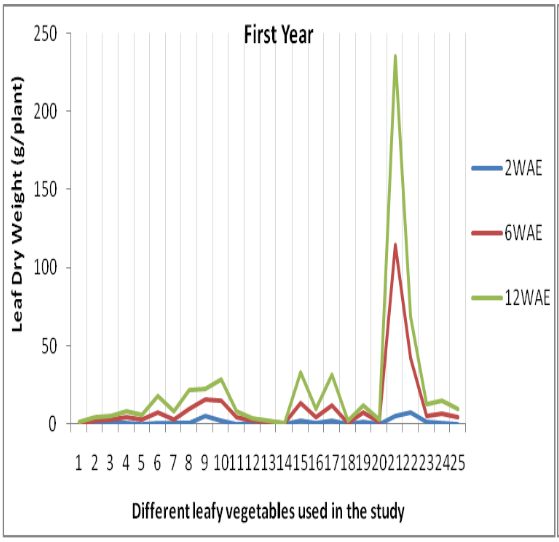
Leaf weight was found to increase with growth of the plants for both the years under study. At 12WAE, during the first year, *Justicia adhatoda* recorded maximum leaf fresh & dry weights (878.83 g/plant and 235.08 g/plant respectively) followed by *Piper longum* (267.75 g/plant and 68.30 g/plant respectively) during the first year of the experiment.

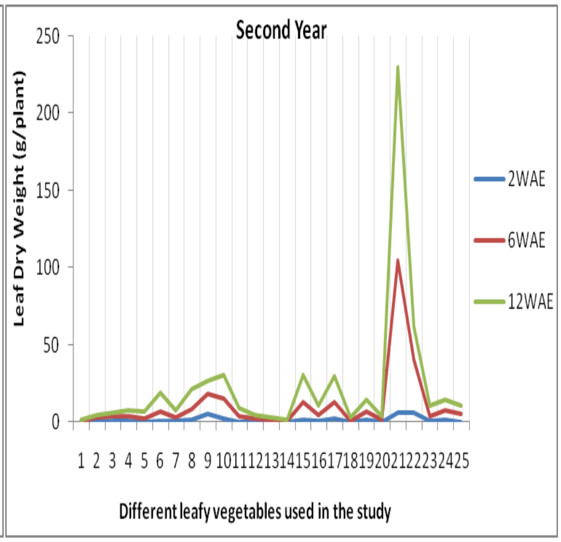
Table 4.7: Leaf Fresh weight (g/plant) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	1.35	2.42	3.36	5.27	5.36	5.40	1.42	2.50	3.17	5.08	5.24	5.67
2.	*Plantago major*	5.09	9.10	13.60	15.58	18.42	19.63	5.53	10.02	15.45	16.23	17.66	19.07
3.	*Houttuynia cordata*	6.6 7	10.95	17.10	24.62	25.65	27.30	7.25	13.86	19.52	25.20	28.05	29.21
4.	*Fagopyrum cymosum*	5.60	12.33	18.86	27.21	30.82	31.28	5.44	10.50	20.21	25.38	26.48	28.95
5.	*Eryngium foetidum*	2.50	4.64	13.05	18.20	22.56	26.32	2.74	4.32	12.14	16.57	19.35	24.92
6.	*Commelina benghalensis*	5.86	22.85	39.35	54.63	70.24	81.25	6.24	23.97	37.50	57.42	74.06	79.36
7.	*Polygonum alatum*	5.96	9.21	15.65	25.34	36.58	40.85	5.04	7.98	16.40	22.70	32.95	37.40
8.	*Hibiscus sabdariffa*	9.70	40.50	65.71	84.12	100.25	113.35	12.14	37.23	61.03	81.39	105.53	118.97
9.	*Diplazium esculentum*	25.24	44.10	69.35	82.35	84.38	90.64	23.56	49.50	76.90	86.32	92.51	98.74
10.	*Colocasia esculenta*	14.34	50.26	84.80	97.25	113.47	118.21	15.55	57.04	83.57	112.67	120.87	125.40
11.	*Emilia sonchifolia*	3.36	17.64	26.52	30.22	37.78	46.85	3.12	18.24	24.44	32.28	38.93	43.98
12.	*Mentha arvensis*	3.72	6.78	11.36	13.65	16.30	19.19	4.58	8.06	13.42	14.23	17.67	18.70
13.	*Spilanthes acmella*	2.96	5.12	7.49	8.53	10.11	11.57	2.62	4.85	8.36	10.04	11.13	12.20
14.	*Oxalis corniculata*	1.68	3.91	4.55	5.42	6.02	6.16	1.82	4.08	5.05	6.35	7.43	7.78
15.	*Basella rubra*	20.28	62.45	93.50	109.20	127.66	135.73	22.58	68.02	99.57	116.66	136.33	146.07
16.	*Alternanthera philoxeroides*	6.16	16.10	33.90	37.82	45.47	50.32	7.58	14.64	27.53	40.35	48.55	50.23
17.	*Passiflora edulis*	18.45	47.95	65.80	91.56	127.80	132.60	16.84	40.62	69.14	93.78	119.67	125.27
18.	*Allium hookeri*	4.82	18.74	34.52	45.24	48.76	51.2	4.57	15.65	31.85	47.26	50.40	53.67
19.	*Rumex nepalensis*	15.56	38.94	58.59	60.60	64.72	68.54	13.76	35.14	51.58	64.24	67.26	71.25
20.	*Amaranthus viridis*	2.24	5.25	10.36	12.68	14.52	15.24	2.68	4.97	9.45	12.96	15.14	16.35
21.	*Justicia adhatoda*	36.56	253.00	586.73	625.20	815.20	878.83	42.15	204.30	602.10	640.33	803.83	868.15
22.	*Piper longum*	40.50	145.53	215.47	245.47	256.69	267.75	37.65	137.59	227.25	238.58	245.93	254.27
23.	*Rumex acetosa*	27.56	51.40	73.25	84.21	88.35	92.60	23.56	47.73	68.42	81.70	84.13	88.91
24.	*Brassica juncea*	14.66	25.74	75.24	93.60	105.47	110.73	19.32	27.59	80.26	97.53	107.96	113.53
25.	*Chenopodium album*	4.46	11.93	29.14	31.26	46.87	52.35	3.67	12.78	31.72	35.53	48.13	50.72
	SEM ±	1.07	1.93	2.88	2.92	2.86	3.45	0.98	1.92	3.34	3.96	3.86	4.37
	CD 5%	3.04	5.48	8.19	8.28	8.12	9.81	2.79	5.47	9.45	11.26	10.98	12.42

Table 4.8: Leaf Dry weight (g/plant) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	0.20	0.40	0.59	1.03	1.26	1.39	0.19	0.36	0.49	0.90	1.04	1.47
2.	*Plantago major*	0.75	1.43	2.28	2.78	4.11	4.91	0.91	1.77	2.84	3.22	3.66	4.08
3.	*Houttuynia cordata*	1.07	1.83	3.08	4.49	4.92	5.60	0.98	2.08	3.32	4.33	4.95	5.52
4.	*Fagopyrum cymosum*	1.03	2.32	3.94	6.79	8.37	8.61	0.86	1.73	3.82	5.51	6.29	7.48
5.	*Eryngium foetidum*	0.39	0.87	2.66	3.79	5.15	6.30	0.38	0.72	2.40	3.61	4.37	6.12
6.	*Commelina benghalensis*	0.76	3.34	7.02	10.25	13.31	17.83	0.83	3.75	6.28	10.47	15.05	18.61
7.	*Polygonum alatum*	0.82	1.46	2.61	4.79	7.24	8.33	0.59	1.01	2.59	3.79	6.19	7.26
8.	*Hibiscus sabdariffa*	1.08	4.62	9.45	13.61	17.43	22.06	1.30	4.42	7.93	12.09	17.40	21.01
9.	*Diplazium esculentum*	5.34	9.66	15.80	19.11	20.08	22.66	5.05	10.83	18.03	20.59	22.96	26.51
10.	*Colocasia esculenta*	2.11	8.34	15.05	19.33	25.84	28.49	2.41	9.18	14.89	22.97	26.89	30.34
11.	*Emilia sonchifolia*	0.47	2.59	4.07	4.80	6.23	8.67	0.44	2.62	3.80	5.57	7.16	8.44
12.	*Mentha arvensis*	0.54	1.10	1.99	2.58	3.21	3.91	0.68	1.14	2.24	2.45	3.22	3.95
13.	*Spilanthes acmella*	0.47	0.85	1.38	1.61	1.96	2.33	0.35	0.70	1.24	1.62	1.85	2.31
14.	*Oxalis corniculata*	0.13	0.37	0.45	0.57	0.65	0.79	0.15	0.38	0.56	0.78	1.03	1.14
15.	*Basella rubra*	2.12	8.37	13.35	19.10	23.72	33.51	1.48	5.13	12.54	16.80	22.83	30.33
16.	*Alternanthera philoxeroides*	0.71	2.09	4.46	5.52	8.23	10.06	1.16	2.06	4.23	6.29	8.11	10.62
17.	*Passiflora edulis*	2.57	7.14	11.71	18.09	28.62	31.56	2.65	7.07	12.87	18.66	25.84	29.83
18.	*Allium hookeri*	0.15	0.30	0.53	1.02	1.29	2.03	0.19	0.32	0.59	1.34	1.84	2.49
19.	*Rumex nepalensis*	1.51	4.21	6.93	8.94	10.74	11.84	1.42	4.28	6.40	9.31	10.56	14.09
20.	*Amaranthus viridis*	0.24	0.65	1.45	1.88	2.84	3.30	0.20	0.52	1.11	1.76	2.68	3.19
21.	*Justicia adhatoda*	5.41	42.50	114.28	133.79	194.17	235.08	5.77	32.69	104.47	126.39	182.31	230.05
22.	*Piper longum*	7.52	27.50	41.69	47.78	61.30	68.30	5.87	22.78	40.22	46.16	53.60	61.53
23.	*Rumex acetosa*	1.49	3.14	5.32	16.51	10.04	12.48	0.91	2.29	3.93	6.43	8.37	10.58
24.	*Brassica juncea*	1.16	2.11	6.66	9.82	13.39	15.14	1.39	2.32	7.45	10.14	11.90	14.46
25.	*Chenopodium album*	0.42	1.65	4.25	5.34	8.68	10.12	0.41	1.58	4.81	6.18	8.66	10.19
	SEM ±	0.28	1.43	0.96	1.95	2.15	2.00	0.15	0.47	1.59	2.64	2.33	1.23
	CD 5%	0.80	4.07	2.74	5.55	6.10	5.69	0.44	1.33	4.51	7.50	6.62	3.49





Figs. 40 & 41: Leaf Dry Weight (g/plant) of the leafy vegetables under study at different stages of maturity

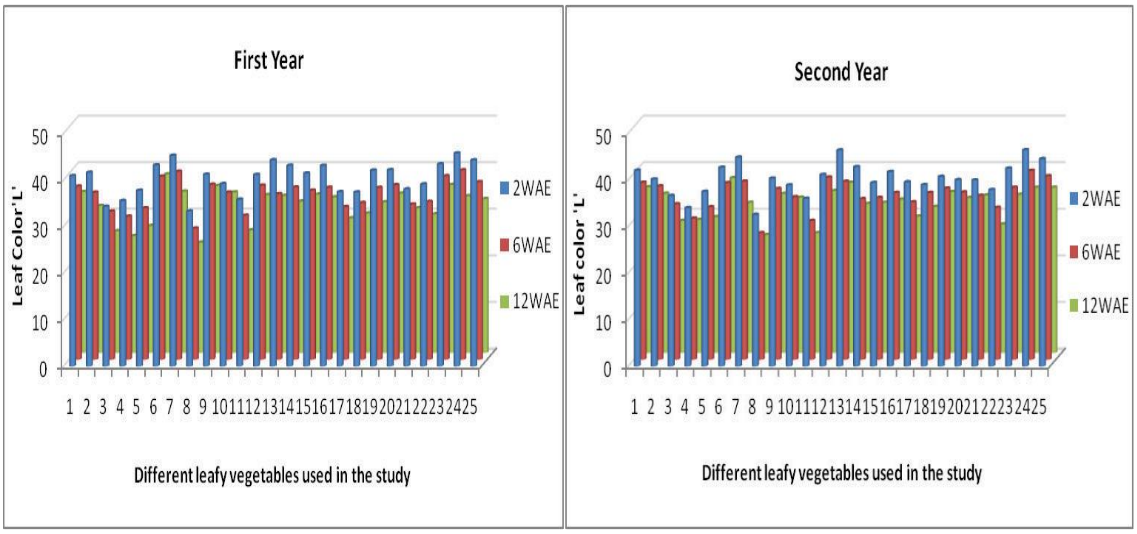
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*, 12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

4.2.1.8 Leaf color

4.2.1.8.1 Leaf Color values for 'L', 'a' and 'b'

Data for leaf color values of the leafy vegetables at different stages of maturity are presented below. Significant differences were observed in the leaf color values of the leafy vegetables under study. Among the different vegetables under study, the color values for 'L' (Figures 42, 43 and Table 4.9) were found to be high in *Brassica juncea*, *Commelina benghalensis*, *Spilanthes acmella* and *Chenopodium album*; whereas lowesr 'L' values were recorded in *Hibiscus sabdariffa*. It was observed that

'L' values decreased with increasing age of the crops. Highest 'L' value (46.44) was found in *Brassica juncea* at 2WAE during the second year of the experiment, followed *by Spilanthes acmella* with 'L' values of 46.40 at 2WAE during the same year. Lowest score for L (23.70) was recorded in *Hibiscus sabdiriffa* at 12WAE during the first year. *Fagopyrum cymosum* and *Emilia sonchifolia* also recorded lower 'L' values of 25.07 at 12WAE during the first year and 25.73 at 12WAE during the second year of the study respectively.



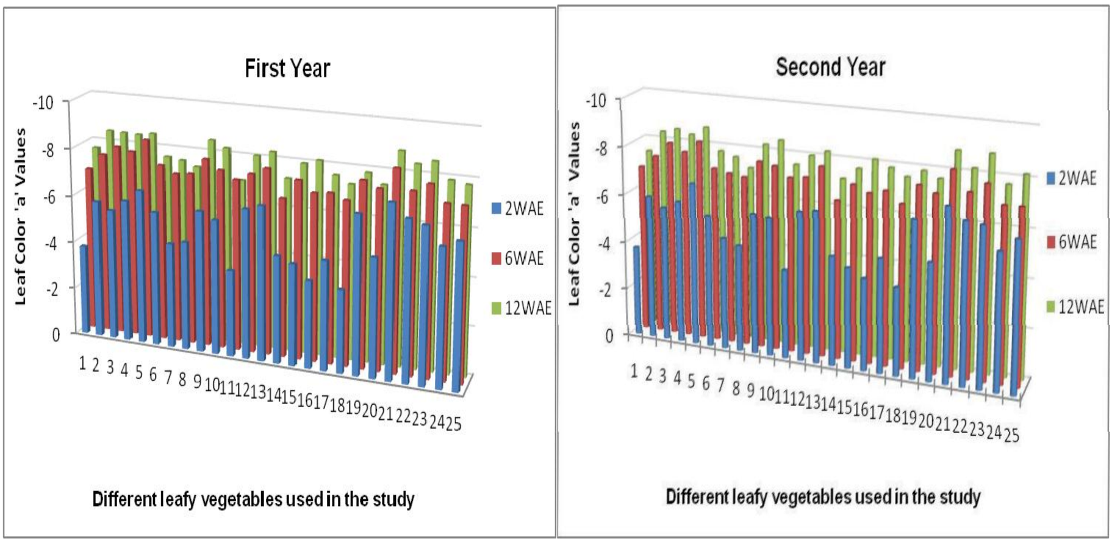
Figs. 42 & 43: Leaf Color Value 'L' of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.9: Leaf color 'L' values of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	40.89	37.70	37.18	36.42	35.97	34.56	42.05	38.11	38.00	38.76	36.67	35.58
2.	*Plantago major*	41.62	37.92	35.88	35.30	33.58	31.56	40.15	38.56	37.22	36.03	34.53	34.19
3.	*Houttuynia cordata*	34.29	33.66	31.81	29.66	27.39	26.15	36.62	34.65	33.37	28.98	28.65	28.34
4.	*Fagopyrum cymosum*	35.54	32.82	30.72	28.80	26.93	25.07	34.01	31.84	30.32	30.06	28.44	28.56
5.	*Eryngium foetidum*	37.74	33.04	32.49	31.38	30.29	27.26	37.50	34.10	32.73	33.05	30.85	29.18
6.	*Commelina benghalensis*	43.19	40.85	39.32	39.25	38.35	38.36	42.69	39.66	37.93	37.26	37.59	37.53
7.	*Polygonum alatum*	45.25	41.28	40.36	37.60	35.52	34.64	44.85	40.56	38.25	36.58	32.55	32.24
8.	*Hibiscus sabdariffa*	33.29	29.01	28.15	26.58	25.54	23.70	32.55	28.92	27.18	27.29	25.98	25.31
9.	*Diplazium esculentum*	41.19	39.12	37.58	37.70	37.39	35.86	40.33	37.23	36.66	36.12	35.65	34.15
10.	*Colocasia esculenta*	39.17	36.93	35.89	36.10	34.89	34.46	38.89	35.67	34.89	34.73	33.77	33.32
11.	*Emilia sonchifolia*	35.83	33.64	30.92	28.88	27.34	26.32	36.00	32.81	29.78	27.73	27.09	25.73
12.	*Mentha arvensis*	41.14	38.16	37.37	36.66	35.91	33.90	41.15	39.02	39.13	38.02	36.36	34.76
13.	*Spilanthes acmella*	44.31	39.36	35.57	36.42	34.25	33.73	46.40	42.74	38.22	37.87	37.87	36.54
14.	*Oxalis corniculata*	43.11	40.26	36.99	34.92	34.20	32.51	42.83	39.90	34.48	33.69	32.67	32.00
15.	*Basella rubra*	41.46	38.95	36.30	35.29	33.53	34.00	39.41	37.08	34.74	33.62	32.73	32.24
16.	*Alternanthera philoxeroides*	43.09	39.27	36.93	36.02	33.10	33.42	41.76	37.71	35.80	34.89	34.13	32.93
17.	*Passiflora edulis*	37.45	35.15	32.78	31.83	29.61	28.91	39.56	35.89	33.80	32.07	31.28	29.28
18.	*Allium hookeri*	37.38	34.85	33.66	33.91	31.53	29.95	38.94	36.50	35.79	33.39	31.79	31.35
19.	*Rumex nepalensis*	42.09	38.89	36.90	33.73	33.16	32.35	40.72	37.95	36.74	34.55	35.21	34.55
20.	*Amaranthus viridis*	42.16	39.27	37.48	36.65	34.83	34.20	40.03	37.24	35.92	35.32	34.27	33.27
21.	*Justicia adhatoda*	38.05	34.98	33.33	33.83	32.48	31.07	39.96	37.11	35.20	35.13	34.13	33.82
22.	*Piper longum*	39.12	35.02	33.89	32.65	29.75	29.76	37.89	33.73	32.61	30.61	29.27	27.61
23.	*Rumex acetosa*	43.43	40.04	39.40	36.19	35.89	36.06	42.49	39.16	36.93	36.08	35.42	33.96
24.	*Brassica juncea*	45.75	43.24	40.67	37.85	35.95	33.68	46.44	42.53	40.55	38.22	37.39	35.49
25.	*Chenopodium album*	44.28	39.52	38.13	36.78	35.14	33.04	44.53	41.14	39.39	37.83	37.16	35.49
	SEM ±	0.94	2.47	0.97	2.55	0.73	0.85	1.14	1.38	1.40	0.97	1.15	1.08
	CD 5%	2.66	7.02	2.76	7.24	2.07	2.40	3.23	3.92	3.99	2.76	3.26	3.07

The ‘a’ values for leaf color were found to be negative for all the crops and the values increased with increasing maturity (Figures 44, 45 and Table 4.10). In general, ‘a’ values were found to be high in *Justicia adhatoda*, *Eryngium foetidum*, *Rumex acetosa*, *Spilanthes acmella*, *Houttuynia cordata etc.* The highest ‘a’ values of -8.85 and -8.82 were recorded in *Justicia adhatoda*, closely followed by *Rumex acetosa* with ‘a’ values o f -8.57 and -8.83 at 12 WAE during the first and second years respectively; while *Allium hookeri* scored the lowest ‘a’ value of -3.46 at 2WAE during the first year of the study.

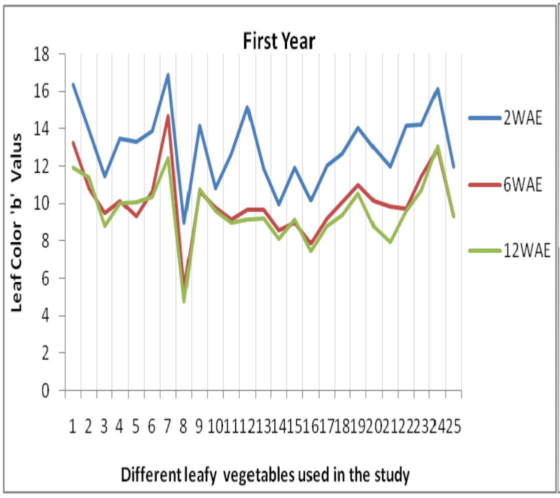


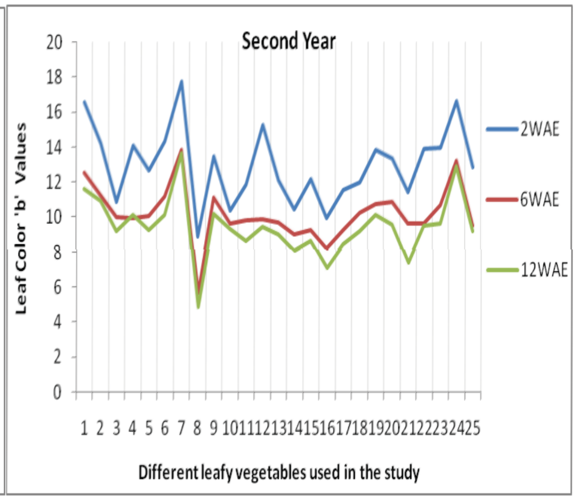
Figs. 44 & 45: Leaf Color Value ‘a’ of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica,* 2 = *Houttuynia cordata,* 3 = *Plantago major,* 4 = *Fagopyrum cymosum,*5 = *Eryngium foetidum,*6 = *Commelina benghalensis,* 7 = *Polygonum alatum,* 8 = *Hibiscus sabdariffa,* 9 = *Diplazium esculentum,*10 = *Colocasia esculenta,* 11 = *Emilia sonchifolia,*12 = *Mentha arvensis,* 13 = *Spilanthes acmella,* 14 = *Oxalis corniculata,* 15 = *Basella rubra,* 16 = *Alternanthera philoxeroides,* 17 = *Passiflora edulis,* 18 = *Allium hookeri* , 19 = *Rumex nepalensis,* 20 = *Amaranthus viridis,* 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa,* 24 = *Brassica juncea,* 25 = *Chenopodium album*).

Table 4.10: Leaf color 'a' values of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	-3.80	-6.65	-6.95	-7.15	-7.48	-7.68	-3.74	-6.52	-6.97	-7.26	-7.36	-7.45
2.	*Plantago major*	-5.80	-7.33	-7.62	-8.37	-8.17	-8.47	-5.97	-7.14	-7.48	-8.08	-8.13	-8.34
3.	*Houttuynia cordata*	-5.50	-7.75	-8.02	-8.14	-8.35	-8.45	-5.58	-8.02	-8.10	-8.25	-8.29	-8.51
4.	*Fagopyrum cymosum*	-5.98	-7.50	-7.88	-8.31	-8.55	-8.43	-5.91	-7.38	-7.79	-8.14	-8.31	-8.34
5.	*Eryngium foetidum*	-6.49	-8.16	-8.44	-8.20	-8.46	-8.53	-6.74	-8.10	-8.28	-8.36	-8.50	-8.70
6.	*Commelina benghalensis*	-5.65	-6.88	-7.44	-7.59	-7.83	-7.61	-5.47	-6.52	-7.24	-7.61	-7.70	-7.78
7.	*Polygonum alatum*	-4.40	-6.85	-7.15	-7.43	-7.34	-7.53	-4.63	-6.89	-7.11	-7.47	-7.45	-7.60
8.	*Hibiscus sabdariffa*	-4.55	-6.50	-7.22	-7.35	-7.22	-7.32	-4.41	-6.30	-7.03	-7.23	-7.31	-7.21
9.	*Diplazium esculentum*	-5.93	-7.53	-7.90	-8.21	-8.45	-8.51	-5.78	-7.56	-7.74	-8.00	-8.29	-8.25
10.	*Colocasia esculenta*	-5.64	-7.17	-7.51	-7.83	-8.04	-8.24	-5.71	-7.12	-7.63	-7.87	-8.14	-8.49
11.	*Emilia sonchifolia*	-3.62	-6.56	-7.18	-7.55	-7.38	-6.96	-3.66	-6.71	-7.22	-7.70	-7.54	-7.56
12.	*Mentha arvensis*	-6.26	-7.05	-7.49	-7.83	-8.03	-8.06	-6.12	-6.96	-7.31	-7.75	-7.90	-8.00
13.	*Spilanthes acmella*	-6.47	-7.94	-7.79	-8.22	-8.38	-8.28	-6.23	-7.66	-7.82	-8.15	-8.26	-8.24
14.	*Oxalis corniculata*	-4.50	-6.06	-6.63	-7.20	-7.08	-7.25	-4.50	-5.67	-6.52	-7.00	-7.26	-7.20
15.	*Basella rubra*	-4.25	-6.65	-7.45	-7.92	-8.06	-7.94	-4.12	-6.58	-7.24	-7.88	-7.48	-7.68
16.	*Alternanthera philoxeroides*	-3.65	-6.17	-7.00	-7.65	-8.10	-8.13	-3.78	-6.50	-6.97	-7.71	-7.90	-8.12
17.	*Passiflora edulis*	-4.56	-6.61	-7.07	-7.27	-7.44	-7.60	-4.68	-6.68	-7.14	-7.4	-7.56	-7.86
18.	*Allium hookeri*	-3.46	-6.09	-6.85	-7.25	-7.49	-7.30	-3.61	-6.19	-6.69	-7.33	-7.65	-7.56
19.	*Rumex nepalensis*	-6.61	-7.33	-7.73	-8.11	-8.02	-7.84	-6.39	-7.15	-7.52	-7.87	-7.80	-7.88
20.	*Amaranthus viridis*	-4.95	-6.67	-7.47	-7.67	-7.52	-7.42	-4.79	-6.50	-7.26	-7.55	-7.59	-7.64
21.	*Justicia adhatoda*	-7.21	-7.91	-8.35	-8.75	-8.65	-8.85	-7.06	-7.69	-8.27	-8.63	-8.76	-8.82
22.	*Piper longum*	-6.65	-7.09	-7.52	-7.86	-8.19	-8.39	-6.58	-7.11	-7.46	-7.83	-8.32	-8.19
23.	*Rumex acetosa*	-6.47	-7.36	-7.87	-8.27	-8.54	-8.57	-6.50	-7.39	-7.87	-8.30	-8.54	-8.83
24.	*Brassica juncea*	-5.72	-6.53	-7.18	-7.61	-7.98	-7.89	-5.57	-6.60	-7.11	-7.46	-7.89	-7.71
25.	*Chenopodium album*	-6.01	-6.58	-7.17	-7.68	-8.01	-7.78	-6.13	-6.64	-7.13	-7.80	-8.13	-8.17
	SEM ±	0.30	0.26	0.23	0.28	0.28	0.23	0.29	0.24	0.23	0.23	0.29	0.24
	CD 5%	0.84	0.74	0.64	0.81	0.81	0.65	0.83	0.70	0.64	0.66	0.82	0.68





Figs. 46 & 47: Leaf Color Value 'b' of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

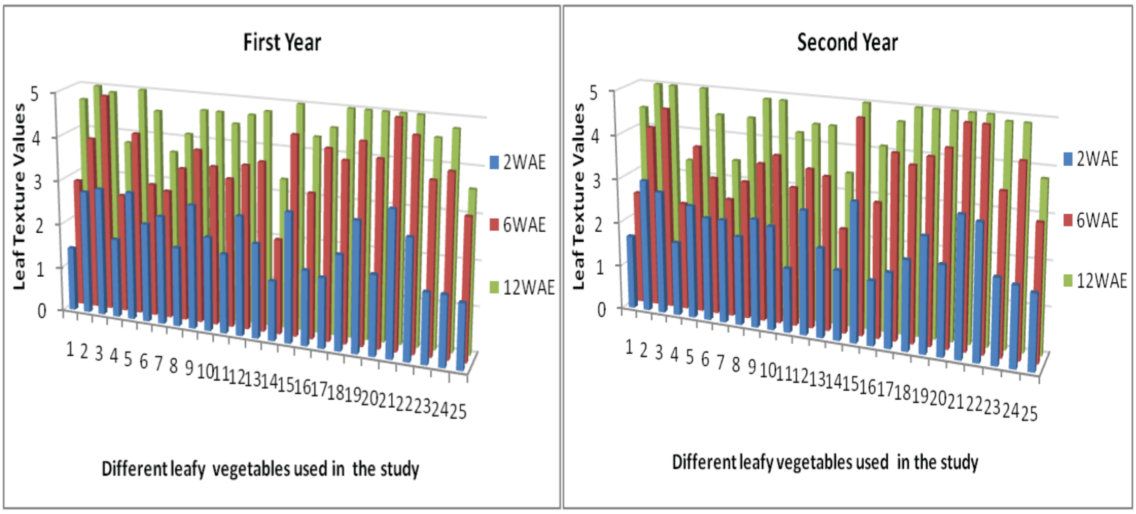
As regards to leaf color scores for 'b' (Figures 46, 47 and Table 4.11), higher values were obtained in *Polygonum alatum*, *Brassica juncea* and *Centella asiatica*, while lower 'b' values were recorded in *Hibiscus sabdariffa*. The 'b' values were found to decrease with age of the crops and lowest values were recorded at 12WAE in both the years of study for most of the vegetables. A highest color value for 'b' (17.75) was observed in *Polygonum alatum* at 2WAE during the second year; whereas 4.78 was the lowest value found in *Hibiscus sabdariffa* at 12WAE during the first year of the experiment.

Table 4.11: Leaf color 'b' values of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	16.34	15.60	13.23	12.00	11.63	11.89	16.59	15.01	12.56	11.66	11.40	11.64
2.	*Plantago major*	13.93	12.72	10.84	10.42	10.65	11.36	14.21	13.12	11.27	11.10	10.73	10.96
3.	*Houttuynia cordata*	11.49	10.18	9.51	9.34	9.11	8.77	10.87	10.42	10.04	9.63	9.73	9.18
4.	*Fagopyrum cymosum*	13.48	10.98	10.12	10.00	9.91	10.00	14.1	11.52	9.97	9.64	9.95	10.14
5.	*Eryngium foetidum*	13.31	11.02	9.32	8.99	9.93	10.07	12.68	9.97	10.1	9.73	9.40	9.24
6.	*Commelina benghalensiss*	13.90	12.24	10.65	10.02	10.05	10.35	14.32	11.8	11.17	10.84	10.27	10.11
7.	*Polygonum alatum*	16.88	16.21	14.69	11.79	12.05	12.4	17.75	16.22	13.84	12.22	12.41	13.66
8.	*Hibiscus sabdariffa*	9.00	6.80	5.48	5.66	5.20	4.78	8.89	7.23	5.69	5.76	5.27	4.85
9.	*Diplazium esculentum*	14.18	11.42	10.68	10.39	10.35	10.75	13.50	11.07	11.13	10.61	9.96	10.17
10.	*Colocasia esculenta*	10.84	9.87	9.77	9.60	9.64	9.58	10.38	10.05	9.66	9.61	9.15	9.33
11.	*Emilia sonchifolia*	12.68	10.63	9.18	8.58	8.51	8.98	11.86	10.82	9.82	8.49	8.48	8.65
12.	*Mentha arvensis*	15.15	10.92	9.70	9.54	9.14	9.14	15.29	11.21	9.88	9.45	9.27	9.42
13.	*Spilanthes acmella*	11.88	9.84	9.71	9.75	9.29	9.19	12.13	10.06	9.73	9.53	9.59	9.01
14.	*Oxalis corniculata*	10.00	8.89	8.56	8.60	8.42	8.10	10.43	9.41	9.03	8.57	7.94	8.08
15.	*Basella rubra*	11.96	9.77	8.97	9.24	8.87	9.14	12.2	10.13	9.27	8.86	8.39	8.62
16.	*Alternanthera philoxeroides*	10.23	8.49	7.91	7.82	7.61	7.48	9.94	9.15	8.23	8.44	7.25	7.10
17.	*Passiflora edulis*	12.02	9.78	9.21	8.85	8.81	8.77	11.57	10.16	9.3	8.68	8.45	8.42
18.	*Allium hookeri*	12.66	10.74	10.10	10.16	9.35	9.35	11.96	10.94	10.28	10.2	9.16	9.18
19.	*Rumex nepalensis*	14.06	10.95	10.98	10.91	10.76	10.53	13.84	11.44	10.77	10.54	10.08	10.1
20.	*Amaranthus viridis*	12.96	10.83	10.16	9.93	8.58	8.71	13.36	11.23	10.85	10.32	9.49	9.58
21.	*Justicia adhatoda*	12.00	10.41	9.87	8.33	8.21	7.91	11.42	10.12	9.65	8.15	8.41	7.41
22.	*Piper longum*	14.20	11.81	9.76	9.49	9.58	9.60	13.93	11.75	9.63	9.30	9.39	9.51
23.	*Rumex acetosa*	14.24	11.98	11.48	10.98	10.70	10.67	13.99	11.45	10.69	10.75	9.79	9.64
24.	*Brassica juncea*	16.14	13.48	12.93	12.75	12.85	13.04	16.66	13.9	13.24	13.48	13.02	12.94
25.	*Chenopodium album*	12.00	9.91	9.33	9.38	9.63	9.29	12.86	10.21	9.52	9.32	9.21	9.20
	SEM ±	0.43	0.66	0.53	0.47	0.53	0.50	0.33	0.48	0.30	0.31	0.36	0.36
	CD 5%	1.23	1.87	1.50	1.32	1.51	1.41	0.95	1.35	0.85	0.89	1.02	1.01

4.2.1.9 Leaf texture

Data for leaf texture are presented in Figures 48, 49 and Table 4.12. Leaf texture was found to be significantly affected by the different types of vegetables. Texture values showed an increasing trend with increasing maturity of the crops. Highest textural score of 5.00 was recorded for *Plantago major*, *Houttuynia cordata*, *Allium hookeri*, *Amaranthus viridis* and *Piper longum* at 10 and 12WAE; *Eryngium foetidum*, *Basella rubra* and *Rumex nepalensis* at 8, 10 and 12WAE and *Justicia adhatoda* at 6,8,10 and 12WAE during the study. The lowest textural score of value of 1.33 was found in *Oxalis corniculata* at 2WAE during the first year of the experiment.



Figs. 48 & 49: Leaf Texture Values of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.12: Leaf texture values of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	1.44	2.33	2.89	3.89	4.33	4.67	1.67	2.44	2.56	3.56	3.78	4.44
2.	*Plantago major*	2.78	3.33	3.89	4.89	5.00	5.00	3.00	3.67	4.11	4.78	5.00	5.00
3.	*Houttuynia cordata*	2.89	4.11	4.89	5.00	5.00	4.89	2.78	3.78	4.56	4.89	5.00	5.00
4.	*Fagopyrum cymosum*	1.78	2.22	2.67	3.22	3.44	3.78	1.67	2.56	2.44	3.00	3.33	3.33
5.	*Eryngium foetidum*	2.89	3.78	4.11	5.00	5.00	5.00	2.56	3.44	3.78	4.78	5.00	5.00
6.	*Commelina benghalensis*	2.22	2.56	3.00	3.78	4.00	4.56	2.33	2.78	3.11	4.11	4.22	4.44
7.	*Polygonum alatum*	2.44	2.67	2.89	3.00	3.44	3.67	2.33	2.56	2.67	2.89	3.11	3.44
8.	*Hibiscus sabdariffa*	1.78	2.44	3.44	3.67	3.89	4.11	2.00	2.56	3.11	3.44	3.67	4.44
9.	*Diplazium esculentum*	2.78	3.22	3.89	4.33	4.44	4.67	2.44	3.00	3.56	4.11	4.56	4.89
10.	*Colocasia esculenta*	2.11	3.00	3.56	4.44	4.67	4.67	2.33	2.78	3.78	4.11	4.89	4.89
11.	*Emilia sonchifolia*	1.78	2.44	3.33	3.67	4.11	4.44	1.44	2.33	3.11	3.56	4.22	4.22
12.	*Mentha arvensis*	2.67	3.11	3.67	3.89	4.44	4.67	2.78	3.33	3.56	4.11	4.33	4.44
13.	*Spilanthes acmella*	2.11	2.78	3.78	4.11	4.67	4.78	2.00	2.89	3.44	3.89	4.33	4.44
14.	*Oxalis corniculata*	1.33	1.78	2.11	2.44	2.56	3.33	1.56	1.67	2.33	2.67	2.89	3.44
15.	*Basella rubra*	2.89	4.22	4.44	5.00	5.00	5.00	3.11	4.11	4.78	5.00	5.00	5.00
16.	*Alternanthera philoxeroides*	1.67	2.33	3.22	3.44	3.56	4.33	1.44	2.11	3.00	3.33	3.44	4.11
17.	*Passiflora edulis*	1.56	3.11	4.22	4.67	4.44	4.56	1.67	3.33	4.11	4.44	4.56	4.67
18.	*Allium hookeri*	2.11	2.78	4.00	4.78	5.00	5.00	2.00	3.00	3.89	4.56	5.00	5.00
19.	*Rumex nepalensis*	2.89	3.67	4.44	5.00	5.00	5.00	2.56	3.56	4.11	4.78	5.00	5.00
20.	*Amaranthus viridis*	1.78	3.11	4.11	4.56	5.00	5.00	2.00	3.33	4.33	4.78	5.00	5.00
21.	*Justicia adhatoda*	3.22	4.33	5.00	5.00	5.00	5.00	3.11	4.00	4.89	5.00	5.00	5.00
22.	*Piper longum*	2.67	3.67	4.67	4.89	5.00	5.00	3.00	3.78	4.89	4.67	4.89	5.00
23.	*Rumex acetosa*	1.56	2.44	3.78	4.33	4.56	4.56	1.89	2.33	3.56	4.22	4.78	4.89
24.	*Brassica juncea*	1.56	2.78	4.00	4.33	4.56	4.78	1.78	3.11	4.22	4.44	4.78	4.89
25.	*Chenopodium album*	1.44	2.22	3.11	3.44	3.67	3.56	1.67	2.44	3.00	3.22	3.56	3.78
	SEM ±	0.17	0.21	0.15	0.19	0.10	0.15	0.17	0.22	0.18	0.18	0.16	0.14
	CD 5%	0.48	0.59	0.42	0.53	0.28	0.41	0.48	0.62	0.52	0.52	0.46	0.39

4.2.1.10 Leaf shape

Different types of leaf shapes of the collected vegetables are presented in Table 4.13.

Table 4.13: Leaf Shape of the leafy vegetables under study

Sl. No.	Crop	Leaf Shape
1.	*Centella asiatica*	Reniform
2.	*Plantago major*	Oval
3.	*Houttuynia cordata*	Heart shaped/cordate
4.	*Fagopyrum cymosum*	Deltoid
5.	*Eryngium foetidum*	Oblanceolate
6.	*Commelina benghalensis*	Elliptical
7.	*Polygonum alatum*	Ovate
8.	*Hibiscus sabdariffa*	Upper leaves, young leaves, simple, lanceolate, older leaves 5-7 lobes, the lobes oblong to oblong lanceolate
9.	*Diplazium esculentum*	Pinnately compound, broadly lanceolate or subdeltoid with acuminate apex, pinnule broad ovate
10.	*Colocasia esculenta*	Sagittate
11.	*Emilia sonchifolia*	Very variable; the lower petioled, lyrate or abovate, toothed or entire; the upper (cauline leaves) more or less emplexicaul and auricled, usually acute.
12.	*Mentha arvensis*	Ovate
13.	*Spilanthes acmella*	Ovate nearly deltoid with serrated margins
14.	*Oxalis corniculata*	Trifoliate with three heartshaped leaflets
15.	*Basella rubra*	Heart shaped/cordate
16.	*Alternanthera philoxeroides*	Lanceolate
17.	*Passiflora edulis*	Three lobed, middle lobe ovate, lateral lobes ovate-oblong
18.	*Allium hookeri*	Linear
19.	*Rumex nepalensis*	Lower leaves oblong- ovate, upper leaves ovate lanceolate
20.	*Amaranthus viridis*	Deltoid - ovate
21.	*Justicia adhatoda*	Elliptic-Lanceolate
22.	*Piper longum*	Reniform/cordate
23.	*Rumex acetosa*	Sagitate
24.	*Brassica juncea*	Ovate and ovovate, variously lobed and teethed
25.	*Chenopodium album*	Lower leaves toothed, rhomboid, upper leaves lanceolate-rhomboid

The vegetables varied greatly with respect to their leaf shape ranging from ovate to pinnately compound leaves.While *Centella asiatica* and *Piper longum* plants had reniform shaped leaves, *Plantago major* plants had oval shaped leaves, *Houttuynia cordata* and *Basella rubra* leaves were heart – shaped, *Diplazium esculentum* plants consisted of pinnately compound leaves etc.

4.2.1.11 Number of harvests

The total numbers of harvests of the leafy vegetables at different stages of maturity are presented in Figure 50 and Table 4.14. The vegetables showed variations in the total number of harvests when harvesting was started at different maturity stages.

In general, *Basella rubra*, *Justicia adhatoda*, *Eryngium foetidum* and *Passiflora edulis* recorded higher number of harvests, while *Plantago major* and *Oxalis corniculata* recorded lower number of harvests than the other vegetables. The number of harvests showed different trends for each vegetable with regards to maturity stages. While for crops like *Centela asiatica* and *Diplazium esculentum*, the number of harvests increased when harvesting age was delayed, for others like *Plantago major* and *Spilanthes acmella* number of harvests decreased with delayed harvest age. Maxiumum number of harvests (9.00) was observed in *Basella rubra* at 6WAE, followed by *Eryngium foetidum* (8.00) at 8WAE, while the lowest number of harvests (1.00) was recorded in *Polygonum alatum* and *Rumex nepalensis* at 12WAE; and *Plantago major* and *Emilia sonchifolia* at 10 and 12WAE.

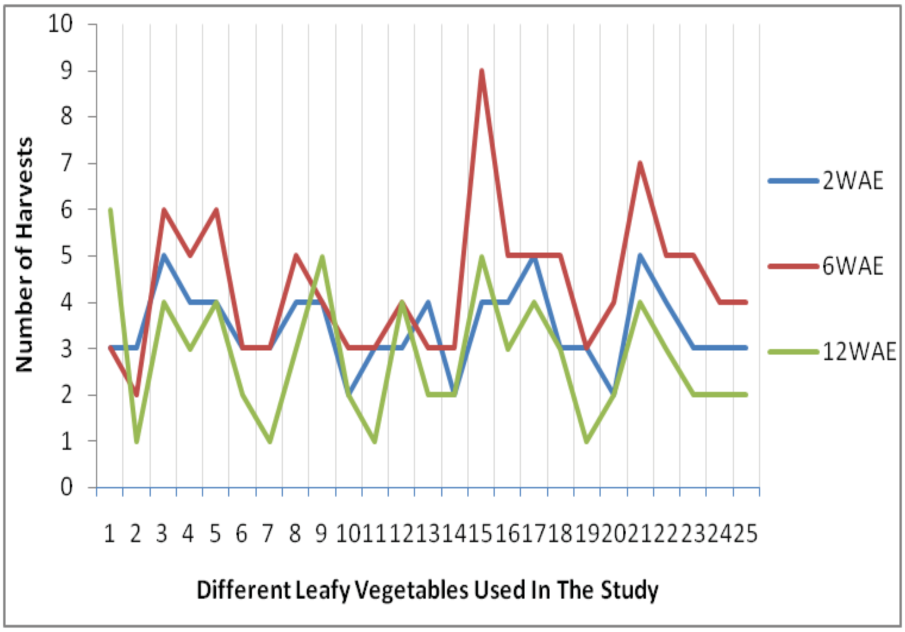


Fig. 50: Number of Harvests of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

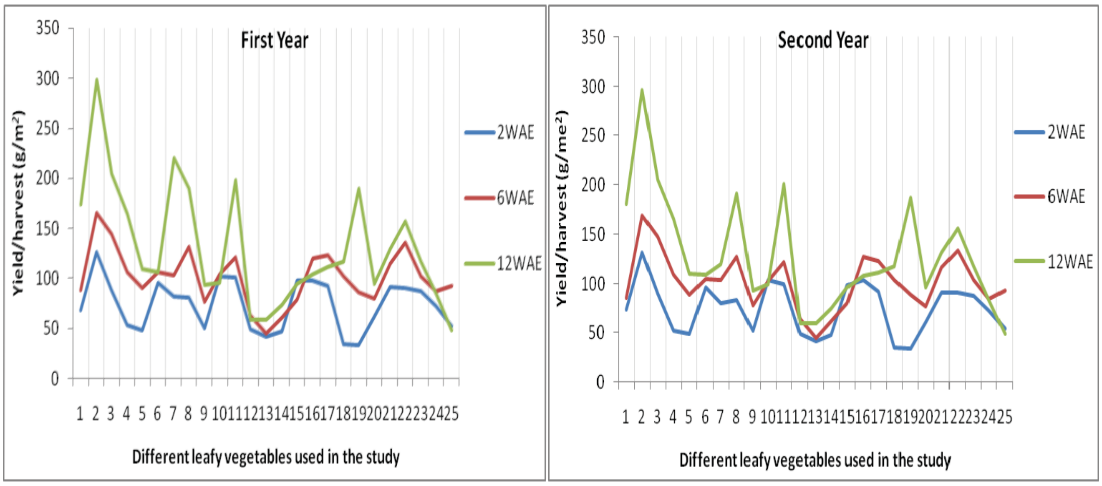
Table 4.14: Number of harvests of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	Week After Emergence					
		2WAE	4WAE	6WAE	8WAE	10WAE	12WAE
1	*Centella asiatica*	3	3	3	4	6	6
2	*Plantago major*	3	3	2	2	1	1
3	*Houttuynia cordata*	5	5	6	5	4	4
4	*Fagopyrum cymosum*	4	4	5	4	4	3
5	*Eryngium foetidum*	4	4	6	8	5	4
6	*Commelina benghalensis*	3	4	3	3	2	2
7	*Polygonum alatum*	3	4	3	2	2	1
8	*Hibiscus sabdariffa*	4	6	5	4	3	3
9	*Diplazium esculentum*	4	4	4	5	5	5
10	*Colocasia esculenta*	2	3	3	2	2	2
11	*Emilia sonchifolia*	3	4	3	2	1	1
12	*Mentha arvensis*	3	4	4	5	4	4
13	*Spilanthes acmella*	4	4	3	3	2	2
14	*Oxalis corniculata*	2	2	3	2	2	2
15	*Basella rubra*	4	5	9	7	5	5
16	*Alternanthera philoxeroides*	4	4	5	4	3	3
17	*Passiflora edulis*	5	6	5	5	4	4
18	*Allium hookeri*	3	5	5	4	4	3
19	*Rumex nepalensis*	3	3	3	2	2	1
20	*Amaranthus viridis*	2	3	4	3	3	2
21	*Justicia adhatoda*	5	5	7	7	5	4
22	*Piper longum*	4	4	5	4	3	3
23	*Rumex acetosa*	3	3	5	4	3	2
24	*Brassica juncea*	3	4	4	3	2	2
25	*Chenopodium album*	3	3	4	3	2	2
SEM ±		0.47	0.65	0.61	0.53	0.49	0.49
CD 5%		1.34	1.86	1.74	1.50	1.39	1.39

4.2.1.12 Yield/harvest

Figures 51, 52 and Table 4.15 represent the yield/harvest of the crops at different stges of maturity which showed significant variations among the different vegetables studied. Yield/harvest was found to be high in *Plantago major*, *Houttuynia cordata* and *Emilia sonchifolia*, while *Spilanthes acmella* and *Mentha arvensis* recorded the lower values for yield/harvest.

The yield/harvest of the crops increased with growth of the crops. This is due to the fact that as the plants mature there is increase of biomass, leaf number and leaf weight, which in turn, increases the yield. For both the years under the experiment, *Plantago major* recorded highest yield/harvest (307.06 and 296.60 g/m^2 respectively) at 10WAE, which was followed by *Houttuynia cordata* (219.90 and 221.45 g/m^2 respectively at 10WAE); whereas *Rumex nepalensis* recorded a lowest yield/harvest of 32.95 g/m^2 at 2WAE during the first year.



Figs. 51 & 52: Yield/harvest (g/m^2) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*,8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.15: Yield/harvest (g/m^2) of the leafy vegetables under study at different stages of maturity

Sl. No	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	67.90	80.80	88.15	108.25	154.48	174.01	73.67	82.18	85.64	116.56	163.40	180.98
2.	*Plantago major*	125.99	169.00	165.38	204.61	307.06	298.65	131.45	173.20	169.34	216.56	296.60	295.80
3.	*Houttuynia cordata*	87.50	112.00	144.00	174.00	219.90	204.33	89.20	115.16	147.45	172.80	221.45	205.20
4.	*Fagopyrum cymosum*	53.00	96.00	106.40	141.20	128.00	164.67	52.24	93.45	109.20	136.70	127.30	165.20
5.	*Eryngium foetidum*	47.50	70.70	90.67	81.71	99.00	109.50	49.10	69.40	88.70	81.20	96.56	110.20
6.	*Commelina benghalensis*	95.09	101.33	106.73	104.58	110.72	106.12	96.40	104.56	105.10	107.70	113.90	109.20
7.	*Polygonum alatum*	81.46	95.87	102.98	122.51	116.40	220.45	80.30	97.10	104.24	118.80	115.60	119.80
8.	*Hibiscus sabdariffa*	80.84	115.26	131.41	148.24	184.61	190.16	83.30	112.67	127.70	145.60	185.20	191.60
9.	*Diplazium esculentum*	49.95	69.03	77.06	85.75	91.82	93.47	51.45	71.12	78.30	88.84	89.70	92.90
10.	*Colocasia esculenta*	101.96	109.21	104.08	129.10	100.95	96.12	103.60	112.40	103.25	132.40	103.20	99.15
11.	*Emilia sonchifolia*	100.11	116.53	120.83	151.34	245.89	198.78	98.76	118.20	122.64	148.60	243.50	200.44
12.	*Mentha arvensis*	48.78	59.91	62.76	61.31	63.24	59.43	48.45	60.16	64.06	60.45	65.20	60.30
13.	*Spilanthes acmella*	41.52	43.24	45.09	44.09	61.50	59.55	40.85	41.80	45.30	46.10	60.86	60.34
14.	*Oxalis corniculata*	46.82	66.93	61.31	84.50	78.90	74.25	47.50	65.30	62.20	86.48	79.10	75.30
15.	*Basella rubra*	97.82	103.07	78.80	82.54	97.67	95.00	98.34	101.80	81.10	82.25	98.65	96.30
16.	*Alternanthera philoxeroides*	97.92	124.53	119.66	140.85	119.37	104.80	103.87	135.56	127.67	131.40	128.23	107.45
17.	*Passiflora edulis*	92.42	113.71	122.96	99.44	122.80	111.65	91.67	111.85	123.67	101.45	119.78	110.74
18.	*Allium hookeri*	34.17	78.71	101.86	91.13	95.96	117.07	35.14	76.65	104.30	92.12	95.20	117.65
19.	*Rumex nepalensis*	32.95	89.83	86.07	118.25	122.60	189.45	33.65	85.25	89.10	118.40	119.60	186.80
20.	*Amaranthus viridis*	61.67	63.83	80.40	81.25	106.70	94.80	60.45	65.20	77.86	80.15	107.30	96.26
21.	*Justicia adhatoda*	91.41	104.55	114.54	107.16	120.25	130.11	90.15	105.42	117.20	107.50	118.90	131.40
22.	*Piper longum*	89.85	121.14	135.37	145.70	172.20	157.36	90.24	123.56	133.60	142.70	170.86	155.56
23.	*Rumex acetosa*	86.77	98.58	102.48	110.13	93.40	117.45	87.56	96.56	104.20	112.35	95.25	117.12
24.	*Brassica juncea*	72.38	82.16	87.59	95.70	95.40	85.50	72.76	84.25	84.78	93.65	96.45	83.40
25.	*Chenopodium album*	52.00	81.60	92.80	77.07	52.53	48.47	53.80	80.65	93.20	75.52	55.67	49.15
	SEM ±	1.51	1.71	1.88	1.60	1.54	1.76	3.50	3.96	3.21	3.59	4.09	5.49
	CD 5%	4.29	4.86	5.34	4.53	4.38	4.99	9.94	11.24	9.11	10.20	11.61	15.61

4.2.1.13 Ratooning effect if any

Effects of ratooning on the leafy vegetables are presented in Table 4.16 which demonstrated that the different vegetables respond differently to harvesting stages and frequencies.

Table 4.16: Ratooning effect on the leafy vegetables under study

Sl. No.	Crop	Ratooning Effect
1.	*Centella asiatica*	Early harvests results in less yield
2.	*Plantago major*	Less leaves are produced in the ratoon crop
3.	*Houttuynia cordata*	NA
4.	*Fagopyrum cymosum*	NA
5.	*Eryngium foetidum*	Early harvests results in less yield
6.	*Commelina benghalensis*	NA
7.	*Polygonum alatum*	NA
8.	*Hibiscus sabdariffa*	Less leaves are produced in the ratoon crop
9.	*Diplazium esculentum*	Early harvests results in less yield
10.	*Colocasia esculenta*	Leaf size is reduced
11.	*Emilia sonchifolia*	Subsequent yields are reduced
12.	*Mentha arvensis*	NA
13.	*Spilanthes acmella*	Subsequent yields are reduced
14.	*Oxalis corniculata*	Subsequent yields are reduced
15.	*Basella rubra*	Early harvests results in less yield
16.	*Alternanthera philoxeroides*	NA
17.	*Passiflora edulis*	NA
18.	*Allium hookeri*	NA
19.	*Rumex nepalensis*	Less leaves are produced in the ratoon crop
20.	*Amaranthus viridis*	Subsequent yields are reduced
21.	*Justicia adhatoda*	NA
22.	*Piper longum*	NA
23.	*Rumex acetosa*	Subsequent yields are reduced
24.	*Brassica juncea*	Subsequent yields are reduced
25.	*Chenopodium album*	Subsequent yields are reduced

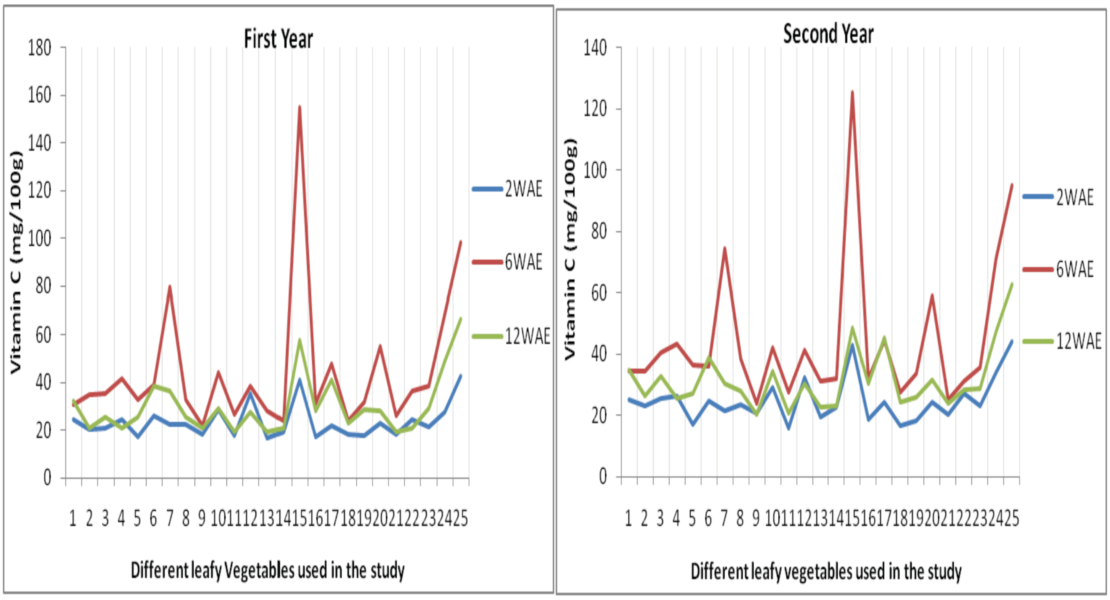
For crops like *Centella asiatica*, *Eryngium foetidum*, *Diplazium esculentum* and *Basella rubra* yield was reduced when harvesting was done at early stage, for *Plantago major*, *Hibiscus sabdariffa* etc yields were reduced in the ratoon crops. Again for crops like *Hottuynia cordata*, *Fagopyrum cymosum* no major effect was observed in the ratoon crops. These variations among the different types of vegetables indicated the significance of identifying optimum requirements of harvesting age before initiating any kind of economic production.

4.2.2 Physicochemical parameters

4.2.2.1 Vitamin C content

The patterns for changes in vitamin C content of the leafy vegetables at different stages of maturity are presented in Figures 53, 54 and Table 4.17.

Significant variations were observed among the different vegetables as regards to their vitamin C content. Most of the vegetables were found to be rich sources of vitamin C. Some plants with higher vitamin C content included *Basella rubra*, *Chenopodium album*, *Brassica juncea and* Colocasia *esculenta etc*. A gradual increase in vitamin C was observed in all the leafy vegetables at the beginning of growth period which reached peak values between 6^{th} and 8^{th} WAE and declined subsequently for majority of the vegetables during both the years of the experiment. Highest vitamin C values of 155.00 mg/100g and 125.50 mg/100g were recorded in *Basella rubra* at 6WAE, which was followed by *Chenopodium album* (98.50 mg/100g and 95.20 mg/100g at 6WAE) and *Colocasia esculenta* (95.20 mg/100g and 92.90 mg/100g at 8WAE) during the two years under the study; while the lowest value for vitamin C (15.80 mg/100g) was recorded in *Emilia sonchifolia* at 2WAE during the second year of study.



Figs. 53 & 54: Vitamin C content (mg/100g) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*,8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

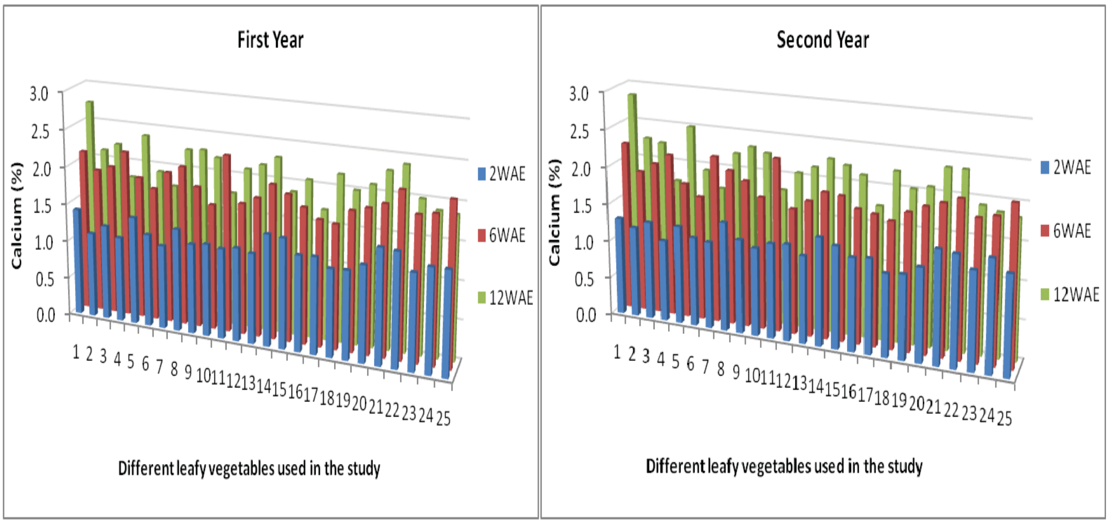
Table 4.17: Vitamin C content (mg/100g) of the leafy vegetables under study at different stages of maturity

Sl. No	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	24.20	29.50	30.80	33.00	36.40	32.50	25.10	30.30	34.40	37.10	40.50	34.70
2.	*Plantago major*	20.00	27.50	35.20	25.30	24.00	21.20	23.06	28.00	34.50	28.60	25.80	26.00
3.	*Houttuynia cordata*	20.80	30.60	35.40	42.00	33.50	25.60	25.35	33.50	40.60	53.20	35.70	32.60
4.	*Fagopyrum cymosum*	24.00	34.40	42.00	33.20	28.80	20.80	26.50	37.30	43.60	40.10	32.30	25.20
5.	*Eryngium foetidum*	17.00	25.40	33.00	31.30	27.20	25.60	17.00	27.25	36.40	30.25	27.85	26.80
6.	*Commelina benghalensis*	26.00	32.45	39.00	50.40	48.00	38.50	24.80	27.20	36.10	47.50	43.20	38.80
7.	*Polygonum alatum*	22.00	37.00	79.60	48.20	44.00	36.65	21.30	35.23	74.40	40.26	43.20	30.20
8.	*Hibiscus sabdariffa*	22.10	26.40	32.80	36.60	41.60	25.50	23.50	30.10	38.70	40.20	43.10	27.70
9.	*Diplazium esculentum*	18.00	21.60	22.00	28.60	19.20	20.84	20.70	22.30	24.00	31.20	23.10	20.10
10.	*Colocasia esculenta*	28.50	36.00	44.20	95.20	33.80	29.46	29.20	39.10	42.10	92.90	44.60	34.10
11.	*Emilia sonchifolia*	17.60	27.60	26.80	32.30	24.20	19.50	15.80	24.65	27.76	30.60	22.50	20.50
12.	*Mentha arvensis*	35.20	39.00	38.40	55.80	45.60	27.65	32.60	36.10	41.36	58.50	47.10	30.10
13.	*Spilanthes acmella*	16.40	24.20	28.00	25.20	22.00	19.45	19.60	25.80	31.10	24.20	25.30	22.40
14.	*Oxalis corniculata*	19.20	21.60	24.20	22.00	21.12	21.20	22.70	25.10	32.00	30.60	27.40	23.10
15.	*Basella rubra*	40.80	64.50	155.00	88.50	66.60	57.70	43.00	60.00	125.50	90.10	70.20	48.60
16.	*Alternanthera philoxeroides*	16.80	24.00	31.50	40.50	35.20	28.40	18.70	26.70	32.00	43.50	36.60	30.20
17.	*Passiflora edulis*	21.60	40.20	48.00	59.00	52.95	41.00	24.35	35.95	44.50	55.90	52.10	45.35
18.	*Allium hookeri*	18.20	20.00	24.00	26.46	26.00	23.32	16.80	23.30	27.50	31.20	27.20	24.30
19.	*Rumex nepalensis*	17.50	27.20	31.80	45.60	29.70	28.80	18.20	23.10	33.60	42.20	28.70	25.60
20.	*Amaranthus viridis*	22.80	35.30	55.50	45.80	37.56	28.47	24.50	36.40	59.10	46.70	40.20	31.50
21.	*Justicia adhatoda*	18.10	24.10	26.00	28.15	40.30	19.60	20.20	23.20	25.25	33.20	43.30	23.70
22.	*Piper longum*	24.20	26.40	36.40	39.00	36.40	20.80	27.00	30.60	31.30	37.80	35.00	28.10
23.	*Rumex acetosa*	21.25	27.46	38.70	36.40	34.20	29.30	23.10	25.40	35.90	34.30	32.50	28.40
24.	*Brassica juncea*	27.57	59.40	68.60	84.00	63.20	48.90	34.20	55.50	71.20	79.80	58.20	47.20
25.	*Chenopodium album*	42.40	78.80	98.50	78.60	74.50	66.65	44.20	75.70	95.20	75.60	70.40	62.60
	SEM ±	1.74	1.80	1.83	1.92	1.67	1.73	1.40	1.33	1.49	1.54	1.40	1.40
	CD 5%	4.95	5.13	5.19	5.46	4.74	4.91	3.99	3.78	4.23	4.38	3.98	3.96

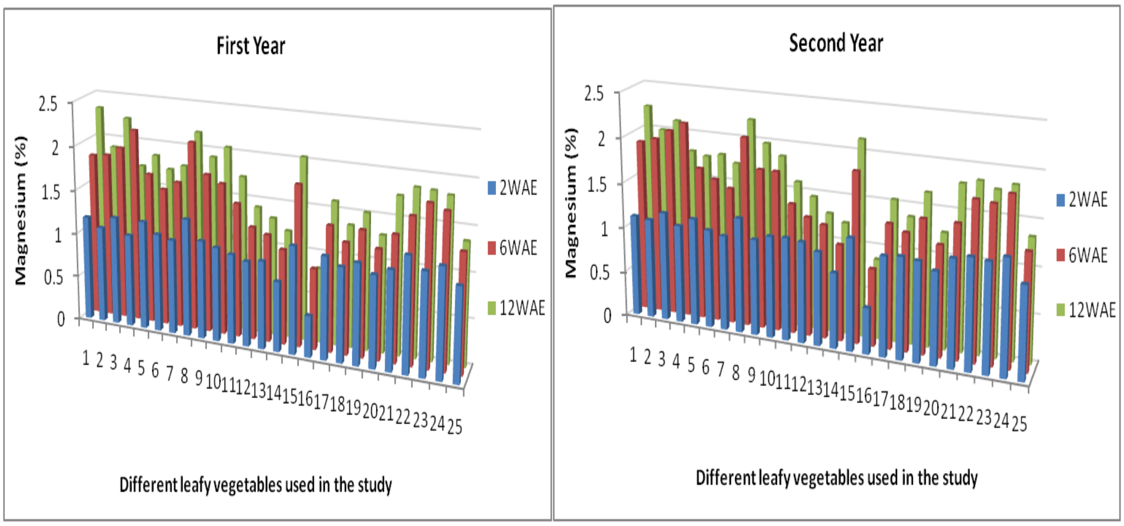
4.2.2.2 Minerals content

4.2.2.2.1 Calcium and Magnesium

The calcium and magnesium contents of the leafy vegetables (Figures 55, 56, Table 4.18 and Figures 57, 58 and Table 4.19 respectively) showed variations among the vegetables studied. The vegetables under study were found to be rich sources of calcium and magnesium. The calcium content was found to be high in *Centella asiatica*, *Oxalis corniculata*, *Piper longum*, *Houttuynia cordata* and *Eryngium foetidum*; while for magnesium content, higher values were observed in *Houttuynia cordata*, *Hibiscus sabdariffa*, *Centella asiatica*, *Plantago major* and *Basella rubra*. The calcium and magnesium contents were found to be low during the initial phase of development which increased as the plants matured and then showed a gradual decline in most of the vegetables, with different vegetables showing peak values at different stages; while for some crops like *Centella asiatica* and *Justicia adhatoda* the values showed a continuous increase. *Centella asiatica* recorded the highest calcium values of 2.85% and 2.75% at 12WAE during the second and first years of study respectively; which were significantly superior over other vegetables.Higher calcium contents were also recorded in *Houttuynia cordata* and *Oxalis corniculata* with values of 2.72%, 2.60% and 2.70%, 2.65% respectively at 8WAE during the period under study, while *Fagopyrum cymosum* and *Allium hookeri* recorded lowest calcium values of 1.08% at 2WAE during the second year of the study. As regards to magnesium content, *Houttuynia cordata* was found to contain maximum value of 2.55% at 8WAE (during the first year), followed by Hibiscus sabdariffa (2.46% at 10WAE for the 2nd year) and *Centella asiatica* (2.34% at 12WAEduring the first year of the experiment). A lowest magnesium content of 0.46% was observed in *Alternanthera philoxeroides* at 2WAE during the same period.



Figs. 55 & 56: Calcium content (%) of the leafy vegetables under study at different stages of maturity



Figs. 57 & 58: Magnesium content (%) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*,10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.18: Calcium content (%) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	1.42	1.72	2.14	2.30	2.68	2.75	1.30	1.64	2.25	2.35	2.48	2.85
2.	*Plantago major*	1.12	1.65	1.91	2.50	2.18	2.12	1.20	1.55	1.89	2.42	2.32	2.28
3.	*Houttuynia cordata*	1.25	1.82	1.98	2.72	2.50	2.22	1.30	1.72	2.02	2.60	2.42	2.24
4.	*Fagopyrum cymosum*	1.12	1.56	2.20	2.08	2.05	1.80	1.08	1.52	2.16	2.06	2.00	1.75
5.	*Eryngium foetidum*	1.42	1.75	1.88	2.25	2.50	2.38	1.30	1.62	1.80	2.32	2.54	2.50
6.	*Commelina benghalensis*	1.22	1.30	1.76	2.22	2.10	1.92	1.18	1.35	1.65	2.15	2.00	1.94
7.	*Polygonum alatum*	1.10	1.38	2.00	2.18	2.10	1.75	1.15	1.58	2.21	2.08	1.95	1.72
8.	*Hibiscus sabdariffa*	1.35	1.68	2.10	2.22	2.60	2.26	1.44	1.72	2.05	2.15	2.55	2.21
9.	*Diplazium esculentum*	1.18	1.65	1.86	2.08	2.20	2.28	1.24	1.76	1.94	2.15	2.24	2.32
10.	*Colocasia esculenta*	1.21	1.42	1.65	1.92	2.36	2.20	1.16	1.38	1.75	2.06	2.44	2.26
11.	*Emilia sonchifolia*	1.18	1.52	2.32	2.24	1.86	1.76	1.25	1.53	2.28	2.15	1.92	1.80
12.	*Mentha arvensis*	1.22	1.38	1.72	1.98	2.26	2.10	1.27	1.41	1.65	1.95	2.20	2.05
13.	*Spilanthes acmella*	1.18	1.42	1.82	2.06	2.30	2.18	1.15	1.37	1.78	2.05	2.24	2.15
14.	*Oxalis corniculata*	1.46	1.79	2.02	2.70	2.46	2.30	1.42	1.76	1.92	2.65	2.43	2.28
15.	*Basella rubra*	1.44	1.82	1.92	2.40	2.36	1.88	1.34	1.78	1.90	2.10	2.38	2.22
16.	*Alternanthera philoxeroides*	1.25	1.52	1.78	2.00	2.38	2.06	1.22	1.47	1.76	1.96	2.35	2.12
17.	*Passiflora edulis*	1.26	1.45	1.65	1.90	2.08	1.70	1.24	1.42	1.72	1.86	2.12	1.75
18.	*Allium hookeri*	1.14	1.40	1.62	2.00	2.30	2.18	1.08	1.32	1.66	1.90	2.28	2.22
19.	*Rumex nepalensis*	1.15	1.56	1.82	2.22	2.12	2.00	1.10	1.50	1.80	2.15	2.10	2.02
20.	*Amaranthus viridis*	1.25	1.46	1.88	2.26	2.15	2.10	1.22	1.52	1.90	2.20	2.13	2.07
21.	*Justicia adhatoda*	1.50	1.82	1.96	2.08	2.20	2.30	1.48	1.88	1.97	2.02	2.08	2.34
22.	*Piper longum*	1.48	1.92	2.16	2.32	2.48	2.40	1.45	1.80	2.05	2.24	2.54	2.34
23.	*Rumex acetosa*	1.25	1.42	1.88	2.34	2.11	2.00	1.28	1.45	1.84	2.28	2.04	1.92
24.	*Brassica juncea*	1.35	1.70	1.92	2.22	2.12	1.88	1.46	1.75	1.89	2.24	2.17	1.86
25.	*Chenopodium album*	1.35	1.62	2.12	2.08	1.90	1.86	1.30	1.65	2.08	2.05	1.84	1.82
	SEM ±	0.09	0.10	0.11	0.10	0.09	0.08	0.08	0.09	0.09	0.10	0.10	0.09
	CD 5%	0.25	0.27	0.31	0.28	0.27	0.24	0.24	0.25	0.25	0.28	0.29	0.26

Table 4.19: Magnesium content (%) of the leafy vegetables under study at different stages of maturity

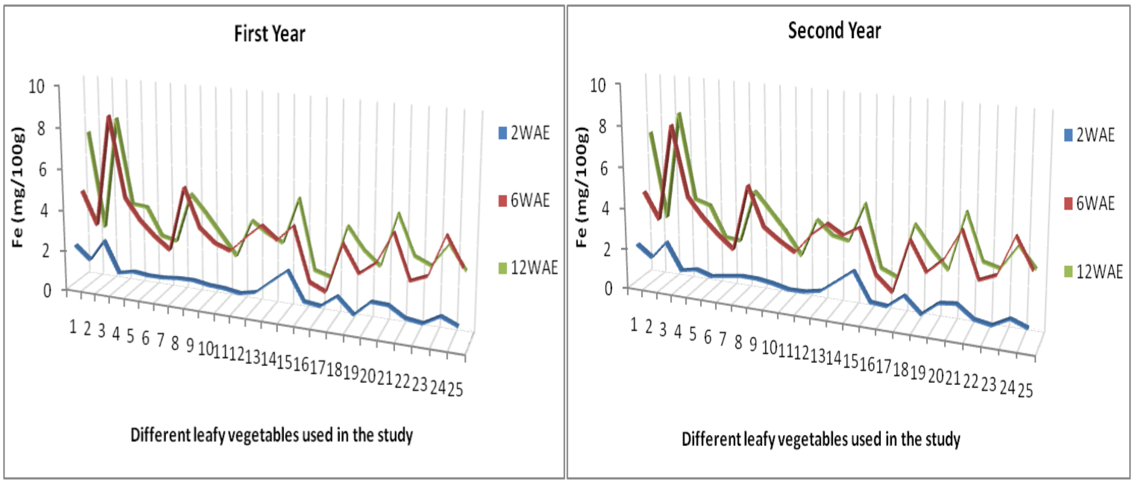
Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	1.18	1.36	1.84	2.12	2.20	2.34	1.12	1.32	1.90	2.06	2.12	2.25
2.	*Plantago major*	1.08	1.50	1.86	2.24	2.12	1.90	1.10	1.45	1.95	2.28	2.08	2.00
3.	*Houttuynia cordata*	1.22	1.64	1.96	2.55	2.36	2.25	1.20	1.74	2.06	2.32	2.28	2.12
4.	*Fagopyrum cymosum*	1.04	1.36	2.18	1.96	1.84	1.72	1.08	1.45	2.16	2.05	1.92	1.80
5.	*Eryngium foetidum*	1.22	1.42	1.70	1.82	2.20	1.86	1.18	1.54	1.68	1.80	2.06	1.76
6.	*Commelina benghalensis*	1.10	1.28	1.55	1.96	1.85	1.72	1.08	1.36	1.58	1.90	1.84	1.80
7.	*Polygonum alatum*	1.06	1.34	1.65	1.96	1.82	1.78	1.04	1.26	1.50	1.92	1.80	1.72
8.	*Hibiscus sabdariffa*	1.32	1.54	2.12	2.35	2.38	2.18	1.26	1.49	2.08	2.30	2.46	2.22
9.	*Diplazium esculentum*	1.10	1.56	1.78	2.00	2.18	1.92	1.05	1.48	1.75	1.95	2.12	1.98
10.	*Colocasia esculenta*	1.05	1.32	1.70	2.08	2.12	2.05	1.11	1.27	1.75	1.92	2.18	1.86
11.	*Emilia sonchifolia*	1.00	1.32	1.50	1.88	1.80	1.74	1.12	1.23	1.42	1.86	1.72	1.60
12.	*Mentha arvensis*	0.95	1.18	1.26	1.44	1.52	1.42	1.10	1.22	1.30	1.42	1.55	1.46
13.	*Spilanthes acmella*	0.98	1.14	1.20	1.32	1.40	1.32	1.02	1.16	1.24	1.33	1.45	1.30
14.	*Oxalis corniculata*	0.78	0.95	1.06	1.15	1.24	1.20	0.82	0.98	1.05	1.18	1.30	1.22
15.	*Basella rubra*	1.20	1.45	1.80	1.94	2.20	2.04	1.22	1.52	1.86	1.92	2.26	2.14
16.	*Alternanthera philoxeroides*	0.46	0.75	0.90	1.02	1.06	0.83	0.50	0.71	0.84	0.93	1.02	0.87
17.	*Passiflora edulis*	1.14	1.26	1.40	1.54	1.75	1.60	1.08	1.22	1.35	1.55	1.64	1.54
18.	*Allium hookeri*	1.05	1.18	1.24	1.40	1.44	1.36	1.10	1.20	1.28	1.45	1.50	1.38
19.	*Rumex nepalensis*	1.12	1.26	1.40	1.76	1.60	1.52	1.08	1.30	1.45	1.88	1.76	1.66
20.	*Amaranthus viridis*	1.02	1.10	1.22	1.46	1.42	1.30	1.00	1.14	1.20	1.42	1.34	1.26
21.	*Justicia adhatoda*	1.10	1.28	1.40	1.48	1.66	1.75	1.16	1.30	1.45	1.56	1.72	1.80
22.	*Piper longum*	1.28	1.45	1.62	1.76	1.95	1.86	1.20	1.52	1.72	1.82	2.08	1.85
23.	*Rumex acetosa*	1.14	1.48	1.78	2.18	2.10	1.85	1.18	1.42	1.70	2.22	2.08	1.78
24.	*Brassica juncea*	1.22	1.45	1.72	2.05	1.94	1.82	1.25	1.50	1.82	2.12	1.90	1.85
25.	*Chenopodium album*	1.04	1.26	1.32	1.54	1.40	1.36	1.00	1.18	1.26	1.60	1.38	1.34
	SEM ±	0.08	0.10	0.11	0.09	0.10	0.10	0.07	0.08	0.09	0.10	0.09	0.08
	CD 5%	0.23	0.29	0.30	0.27	0.29	0.29	0.21	0.23	0.27	0.29	0.27	0.24

4.2.2.2.2 Iron and Manganese Contents

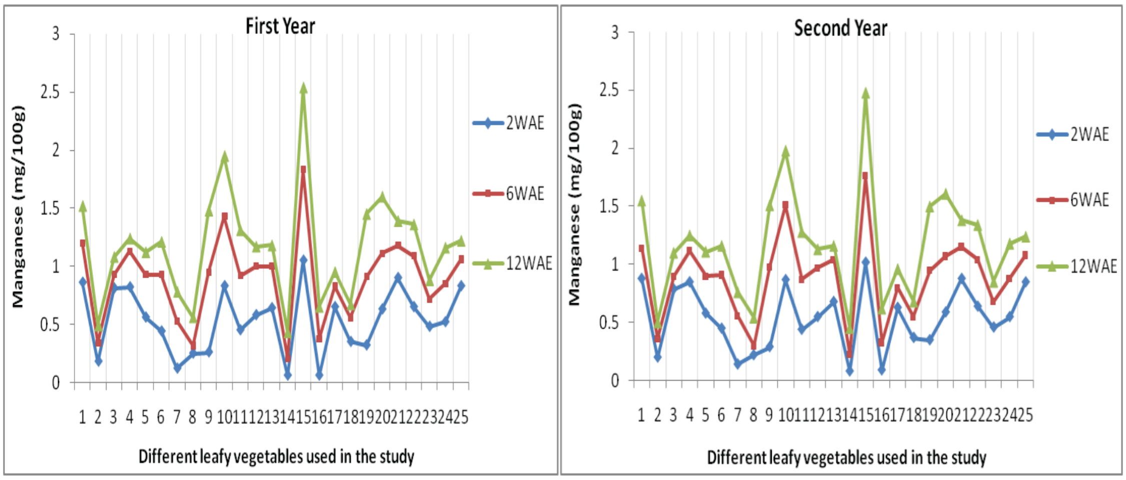
The iron and manganese contents of the leafy vegetables at different harvest stages are presented in Figures 59, 60 Table 4.20 & Figures 61, 62 and Table 4.21 respectively. These crops were found to contain high values of both the minerals.

Significant variations were observed among the vegetables in terms of their iron and manganesecontents among the different vegetables. Higher values for iron were observed in *Houttuynia cordata*, *Centella asiatica*, *Basella rubra*, *Justicia adhatoda* and *Hibiscus sabdariffa*; while manganese content was found to be high in *Basella rubra*, *Colocasia esculenta*, *Centella asiatica*, *Amaranthus viridis* and *Justicia adhatoda*.

The iron content of the vegetables increased during growth of the plants upto certain point and decreased thereafter; whereas the manganese content of the vegetables was found to increase with maturity of the crops. *Houttuynia cordata* was found to contain the maximum values for iron (9.66 mg/100g and 9.86 mg/100g) at 8WAE, followed by *Centella asiatica* with iron content of 7.97mg/100g and 8.01mg/100g at 10WAE during the period under study. Among the crops, *Rumex nepalensis* recorded the lowest value of 0.84 mg/100g during the first year of study at 2WAE. Similarly, for manganese content, highest values (2.54 mg/100g and 2.48mg/100g) were obtained in *Basella rubra* at 12WAE during the first and second years respectively, followed by *Colocasia esculenta* (1.95 mg/100g and 1.98 mg/100g at 12WAE during the first and second years respectively); while the lowest value (0.06 mg/100g) was recorded in *Oxalis corniculata* and *Alternanthera philoxeroides* at 2WAE during the first year.



Figs. 59 & 60: Fe content (mg/100g) of the leafy vegetables under study at different stages of maturity



Figs. 61 & 62: Mn content (mg/100g) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa* , 9 = *Diplazium esculentum*,10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.20: Iron content (mg/100g) of the leafy vegetables under study at different stages of maturity

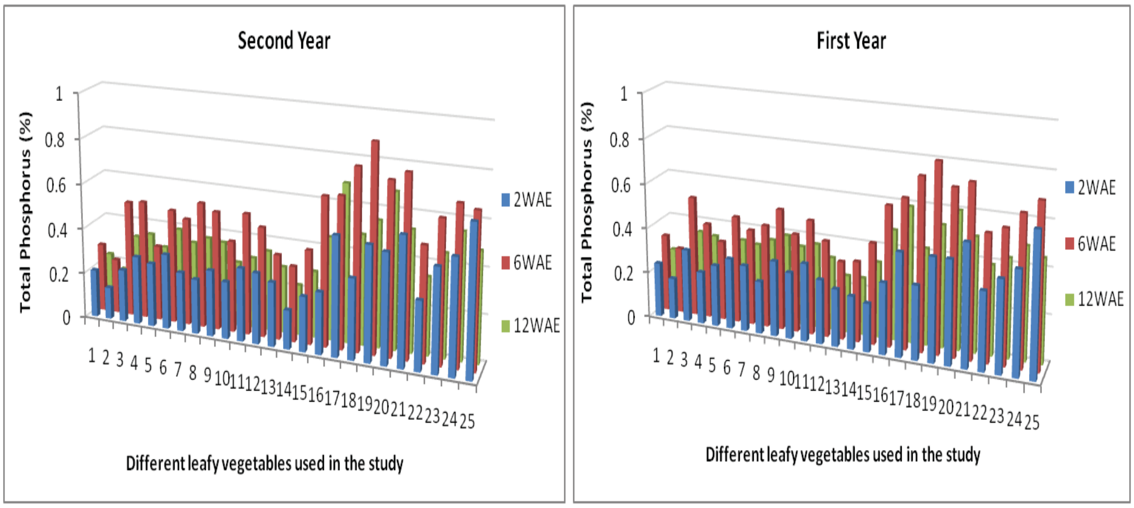
Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	2.15	4.13	4.60	5.41	7.97	7.30	2.11	4.16	4.46	5.32	8.01	7.19
2.	*Plantago major*	1.52	2.41	2.98	2.93	2.72	2.61	1.56	2.37	3.16	3.00	2.80	2.54
3.	*Houttuynia cordata*	2.58	4.61	8.46	9.66	9.36	8.13	2.43	4.37	7.91	9.86	9.23	8.28
4.	*Fagopyrum cymosum*	1.09	3.24	4.52	4.98	4.94	3.96	1.14	3.33	4.48	5.02	5.05	4.10
5.	*Eryngium foetidum*	1.26	3.23	3.51	4.41	4.63	3.90	1.30	3.15	3.56	4.38	4.80	3.88
6.	*Commelina benghalensis*	1.18	2.28	2.80	2.77	2.65	2.56	1.08	2.12	2.82	2.76	2.61	2.40
7.	*Polygonum alatum*	1.19	1.93	2.25	2.59	2.52	2.40	1.21	1.87	2.20	2.62	2.56	2.33
8.	*Hibiscus sabdariffa*	1.27	2.84	5.42	5.27	5.16	4.84	1.32	2.93	5.43	5.24	5.09	4.90
9.	*Diplazium esculentum*	1.29	2.68	3.55	4.76	4.28	3.98	1.31	2.65	3.52	4.83	4.33	4.03
10.	*Colocasia esculenta*	1.17	2.49	2.90	3.26	3.10	3.03	1.20	2.60	2.96	3.16	3.06	3.13
11.	*Emilia sonchifolia*	1.13	1.80	2.63	2.33	2.17	2.09	1.03	1.77	2.50	2.38	2.12	2.05
12.	*Mentha arvensis*	1.01	2.44	3.39	4.48	4.11	3.92	1.05	2.50	3.44	4.40	4.17	3.90
13.	*Spilanthes acmella*	1.18	2.94	4.07	4.03	3.62	3.40	1.21	3.03	4.10	4.08	3.67	3.23
14.	*Oxalis corniculata*	1.82	2.83	3.47	3.31	3.21	3.05	1.80	2.89	3.65	3.43	3.23	3.08
15.	*Basella rubra*	2.44	3.85	4.25	5.51	5.19	5.29	2.40	3.71	4.12	5.45	5.11	4.98
16.	*Alternanthera philoxeroides*	1.09	1.38	1.68	2.13	2.06	1.95	1.05	1.33	2.00	2.00	1.67	2.00
17.	*Passiflora edulis*	1.00	1.11	1.34	1.44	1.80	1.73	0.98	1.03	1.30	1.41	1.68	1.67
18.	*Allium hookeri*	1.58	2.63	3.73	5.13	4.79	4.27	1.60	2.51	3.89	5.18	4.96	4.32
19.	*Rumex nepalensis*	0.84	1.97	2.43	3.63	3.38	3.24	0.86	1.94	2.47	3.78	3.35	3.27
20.	*Amaranthus viridis*	1.56	2.30	3.04	2.91	2.75	2.58	1.50	2.18	3.20	3.10	2.49	2.37
21.	*Justicia adhatoda*	1.53	3.34	4.56	5.02	5.36	5.16	1.60	3.20	4.66	5.05	5.41	5.21
22.	*Piper longum*	1.05	1.75	2.44	3.04	3.52	3.28	1.01	1.66	2.47	2.99	3.60	2.99
23.	*Rumex acetosa*	0.94	2.09	2.77	3.52	3.11	2.94	0.87	1.98	2.81	3.50	3.04	2.79
24.	*Brassica juncea*	1.39	3.79	4.75	4.52	4.23	4.04	1.30	3.73	4.70	4.49	4.17	3.96
25.	*Chenopodium album*	1.06	2.30	3.38	3.19	3.15	2.92	1.00	2.27	3.25	3.11	3.06	2.99
	SEM ±	0.10	0.19	0.15	0.12	0.14	0.12	0.12	0.22	0.17	0.14	0.12	0.15
	CD 5%	0.27	0.53	0.41	0.35	0.39	0.34	0.33	0.62	0.47	0.40	0.35	0.43

Table 4. 21: Manganese content (mg/100g) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	0.86	1.08	1.20	1.27	1.32	1.52	0.88	1.01	1.14	1.21	1.30	1.55
2.	*Plantago major*	0.18	0.25	0.34	0.40	0.42	0.49	0.20	0.26	0.36	0.43	0.45	0.50
3.	*Houttuynia cordata*	0.81	0.82	0.93	0.95	0.99	1.08	0.79	0.83	0.90	0.94	0.97	1.10
4.	*Fagopyrum cymosum*	0.82	1.00	1.13	1.19	1.21	1.24	0.85	1.05	1.12	1.22	1.27	1.25
5.	*Eryngium foetidum*	0.56	0.77	0.93	1.00	1.08	1.12	0.58	0.75	0.90	0.98	1.07	1.11
6.	*Commelina benghalensis*	0.44	0.81	0.93	1.03	1.13	1.21	0.45	0.78	0.91	0.99	1.10	1.16
7.	*Polygonum alatum*	0.12	0.39	0.53	0.62	0.73	0.78	0.14	0.40	0.56	0.65	0.78	0.76
8.	*Hibiscus sabdariffa*	0.25	0.30	0.32	0.44	0.50	0.56	0.22	0.29	0.30	0.41	0.48	0.54
9.	*Diplazium esculentum*	0.26	0.66	0.95	1.19	1.34	1.48	0.29	0.69	0.98	1.26	1.38	1.51
10.	*Colocasia esculenta*	0.83	1.12	1.43	1.59	1.81	1.95	0.87	1.16	1.51	1.61	1.85	1.98
11.	*Emilia sonchifolia*	0.45	0.63	0.92	1.15	1.25	1.31	0.44	0.61	0.87	1.12	1.21	1.28
12.	*Mentha arvensis*	0.58	0.83	1.00	1.06	1.12	1.17	0.55	0.79	0.97	1.03	1.09	1.13
13.	*Spilanthes acmella*	0.64	0.89	1.00	1.10	1.13	1.18	0.68	0.91	1.04	1.09	1.12	1.16
14.	*Oxalis corniculata*	0.06	0.13	0.21	0.29	0.38	0.43	0.08	0.16	0.23	0.28	0.40	0.45
15.	*Basella rubra*	1.05	1.41	1.83	2.15	2.35	2.54	1.02	1.33	1.76	2.07	2.29	2.48
16.	*Alternanthera philoxeroides*	0.06	0.26	0.38	0.43	0.52	0.65	0.09	0.29	0.33	0.45	0.47	0.62
17.	*Passiflora edulis*	0.65	0.70	0.83	0.87	0.97	0.95	0.63	0.72	0.80	0.83	0.93	0.96
18.	*Allium hookeri*	0.35	0.44	0.56	0.60	0.65	0.67	0.37	0.48	0.55	0.65	0.69	0.68
19.	*Rumex nepalensis*	0.32	0.67	0.91	1.04	1.26	1.45	0.35	0.70	0.95	1.07	1.35	1.50
20.	*Amaranthus viridis*	0.63	0.96	1.11	1.38	1.55	1.60	0.59	0.94	1.07	1.36	1.51	1.61
21.	*Justicia adhatoda*	0.90	1.06	1.18	1.24	1.41	1.39	0.88	1.01	1.15	1.20	1.31	1.38
22.	*Piper longum*	0.65	0.82	1.09	1.17	1.28	1.36	0.64	0.80	1.04	1.14	1.27	1.34
23.	*Rumex acetosa*	0.48	0.61	0.72	0.84	0.82	0.88	0.46	0.60	0.68	0.81	0.81	0.85
24.	*Brassica juncea*	0.52	0.79	0.85	0.96	1.12	1.16	0.55	0.83	0.88	1.03	1.15	1.18
25.	*Chenopodium album*	0.83	1.22	1.06	1.11	1.17	1.22	0.85	1.03	1.08	1.15	1.15	1.24
	SEM ±	0.02	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
	CD 5%	0.05	0.12	0.08	0.07	0.06	0.06	0.05	0.06	0.08	0.05	0.07	0.06

4.2.2.2.3 Total Phosphorus Content

The total phosphorus content as shown in Figures 63, 64 and Table 4.22 revealed significant differences among the leafy vegetables in their total phosphorus content. All the vegetables studied were found to contain appreciable amounts of total phosphorus in their leaves. *Amaranthus viridis*, *Passiflora edulis*, *Rumex nepalensis*, *Chenopodium album*, *Justicia adhatoda*, *Brassica juncea* and *Allium hookeri* recorded higher values for total phosphorus content. The total phosphorus content of the different vegetables increased with increasing growth of the plants and then declined gradually for both the years of the experiment; which could be due to the partitioning of photosynthetic products which with age is directed to the reproductive growth. *Passiflora edulis* was found to contain a highest total phosphorus content of 0.96% at 8WAE during the second year, closely followed by *Rumex nepalensis* and *Amaranthus viridis* with total phosphorus values of 0.90% at 6WAE and 0.83% at WAE respectively during the same year; while a lowest total phosphorus value of 0.14% was found in *Plantago major* leaves at 2WAE during the same period.



Figs. 63 & 64: Total Phosphorus Content (%) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridi*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

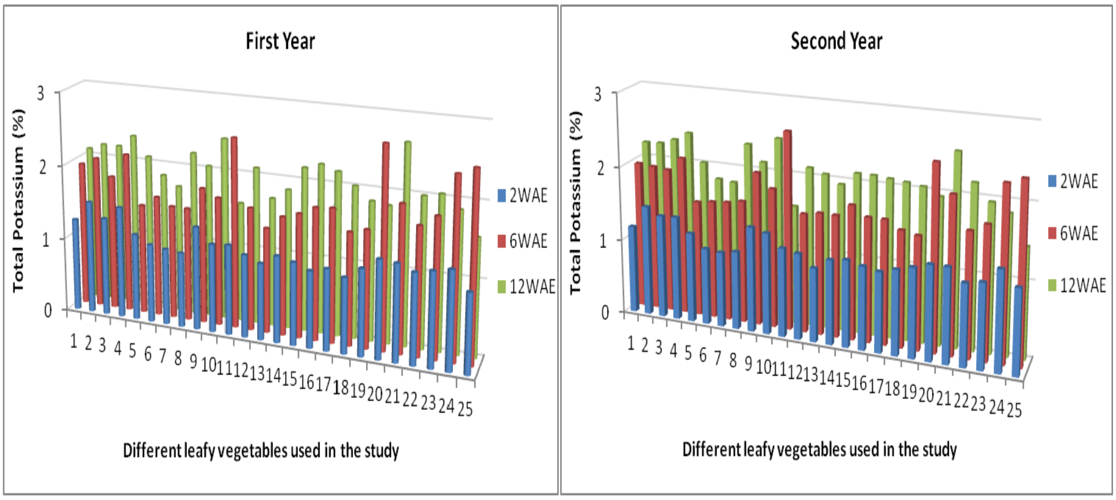
Table 4.22: Total Phosphorus content (%) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	0.24	0.28	0.34	0.33	0.28	0.25	0.21	0.25	0.30	0.29	0.26	0.23
2.	*Plantago major*	0.18	0.26	0.29	0.27	0.26	0.22	0.14	0.19	0.24	0.22	0.21	0.17
3.	*Houttuynia cordata*	0.32	0.47	0.53	0.44	0.39	0.35	0.23	0.40	0.51	0.40	0.37	0.33
4.	*Fagopyrum cymosum*	0.23	0.35	0.42	0.39	0.36	0.34	0.30	0.41	0.52	0.47	0.43	0.35
5.	*Eryngium foetidum*	0.27	0.32	0.35	0.37	0.27	0.24	0.28	0.31	0.33	0.35	0.33	0.30
6.	*Commelina benghalensis*	0.31	0.36	0.47	0.43	0.39	0.34	0.33	0.44	0.50	0.46	0.43	0.39
7.	*Polygonum alatum*	0.29	0.37	0.42	0.44	0.38	0.33	0.26	0.33	0.47	0.43	0.35	0.34
8.	*Hibiscus sabdariffa*	0.23	0.37	0.45	0.42	0.39	0.36	0.24	0.40	0.55	0.45	0.41	0.37
9.	*Diplazium esculentum*	0.33	0.42	0.53	0.49	0.41	0.39	0.29	0.41	0.52	0.43	0.42	0.36
10.	*Colocasia esculenta*	0.29	0.34	0.43	0.40	0.38	0.35	0.25	0.31	0.40	0.37	0.33	0.28
11.	*Emilia sonchifolia*	0.34	0.56	0.50	0.47	0.42	0.37	0.32	0.58	0.53	0.45	0.34	0.31
12.	*Mentha arvensis*	0.28	0.33	0.42	0.37	0.35	0.32	0.31	0.36	0.48	0.40	0.37	0.35
13.	*Spilanthes acmella*	0.25	0.30	0.34	0.29	0.28	0.25	0.28	0.33	0.37	0.35	0.32	0.29
14.	*Oxalis corniculata*	0.23	0.28	0.35	0.29	0.26	0.25	0.17	0.24	0.33	0.26	0.24	0.22
15.	*Basella rubra*	0.21	0.34	0.44	0.39	0.36	0.33	0.24	0.31	0.41	0.36	0.33	0.29
16.	*Alternanthera philoxeroides*	0.31	0.42	0.61	0.55	0.51	0.48	0.27	0.44	0.65	0.51	0.48	0.45
17.	*Passiflora edulis*	0.45	0.53	0.65	0.69	0.62	0.59	0.52	0.58	0.66	0.96	0.89	0.69
18.	*Allium hookeri*	0.32	0.59	0.75	0.62	0.50	0.42	0.35	0.63	0.79	0.56	0.51	0.48
19.	*Rumex nepalensis*	0.45	0.57	0.82	0.75	0.62	0.53	0.50	0.62	0.90	0.72	0.64	0.55
20.	*Amaranthus viridis*	0.45	0.61	0.72	0.78	0.70	0.60	0.48	0.64	0.75	0.83	0.77	0.68
21.	*Justicia adhatoda*	0.53	0.67	0.75	0.60	0.57	0.50	0.56	0.70	0.79	0.62	0.57	0.53
22.	*Piper longum*	0.34	0.43	0.55	0.48	0.43	0.39	0.30	0.37	0.50	0.45	0.40	0.34
23.	*Rumex acetosa*	0.40	0.48	0.58	0.56	0.49	0.43	0.45	0.55	0.62	0.54	0.48	0.45
24.	*Brassica juncea*	0.45	0.60	0.65	0.59	0.54	0.49	0.50	0.63	0.69	0.62	0.58	0.55
25.	*Chenopodium album*	0.62	0.82	0.71	0.66	0.60	0.45	0.65	0.78	0.67	0.61	0.56	0.48
	SEM ±	0.02	0.03	0.02	0.03	0.02	0.02	0.04	0.06	0.05	0.05	0.04	0.04
	CD 5%	0.06	0.09	0.06	0.09	0.06	0.06	0.10	0.16	0.15	0.13	0.12	0.12

4.2.2.2.4 Total Potassium Content

Data pertaining to the total potassium content of the leafy vegetables under study are presented in Figures 65, 66 and Table 4.23, which showed that the different vegetables varied in their total potassium contents at different stages of maturity Higher values for total potassium content were observed in *Fagopyrum cymosum*, *Plantago major*, *Justicia adhatoda*, *Diplazium esculentum*, *Colocasia esculenta*, *Houttuynia cordata*, *Amaranthus viridis* and *Brassica juncea*.

It was evident from the figures that the total potassium content increased at the beginning and then declined with maturity for all the vegetables during the two years under the experiment. Highest total potassium content of 2.92% and 2.85% were observed in *Diplazium esculentum* at 8WAE during the second and first years of study respectively, followed by *Justicia adhatoda* (2.78% and 2.75% respectively at 10WAE during the first and second years); while the lowest total potassium content of 0.98% was recorded in *Spilanthes acmella* at 2WAE during second year.



Figs. 65 & 66: Total Potassium Content (%) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

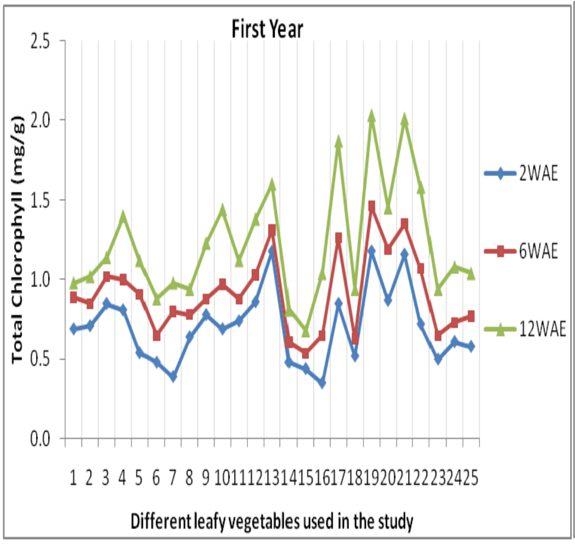
Table 4.23: Total Potassium content (%) of the leafy vegetables under study at different stages of maturity

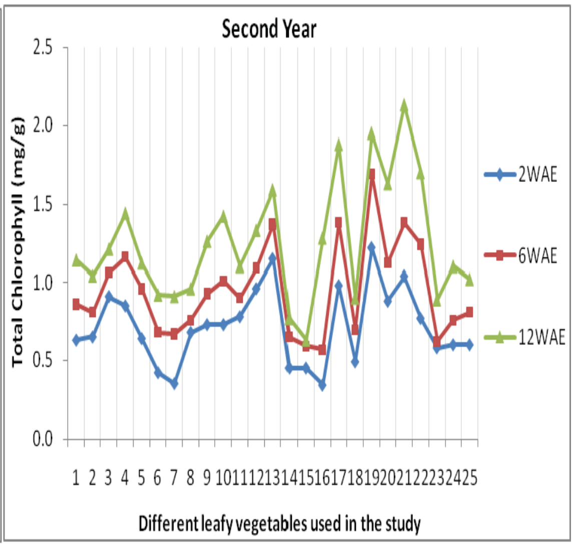
Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	1.25	1.70	1.95	2.02	2.34	2.10	1.18	1.76	1.98	2.00	2.47	2.21
2.	*Plantago major*	1.52	1.84	2.05	2.60	2.36	2.18	1.48	1.80	1.96	2.70	2.45	2.22
3.	*Houttuynia cordata*	1.32	1.62	1.82	2.10	2.55	2.18	1.38	1.66	1.94	2.18	2.42	2.29
4.	*Fagopyrum cymosum*	1.50	1.85	2.15	2.72	2.52	2.34	1.39	1.80	2.12	2.66	2.54	2.40
5.	*Eryngium foetidum*	1.16	1.25	1.48	1.75	2.35	2.08	1.20	1.32	1.55	1.84	2.28	2.02
6.	*Commelina benghalensis*	1.05	1.34	1.62	2.45	2.02	1.85	1.02	1.28	1.58	2.36	2.00	1.82
7.	*Polygonum alatum*	1.02	1.25	1.52	2.55	2.15	1.72	1.00	1.30	1.60	2.62	2.08	1.80
8.	*Hibiscus sabdariffa*	1.00	1.30	1.52	2.05	2.75	2.20	1.04	1.25	1.64	2.14	2.68	2.34
9.	*Diplazium esculentum*	1.38	1.55	1.82	2.85	2.55	2.05	1.40	1.68	2.05	2.92	2.32	2.12
10.	*Colocasia esculenta*	1.18	1.45	1.72	2.15	2.62	2.44	1.35	1.60	1.86	2.18	2.58	2.46
11.	*Emilia sonchifolia*	1.20	1.35	2.54	2.26	2.08	1.60	1.18	1.25	2.64	2.24	1.95	1.58
12.	*Mentha arvensis*	1.10	1.32	1.64	1.90	2.58	2.10	1.14	1.35	1.58	2.04	2.62	2.12
13.	*Spilanthes acmella*	1.02	1.18	1.40	2.32	2.12	1.72	0.98	1.12	1.62	1.48	2.40	2.06
14.	*Oxalis corniculata*	1.15	1.32	1.58	2.60	2.22	1.86	1.12	1.28	1.62	2.40	2.16	1.95
15.	*Basella rubra*	1.10	1.34	1.65	1.94	2.70	2.18	1.15	1.32	1.78	2.00	2.75	2.12
16.	*Alternanthera philoxeroides*	1.02	1.25	1.76	2.62	2.50	2.25	1.10	1.34	1.65	2.56	2.36	2.12
17.	*Passiflora edulis*	1.08	1.45	1.78	2.04	2.40	2.18	1.06	1.28	1.65	2.43	2.20	2.10
18.	*Allium hookeri*	1.00	1.26	1.50	1.74	2.38	2.02	1.12	1.30	1.54	1.76	2.42	2.08
19.	*Rumex nepalensis*	1.15	1.30	1.56	2.44	2.18	1.85	1.18	1.48	1.50	2.50	1.92	2.05
20.	*Amaranthus viridis*	1.30	1.55	2.68	2.00	2.22	1.82	1.25	1.48	2.46	2.18	2.08	1.95
21.	*Justicia adhatoda*	1.28	1.65	1.95	2.28	2.78	2.65	1.25	1.52	2.08	2.26	2.75	2.55
22.	*Piper longum*	1.20	1.35	1.70	1.94	2.68	2.00	1.08	1.40	1.65	1.82	2.45	2.18
23.	*Rumex acetosa*	1.25	1.66	1.85	2.25	2.16	2.05	1.12	1.54	1.76	2.30	2.28	1.96
24.	*Brassica juncea*	1.30	1.54	2.40	2.22	2.12	1.88	1.32	1.46	2.30	2.38	2.06	1.85
25.	*Chenopodium album*	1.05	1.22	2.50	2.18	1.75	1.56	1.12	1.28	2.38	2.12	1.80	1.46
	SEM ±	0.09	0.10	0.11	0.12	0.11	0.10	0.08	0.12	0.13	0.12	0.11	0.12
	CD 5%	0.25	0.30	0.31	0.35	0.31	0.28	0.24	0.34	0.37	0.34	0.31	0.33

4.2.2.3 Total Chlorophyll Content

The total chlorophyll content of the leafy vegetables at different stages of maturity are presented in Figures 67, 68 and Table 4.24, which showed great variations among the vegetables with regards to their total chlorophyll content. Values for total chlorophyll content were found to be high in *Rumex nepalensis*, *Justicia adhatoda*, *Passiflora edulis* and *Spilanthes acmella* etc.

The total chlorophyll content was found to be low at the initial stages of maturity, but it increased rapidly with increasing age of the plants. *Justicia adhatoda* recorded the maximum total chlorophyll content of 2.13 mg/g at 12WAE during the second year of study, which was followed by *Rumex nepalensis* (2.03 mg/g) at 12WAE during the first year. The lowest total chlorophyll content of 0.34 mg/g was observed in *Alternanthera philoxeroides* at 2WAE during the second year of the experiment.





Figs. 67 & 68: Total Chlorophyll Content (mg/g) of the leafy vegetables under study at different stages of maturity

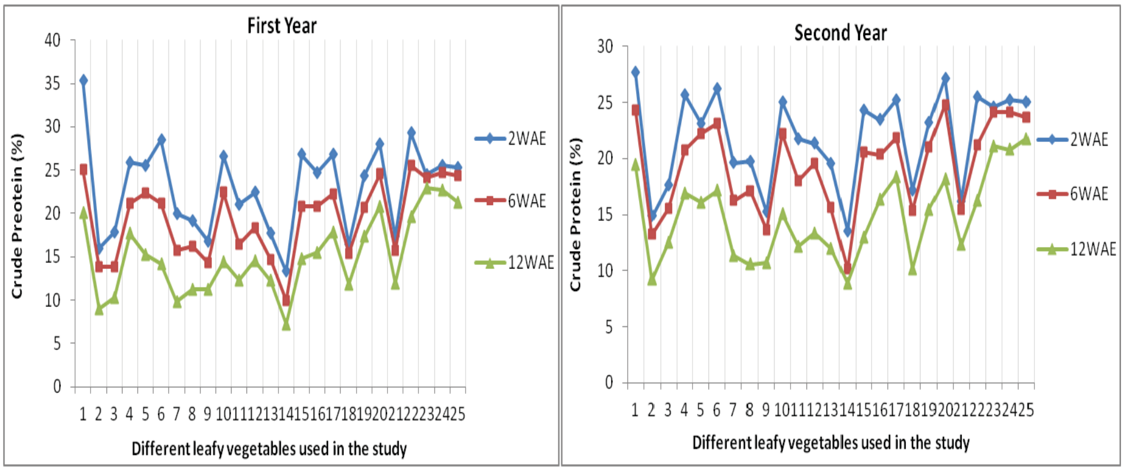
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridi*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.24: Total Chlorophyll content (mg/g) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	0.69	0.77	0.89	0.93	0.96	0.98	0.63	0.72	0.86	0.92	1.01	1.14
2.	*Plantago major*	0.71	0.81	0.85	0.90	0.95	1.02	0.65	0.75	0.81	0.88	0.92	1.04
3.	*Houttuynia cordata*	0.85	0.99	1.02	1.06	1.12	1.14	0.91	0.98	1.06	1.10	1.16	1.21
4.	*Fagopyrum cymosum*	0.81	0.95	1.00	1.12	1.28	1.40	0.85	0.95	1.16	1.22	1.34	1.44
5.	*Eryngium foetidum*	0.54	0.77	0.91	0.97	1.05	1.12	0.64	0.80	0.96	1.02	1.07	1.12
6.	*Commelina benghalensis*	0.48	0.57	0.65	0.78	0.82	0.88	0.42	0.59	0.68	0.74	0.80	0.92
7.	*Polygonum alatum*	0.39	0.66	0.80	0.87	0.93	0.98	0.35	0.54	0.67	0.81	0.87	0.91
8.	*Hibiscus sabdariffa*	0.64	0.75	0.78	0.80	0.88	0.94	0.68	0.72	0.76	0.83	0.89	0.96
9.	*Diplazium esculentum*	0.78	0.83	0.88	0.95	1.07	1.23	0.73	0.87	0.93	0.97	1.12	1.26
10.	*Colocasia esculenta*	0.69	0.90	0.97	1.10	1.14	1.44	0.73	0.82	1.01	1.16	1.24	1.42
11.	*Emilia sonchifolia*	0.74	0.85	0.88	0.96	1.04	1.12	0.78	0.88	0.90	0.98	1.07	1.10
12.	*Mentha arvensis*	0.86	0.99	1.03	1.08	1.14	1.38	0.96	1.00	1.09	1.13	1.25	1.33
13.	*Spilanthes acmella*	1.18	1.23	1.31	1.39	1.45	1.60	1.15	1.26	1.37	1.41	1.52	1.59
14.	*Oxalis corniculata*	0.48	0.58	0.61	0.65	0.73	0.81	0.45	0.53	0.65	0.69	0.71	0.77
15.	*Basella rubra*	0.44	0.50	0.54	0.57	0.65	0.68	0.45	0.58	0.59	0.60	0.63	0.63
16.	*Alternanthera philoxeroides*	0.35	0.56	0.65	0.74	0.82	1.04	0.34	0.59	0.57	0.68	0.84	1.28
17.	*Passiflora edulis*	0.85	1.05	1.26	1.38	1.56	1.87	0.98	1.29	1.38	1.56	1.62	1.88
18.	*Allium hookeri*	0.52	0.61	0.63	0.76	0.82	0.94	0.49	0.55	0.70	0.83	0.86	0.90
19.	*Rumex nepalensis*	1.18	1.33	1.46	1.52	1.71	2.03	1.22	1.35	1.69	1.66	1.83	1.95
20.	*Amaranthus viridis*	0.87	0.97	1.19	1.26	1.32	1.45	0.88	1.05	1.12	1.22	1.40	1.63
21.	*Justicia adhatoda*	1.16	1.20	1.35	1.61	1.80	2.01	1.04	1.25	1.38	1.67	1.75	2.13
22.	*Piper longum*	0.72	1.02	1.07	1.19	1.37	1.58	0.77	0.96	1.24	1.31	1.52	1.70
23.	*Rumex acetosa*	0.50	0.61	0.65	0.75	0.81	0.94	0.58	0.57	0.62	0.68	0.77	0.89
24.	*Brassica juncea*	0.61	0.65	0.73	0.86	1.00	1.08	0.60	0.62	0.76	0.90	0.97	1.10
25.	*Chenopodium album*	0.58	0.71	0.77	0.82	0.96	1.04	0.60	0.76	0.81	0.87	0.94	1.02
	SEM ±	0.08	0.09	0.10	0.08	0.09	0.10	0.07	0.08	0.09	0.08	0.08	0.08
	CD 5%	0.23	0.26	0.29	0.24	0.26	0.29	0.21	0.23	0.26	0.24	0.24	0.23

4.2.2.4 Crude protein content

The crude protein contents of the selected leafy vegetables are shown in Figures 69, 70 and Table 4.25. The different leafy vegetables under study varied considerably in their crude protein content. Maximum values for crude protein content were found in the leaves of *Centella asiatica*, *Brassica juncea*, *Rumex acetosa*, *Amaranthus viridis*, *Chenopodium album* and *Piper longum*.



Figs. 69 & 70: Crude protein content (%) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*,8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

During the stages of development of the vegetables, the crude protein content declined with increasing age for all the crops. Highest crude protein content (35.35%) was observed in *Centella asiatica* at 2WAE during the first year of the experiment. This was followed by *Piper longum* (29.30%), *Commelina benghalensis* (28.50%) and *Amaranthus viridis* (28.00%) at 2WAE; while *Oxalis corniculata* was found to contain the lowest crude protein content of 7.27% at 12WAE during the same year.

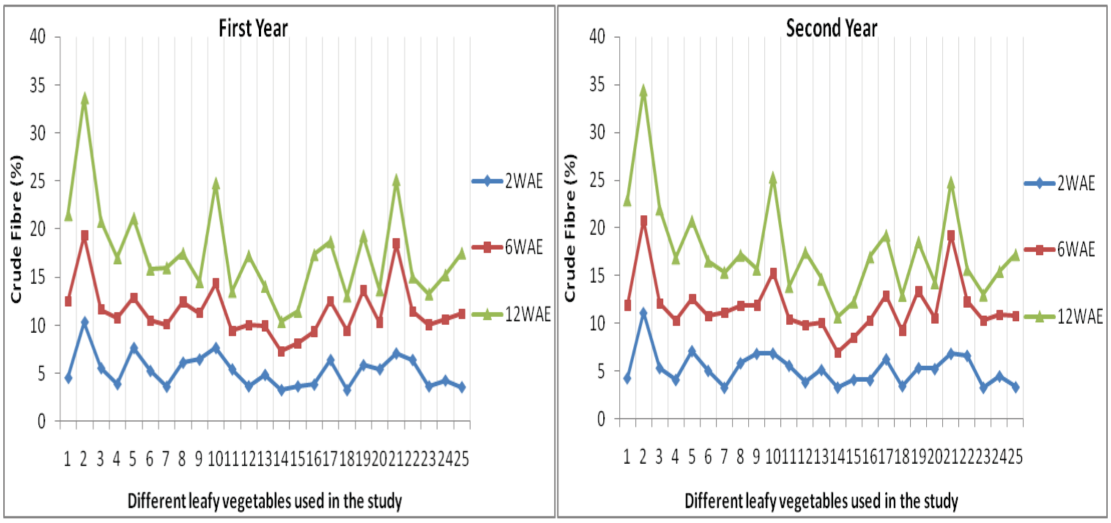
Table 4.25: Crude Protein content (%) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	35.35	28.20	25.05	24.20	20.45	20.13	27.65	25.38	24.33	23.10	20.48	19.42
2.	*Plantago major*	15.93	14.40	13.83	11.21	9.63	8.98	14.85	13.82	13.28	12.14	10.15	9.27
3.	*Houttuynia cordata*	17.85	16.62	13.86	13.07	11.86	10.25	17.68	16.45	15.53	15.06	13.45	12.55
4.	*Fagopyrum cymosum*	25.90	23.10	21.15	20.30	18.32	17.68	25.73	22.98	20.75	20.21	18.15	16.94
5.	*Eryngium foetidum*	25.55	23.18	22.31	21.60	19.26	15.23	23.10	22.59	22.23	20.95	17.62	16.10
6.	*Commelina benghalensis*	28.50	24.24	21.20	19.06	17.20	14.17	26.25	24.33	23.10	22.05	18.53	17.15
7.	*Polygonum alatum*	20.02	18.70	15.75	14.12	11.95	9.86	19.60	18.38	16.23	13.76	13.34	11.33
8.	*Hibiscus sabdariffa*	19.12	18.10	16.24	15.05	13.30	11.20	19.78	18.55	17.12	15.23	13.48	10.55
9.	*Diplazium esculentum*	16.81	15.05	14.32	13.48	12.72	11.20	15.23	14.70	13.62	13.04	12.55	10.68
10.	*Colocasia esculenta*	26.60	24.13	22.40	19.38	16.25	14.47	25.03	23.28	22.23	20.35	17.68	15.05
11.	*Emilia sonchifolia*	21.04	19.92	16.48	16.02	13.37	12.34	21.78	20.12	18.00	15.87	13.26	12.15
12.	*Mentha arvensis*	22.40	21.10	18.38	17.06	15.15	14.52	21.35	20.63	19.60	17.36	14.28	13.33
13.	*Spilanthes acmella*	17.68	16.10	14.70	13.85	12.95	12.25	19.60	16.66	15.58	13.74	13.33	11.98
14.	*Oxalis corniculata*	13.30	11.55	9.98	9.10	8.44	7.27	13.52	12.08	10.15	9.86	9.25	8.84
15.	*Basella rubra*	26.78	24.68	20.82	19.45	15.54	14.75	24.33	23.10	20.58	18.96	15.45	12.95
16.	*Alternanthera philoxeroides*	24.68	23.10	20.82	20.13	16.45	15.50	23.45	22.40	20.34	19.25	18.90	16.38
17.	*Passiflora edulis*	26.78	24.42	22.25	20.65	18.74	17.86	25.20	24.68	21.85	19.78	18.52	18.34
18.	*Allium hookeri*	16.45	16.20	15.42	13.65	12.95	11.85	17.15	16.10	15.38	14.40	12.25	10.15
19.	*Rumex nepalensis*	24.33	22.75	20.65	19.72	19.23	17.32	23.18	22.05	21.00	20.38	17.15	15.48
20.	*Amaranthus viridis*	28.00	27.48	24.54	21.95	21.48	20.77	27.13	26.50	24.75	23.98	19.62	18.15
21.	*Justicia adhatoda*	17.33	15.93	15.72	14.95	14.34	11.98	16.20	15.72	15.40	15.23	13.72	12.30
22.	*Piper longum*	29.30	28.00	25.53	24.18	22.73	19.68	25.50	22.65	21.20	20.15	18.00	16.28
23.	*Rumex acetosa*	24.50	24.37	24.08	23.95	23.68	22.92	24.58	24.33	24.12	23.85	23.20	21.10
24.	*Brassica juncea*	25.55	24.89	24.68	24.25	23.88	22.74	25.20	24.60	24.12	23.33	21.95	20.80
25.	*Chenopodium album*	25.27	24.75	24.40	22.98	22.08	21.28	25.03	24.90	23.67	23.42	22.85	21.74
	SEM ±	2.10	1.93	1.84	1.85	1.74	1.74	1.71	1.72	1.68	1.50	1.59	1.59
	CD 5%	5.96	5.49	5.24	5.26	4.95	4.93	4.85	4.89	4.78	4.25	4.51	4.51

4.2.2.5 Crude Fibre Content

Data furnished in Figures 71, 72 and Table 4.26 revealed that the different leafy vegetables varied greatly in their crude fibre content. In general, *Plantago major*, *Justicia adhatoda* and *Colocasia esculenta* were found to contain higher amount of crude fibre than the other leafy vegetables.

It is evident from the data that as the vegetables grow their crude fibre content increased gradually. In all the stages of maturity *Plantago major* was found to record higher crude fibre values than the other vegetables studied for both the years, with highest values of 34.52% and 33.65% at 12WAE during the second and first year respectively; while the lowest value (3.25%) was recorded in *Oxalis corniculata* and *Allium hookeri* at 2WAE during the first year.



Figures 71 & 72: Crude Fibre Content (%) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

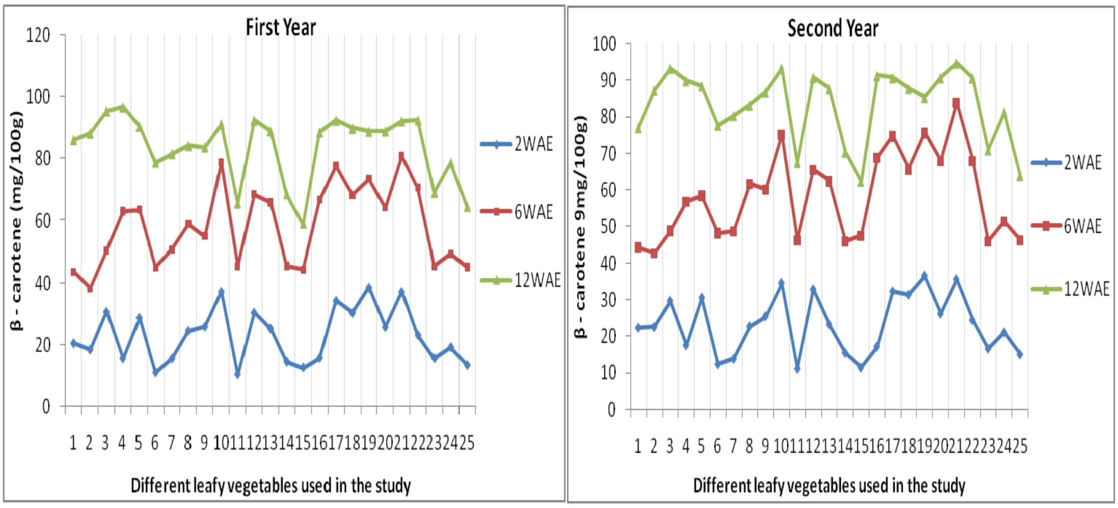
Table 4.26: Crude Fibre content (%) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st						2nd					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	4.53	6.77	12.54	16.33	19.26	21.50	4.28	7.12	11.88	16.54	20.15	22.96
2.	*Plantago major*	10.35	15.63	19.34	28.74	31.15	33.65	11.15	16.44	20.78	27.95	33.06	34.52
3.	*Houttuynia cordata*	5.54	8.34	11.67	15.75	17.43	20.80	5.35	9.15	12.06	15.18	18.35	22.00
4.	*Fagopyrum cymosum*	3.87	5.75	10.79	13.25	14.95	17.03	4.10	6.22	10.26	14.28	16.18	16.84
5.	*Eryngium foetidum*	7.65	9.55	12.87	16.05	18.23	21.15	7.14	10.15	12.54	15.72	18.55	20.75
6.	*Commelina benghalensis*	5.25	7.46	10.54	12.36	14.32	15.85	5.06	8.25	10.78	11.94	15.25	16.55
7.	*Polygonum alatum*	3.60	6.35	10.12	13.30	14.68	16.00	3.28	6.15	11.14	13.58	14.04	15.36
8.	*Hibiscus sabdariffa*	6.12	9.34	12.45	14.64	16.35	17.50	5.86	9.15	11.82	14.22	15.85	17.16
9.	*Diplazium esculentum*	6.44	8.56	11.30	13.65	14.05	14.54	6.85	9.24	11.88	14.02	14.55	15.68
10.	*Colocasia esculenta*	7.65	10.25	14.38	17.64	21.20	24.80	6.88	10.54	15.25	17.36	20.95	25.35
11.	*Emilia sonchifolia*	5.42	7.28	9.45	11.72	12.80	13.52	5.60	6.85	10.36	11.45	12.52	13.85
12.	*Mentha arvensis*	3.65	7.16	10.05	12.55	15.36	17.24	3.84	7.22	9.76	12.38	14.95	17.46
13.	*Spilanthes acmella*	4.84	7.72	9.96	12.38	13.75	14.06	5.15	7.86	10.05	12.42	14.00	14.65
14.	*Oxalis corniculata*	3.25	5.86	7.34	9.25	10.14	10.38	3.30	5.48	6.95	9.05	10.32	10.65
15.	*Basella rubra*	3.64	5.78	8.18	9.64	10.45	11.46	4.12	5.65	8.46	10.12	10.66	12.25
16.	*Alternanthera philoxeroides*	3.82	7.45	9.38	12.42	15.64	17.35	4.06	7.72	10.25	12.38	15.44	16.96
17.	*Passiflora edulis*	6.40	9.56	12.52	15.26	17.16	18.72	6.28	10.14	12.86	15.55	16.94	19.25
18.	*Allium hookeri*	3.25	6.32	9.44	10.56	11.95	13.05	3.45	6.76	9.25	10.02	11.86	12.95
19.	*Rumex nepalensis*	5.86	10.16	13.62	16.45	17.84	19.34	5.35	9.82	13.34	15.92	18.15	18.55
20.	*Amaranthus viridis*	5.42	8.86	10.35	12.22	13.35	13.68	5.25	9.18	10.52	11.96	13.60	14.26
21.	*Justicia adhatoda*	7.08	12.34	18.52	21.34	23.46	25.15	6.85	12.16	19.22	22.10	23.68	24.84
22.	*Piper longum*	6.40	8.42	11.45	14.24	14.86	15.04	6.65	8.25	12.26	13.75	15.14	15.65
23.	*Rumex acetosa*	3.64	7.35	10.08	12.10	12.65	13.28	3.28	6.86	10.27	11.56	12.42	12.98
24.	*Brassica juncea*	4.25	8.86	10.64	13.25	14.48	15.25	4.48	8.45	10.85	12.98	13.75	15.46
25.	*Chenopodium album*	3.55	7.12	11.22	13.68	15.45	17.52	3.34	6.55	10.74	13.80	16.15	17.22
	SEM ±	0.17	0.16	0.70	0.16	0.16	0.15	0.21	0.43	0.44	0.37	0.50	0.59
	CD 5%	0.48	0.44	2.00	0.46	0.46	0.43	0.59	1.22	1.24	1.06	1.42	1.67

4.2.2.6 Antioxidant phytochemicals

4.2.2.6.1 β- Carotene

The effects of harvest time on the beta-carotene content of the different leafy vegetables are presented in Figures 73, 74 and Table 4.27. All the vegetables studied were found to contain appreciable amounts of beta-carotene. Higher beta-carotene values were observed in *Colocasia esculenta*, *Justicia adhatoda*, *Passiflora edulis*, *Rumex nepalensis*, *Mentha arvensis*, *Allium hookeri* and *Piper longum* etc. The beta-carotene content for both the years of study varied significantly among the different leafy vegetables at each stage of maturity.The vegetables were found to contain lower beta-carotene content at the initial growing period which increased with the age of the plants. *Fagopyrum cymosum was* found to contain the highest beta-carotene content of 96.70 mg/100g, followed by *Houttuynia cordata* (95.40mg/100g) at 12WAE during the first year of the study and a lowest value of 10.43 mg/100g was observed in *Emilia sonchifolia* at 2WAE during the same year.



Figures 73 & 74: β – Carotene Content (%) of the leafy vegetables under study at different stages of maturity

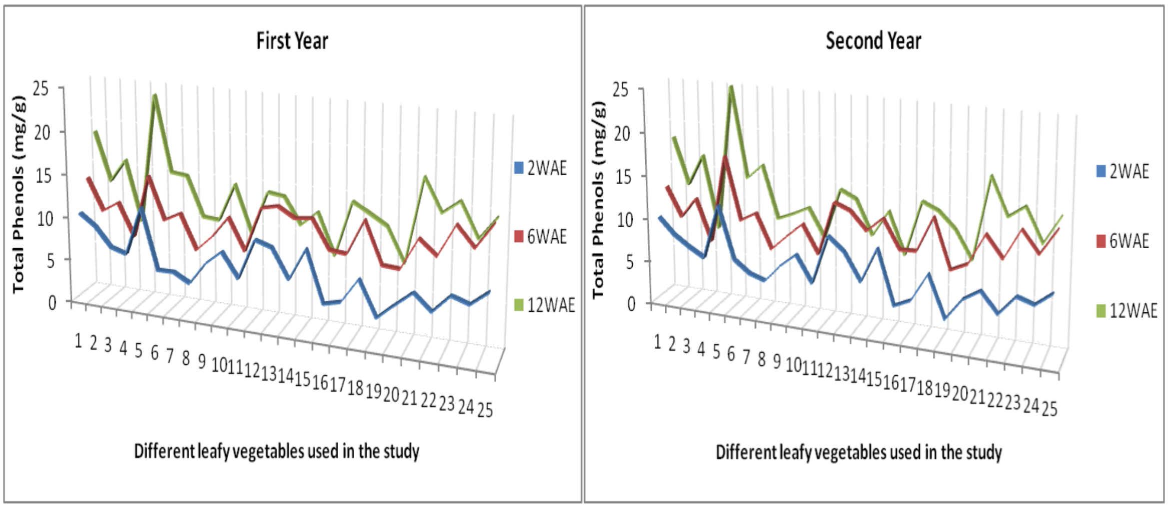
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.27: β -carotene content (mg/100g) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year Week After Emergence						2nd Year Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	20.56	32.06	43.67	57.76	74.15	86.06	22.40	32.56	44.33	60.21	72.55	76.96
2.	*Plantago major*	18.50	31.30	38.40	56.60	67.70	88.12	22.56	33.32	42.68	57.72	69.45	87.24
3.	*Houttuynia cordata*	30.83	38.56	50.40	61.80	88.40	95.40	29.78	45.23	48.79	69.54	91.12	93.23
4.	*Fagopyrum cymosum*	15.62	32.34	63.03	70.05	78.68	96.70	17.59	35.24	56.78	68.65	80.23	89.80
5.	*Eryngium foetidum*	28.90	41.62	63.53	73.89	88.70	90.50	30.65	42.23	58.42	71.45	85.56	88.42
6.	*Commelina benghalensis*	11.09	27.65	45.19	56.70	73.24	78.70	12.40	26.52	48.23	59.44	71.19	77.62
7.	*Polygonum alatum*	15.63	35.64	50.82	58.07	75.60	81.54	13.85	32.72	48.63	57.40	68.82	80.24
8.	*Hibiscus sabdariffa*	24.63	49.56	58.88	65.84	77.69	84.14	22.78	46.42	61.54	66.70	75.86	83.11
9.	*Diplazium esculentum*	25.98	45.43	54.92	75.60	81.18	83.70	25.55	47.63	60.12	77.64	83.12	86.72
10.	*Colocasia esculenta*	37.31	66.22	78.85	84.23	88.76	91.20	34.65	62.15	75.24	83.78	90.11	93.20
11.	*Emilia sonchifolia*	10.43	25.68	45.56	50.82	62.30	65.42	11.15	28.34	46.21	54.33	60.78	67.45
12.	*Mentha arvensis*	30.56	53.29	68.45	82.30	88.60	92.40	32.88	50.36	65.45	83.28	85.11	90.70
13.	*Spilanthes acmella*	25.40	45.52	65.83	78.62	85.60	88.93	23.32	46.55	62.42	75.80	82.89	87.65
14.	*Oxalis corniculata*	14.56	31.30	45.63	59.34	65.65	68.40	15.55	35.42	45.87	57.69	66.42	70.23
15.	*Basella rubra*	12.69	27.89	44.50	48.90	53.40	58.80	11.45	26.23	47.55	52.32	56.48	62.23
16.	*Alternanthera philoxeroides*	15.78	38.32	66.70	77.14	85.73	88.52	17.23	43.25	68.92	76.45	87.34	91.23
17.	*Passiflora edulis*	34.45	52.82	77.69	84.30	88.43	92.40	32.34	49.25	74.76	79.85	86.33	90.65
18.	*Allium hookeri*	30.50	46.84	68.23	80.20	84.75	89.80	31.45	45.28	65.72	78.86	81.24	87.72
19.	*Rumex nepalensis*	38.72	56.65	73.58	78.92	85.40	88.75	36.65	57.24	75.66	80.23	83.37	85.24
20.	*Amaranthus viridis*	25.85	46.78	64.23	80.23	85.58	88.90	26.23	48.84	67.89	81.25	87.25	90.62
21.	*Justicia adhatoda*	37.31	54.24	80.91	85.32	86.44	92.15	35.68	55.72	83.88	87.54	89.12	94.65
22.	*Piper longum*	23.24	45.90	70.56	75.65	90.30	92.45	24.52	44.69	67.85	74.72	87.76	90.55
23.	*Rumex acetosa*	15.68	28.79	45.40	61.80	67.45	68.90	16.65	31.22	45.86	63.24	65.56	70.82
24.	*Brassica juncea*	19.32	35.99	49.32	66.45	70.20	78.63	21.11	33.78	51.45	64.39	72.53	81.28
25.	*Chenopodium album*	13.45	28.65	45.23	55.68	58.46	64.30	15.08	30.23	46.22	57.89	60.24	63.88
	SEM ±	1.33	1.54	1.45	1.42	1.44	1.40	1.30	1.36	1.27	1.41	1.40	1.43
	CD 5%	3.78	4.38	4.13	4.04	4.09	3.97	3.70	3.87	3.60	4.00	3.97	4.07

4.2.2.6.2 Total Phenol content

Data presented in Figures 75, 76 and Table 4.28 showed the total phenol content of the leafy vegetables at different maturity stages which varied significantly. Maximum values for total phenol content were recorded in *Eryngium foetidum*, *Centella asiatica*, *Rumex acetosa*, *Mentha arvensis* and *Justicia adhatoda*.



Figs. 75 & 76: Total Phenols Content (mg/g) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

The results presented showed an increasing trend in the total phenol content of the vegetables with increasing age of the crops. The different leafy vegetables varied greatly in their total phenol contents at different harvest stages with *Eryngium foetidum* recording the highest values (24.90 mg/100g and 23.77 mg/100g at 12WAE during the second and first years under study respectively), followed by *Centella asiatica* (18.78 mg/100g and 18.28 mg/100g at 12WAE during the first and second years under study respectively) and the lowest value (3.33 mg/100g) was recorded at 2WAE during the second year in *Rumex nepalensis*.

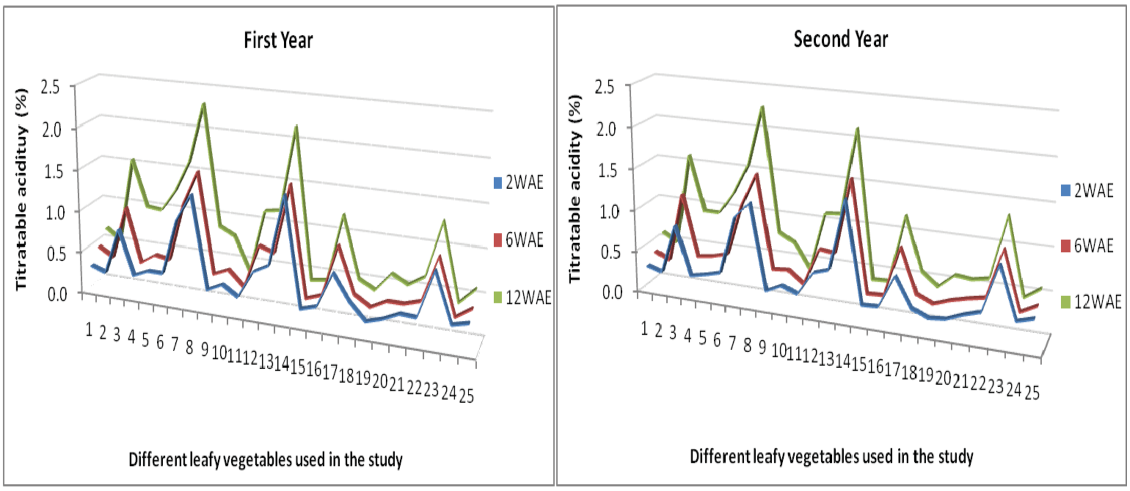
Table 4.28: Total phenol content (mg/g) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	10.35	12.45	13.87	15.43	18.05	18.78	10.05	11.77	13.01	14.77	16.87	18.28
2.	*Plantago major*	9.03	9.77	10.20	12.16	12.61	13.10	8.24	9.42	9.67	12.05	12.27	12.91
3.	*Houttuynia cordata*	6.84	8.64	11.38	14.12	14.98	15.76	7.03	9.92	12.04	14.22	15.46	16.50
4.	*Fagopyrum cymosum*	6.30	6.56	7.63	8.11	8.50	8.78	6.03	6.36	7.26	7.94	8.16	8.16
5.	*Eryngium foetidum*	11.97	14.07	14.93	18.26	23.13	23.77	12.36	15.63	17.42	20.33	23.28	24.90
6.	*Commelina benghalensis*	4.99	7.79	10.09	12.74	15.10	15.00	6.34	8.54	10.22	13.04	15.39	14.51
7.	*Polygonum alatum*	5.04	9.02	11.09	12.31	14.40	14.79	4.99	9.50	11.27	8.77	14.39	16.22
8.	*Hibiscus sabdariffa*	4.03	6.18	7.13	9.08	9.82	10.28	4.43	6.12	7.38	9.24	9.96	10.23
9.	*Diplazium esculentum*	6.60	8.15	8.97	9.62	11.04	10.14	6.45	8.22	9.12	9.88	11.57	11.02
10.	*Colocasia esculenta*	8.21	9.82	11.40	13.60	14.41	14.52	7.97	9.19	10.75	12.78	13.07	11.95
11.	*Emilia sonchifolia*	5.45	7.02	7.81	8.30	9.18	9.24	4.99	6.83	7.58	7.44	8.53	8.77
12.	*Mentha arvensis*	10.09	11.78	12.96	14.17	14.17	14.07	10.60	12.30	13.70	15.54	14.80	14.50
13.	*Spilanthes acmella*	9.50	11.80	13.40	15.30	14.91	13.83	9.07	11.13	12.97	15.00	14.67	13.63
14.	*Oxalis corniculata*	6.20	9.01	12.30	11.91	11.40	10.85	6.00	8.54	10.99	10.73	10.01	9.77
15.	*Basella rubra*	9.91	11.40	12.55	13.23	13.15	12.55	10.00	11.90	12.61	13.50	13.11	12.75
16.	*Alternanthera philoxeroides*	4.10	6.85	9.30	10.70	9.83	7.91	3.92	6.76	9.39	10.55	9.42	8.07
17.	*Passiflora edulis*	4.62	6.38	9.13	12.06	13.91	14.22	4.80	6.70	9.50	12.31	14.50	14.30
18.	*Allium hookeri*	7.43	10.95	13.16	14.21	13.74	13.15	8.00	11.30	13.52	15.00	13.68	13.50
19.	*Rumex nepalensis*	3.50	5.78	8.45	9.87	11.78	12.00	3.33	5.34	7.96	9.31	11.43	11.70
20.	*Amaranthus viridis*	5.22	6.87	8.32	9.52	9.11	8.15	5.80	7.45	8.87	10.00	9.34	8.55
21.	*Justicia adhatoda*	6.85	9.18	11.92	14.84	17.19	17.89	7.00	9.45	12.38	15.16	17.46	18.03
22.	*Piper longum*	5.09	7.41	10.27	12.70	13.29	14.20	4.78	7.01	9.95	12.11	12.85	13.80
23.	*Rumex acetosa*	7.12	10.20	13.92	18.20	16.60	15.73	6.97	10.07	13.40	17.94	16.46	15.16
24.	*Brassica juncea*	6.50	9.13	11.68	12.20	12.03	11.91	6.37	8.82	10.98	11.78	11.58	11.39
25.	*Chenopodium album*	8.11	11.37	14.56	16.80	14.71	14.51	7.87	9.70	13.93	16.13	14.21	14.63
	SEM ±	0.27	0.34	0.37	0.35	0.30	0.31	0.21	0.32	0.32	0.95	0.31	0.38
	CD 5%	0.77	0.96	1.05	0.99	0.84	0.88	0.59	0.92	0.90	2.69	0.88	1.08

4.2.2.7 Titratable Acidity content

Data on titratable acidity content of the leafy vegetables at different stages of maturity are shown in Figures 77, 78 and Table 4.29.

It was observed that the crops varied greatly as regards to their titratable acidity contents. *Hibiscus sabdariffa*, *Oxalis corniculata*, *Polygonum alatum*, *Houttuynia cordata* and *Rumex acetosa* were found to contain high titratable acidity contents. A progressive increase in acidity content was observed for all the crops with advancement of maturity, with highest values at 12WAE for both the years of the experiment. During the both the years of the experiment, maximum titratable acidity contents (2.30% and 2.26%) was observed in *Hibiscus sabdariffa* at 12WAE. This was followed by *Oxalis corniculata* with high titratable acidity contents of 2.15% and 2.12% at 2WAE during the first and second years respectively; while the least titratable acidity content (0.18%) was found in *Rumex nepalensis* during the first year at 2WAE.



Figs. 77 & 78: Titratable Acidity Content (%) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

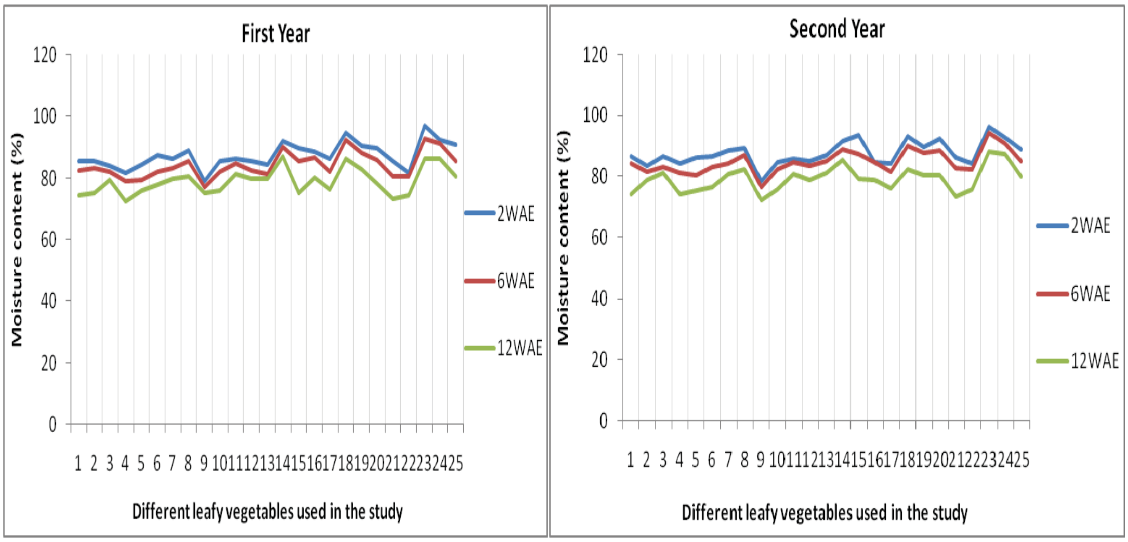
Table 4.29: Titratable acidity content (%) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	0.32	0.38	0.48	0.51	0.56	0.64	0.30	0.34	0.40	0.46	0.53	0.58
2.	*Plantago major*	0.26	0.32	0.37	0.40	0.45	0.51	0.25	0.29	0.32	0.37	0.42	0.48
3.	*Houttuynia cordata*	0.81	0.89	1.01	1.12	1.25	1.54	0.85	0.98	1.16	1.24	1.34	1.58
4.	*Fagopyrum cymosum*	0.28	0.32	0.36	0.56	0.84	0.98	0.26	0.31	0.42	0.60	0.74	0.92
5.	*Eryngium foetidum*	0.36	0.42	0.48	0.56	0.68	0.96	0.30	0.36	0.45	0.55	0.70	0.92
6.	*Commelina benghalensis*	0.36	0.40	0.45	0.53	0.60	1.22	0.35	0.42	0.50	0.56	0.79	1.18
7.	*Polygonum alatum*	1.02	1.08	1.15	1.30	1.43	1.60	1.05	1.10	1.12	1.25	1.40	1.54
8.	*Hibiscus sabdariffa*	1.35	1.40	1.56	1.90	2.04	2.30	1.24	1.39	1.52	1.85	2.00	2.26
9.	*Diplazium esculentum*	0.25	0.31	0.36	0.54	0.64	0.86	0.22	0.30	0.40	0.52	0.55	0.78
10.	*Colocasia esculenta*	0.34	0.38	0.44	0.57	0.65	0.77	0.31	0.34	0.42	0.55	0.60	0.68
11.	*Emilia sonchifolia*	0.22	0.24	0.26	0.28	0.33	0.37	0.24	0.25	0.28	0.31	0.35	0.39
12.	*Mentha arvensis*	0.55	0.66	0.78	0.92	0.96	1.12	0.52	0.58	0.72	0.87	0.94	1.08
13.	*Spilanthes acmella*	0.65	0.68	0.72	0.85	0.96	1.15	0.58	0.65	0.70	0.87	0.98	1.10
14.	*Oxalis corniculata*	1.49	1.53	1.55	1.66	1.92	2.15	1.43	1.48	1.60	1.72	1.87	2.12
15.	*Basella rubra*	0.20	0.21	0.24	0.26	0.33	0.38	0.23	0.25	0.28	0.30	0.34	0.37
16.	*Alternanthera philoxeroides*	0.26	0.29	0.31	0.33	0.36	0.41	0.24	0.27	0.29	0.31	0.33	0.38
17.	*Passiflora edulis*	0.68	0.76	0.92	0.98	1.06	1.20	0.62	0.77	0.88	0.96	1.00	1.18
18.	*Allium hookeri*	0.38	0.41	0.38	0.45	0.48	0.48	0.28	0.33	0.36	0.47	0.51	0.55
19.	*Rumex nepalensis*	0.18	0.22	0.26	0.32	0.34	0.38	0.20	0.23	0.28	0.33	0.35	0.40
20.	*Amaranthus viridis*	0.24	0.30	0.36	0.45	0.52	0.60	0.22	0.28	0.35	0.42	0.50	0.56
21.	*Justicia adhatoda*	0.33	0.32	0.36	0.43	0.46	0.50	0.30	0.34	0.40	0.44	0.48	0.54
22.	*Piper longum*	0.32	0.39	0.42	0.45	0.48	0.62	0.36	0.41	0.44	0.47	0.52	0.58
23.	*Rumex acetosa*	0.88	0.92	0.96	1.08	1.15	1.28	0.92	0.96	1.02	1.05	1.12	1.33
24.	*Brassica juncea*	0.30	0.31	0.30	0.33	0.36	0.38	0.32	0.33	0.34	0.35	0.38	0.42
25.	*Chenopodium album*	0.35	0.38	0.43	0.46	0.53	0.57	0.38	0.43	0.44	0.48	0.52	0.55
	SEM ±	0.05	0.07	0.07	0.09	0.09	0.13	0.08	0.08	0.11	0.12	0.11	0.12
	CD 5%	0.14	0.20	0.21	0.27	0.26	0.38	0.24	0.23	0.31	0.35	0.32	0.35

4.2.2.8 Moisture Content

The moisture contents of the leafy vegetables at different growth stages are presented in Figures 79, 80 and Table 4.30. The different leafy vegetables varied greatly in their moisture contents at different growth stages. Higher moisture contents were recorded in *Rumex acetosa*, *Brassica juncea*, *Allium hookeri* and *Oxalis corniculata* etc.

It is evident from the data that as the plants grow, the moisture contents showed a gradual decline. *Rumex acetosa* was found to contain the maximum moisture contents of (96.14% and 95.20%) at 2WAE during the second and first years of study respectively, which was followed by *Allium hookeri* (94.47% and 93.08% at 2WAE during the first and second years respectively); while 72.15% was the lowest value for moisture content recorded at 12WAE in the second year in *Diplazium esculentum*.



Figs. 79 & 80: Moisture Content (%) of the leafy vegetables under study at different stages of maturity

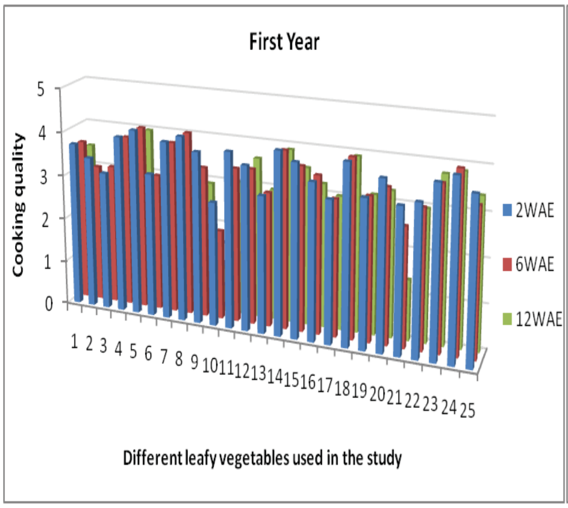
(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa* , 9 = *Diplazium esculentum*,10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

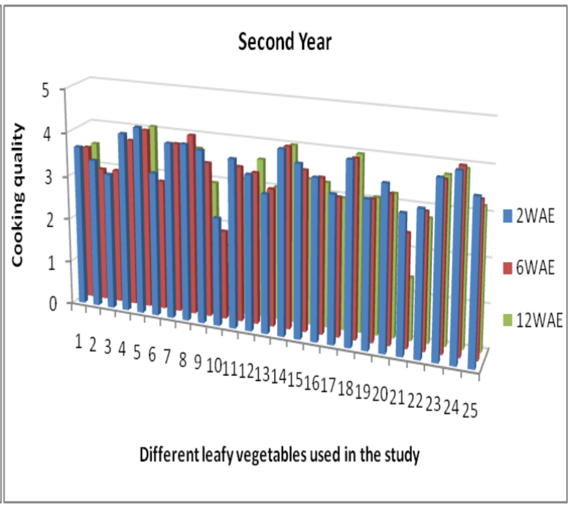
Table 4.30: Moisture content (%) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	85.45	83.30	82.42	80.50	76.42	74.32	86.60	85.80	84.40	82.30	80.10	74.09
2.	*Plantago major*	85.20	84.30	83.20	82.15	77.70	75.00	83.52	82.35	81.60	80.15	79.25	78.60
3.	*Houttuynia cordata*	84.00	83.30	82.00	81.77	80.80	79.50	86.50	85.00	83.00	82.80	82.34	81.10
4.	*Fagopyrum cymosum*	81.65	81.20	79.10	75.04	72.84	72.46	84.25	83.55	81.11	78.30	76.24	74.15
5.	*Eryngium foetidum*	84.25	81.30	79.65	79.20	77.15	76.05	86.05	83.30	80.23	78.24	77.42	75.45
6.	*Commelina benghalensis*	87.08	85.40	82.15	81.23	81.05	78.05	86.75	84.34	83.25	81.77	79.68	76.55
7.	*Polygonum alatum*	86.20	84.20	83.30	81.10	80.20	79.60	88.32	87.35	84.18	83.30	81.20	80.58
8.	*Hibiscus sabdariffa*	88.85	88.60	85.62	83.82	82.62	80.55	89.28	88.14	87.00	85.14	83.50	82.34
9.	*Diplazium esculentum*	78.85	78.10	77.22	76.80	76.20	75.00	78.55	78.12	76.55	76.15	74.32	72.15
10.	*Colocasia esculenta*	85.30	83.40	82.25	80.12	77.23	75.90	84.48	83.90	82.18	79.62	77.76	75.81
11.	*Emilia sonchifolia*	86.13	85.30	84.65	84.12	83.50	81.50	85.94	85.65	84.46	82.75	81.62	80.80
12.	*Mentha arvensis*	85.50	83.80	82.44	81.10	80.30	79.62	85.15	85.85	83.30	82.78	81.75	78.88
13.	*Spilanthes acmella*	84.23	83.40	81.55	81.12	80.63	79.82	86.82	85.55	85.15	83.88	83.34	81.09
14.	*Oxalis corniculata*	92.00	90.60	90.20	89.55	89.18	87.12	91.60	90.60	88.84	87.72	86.15	85.35
15.	*Basella rubra*	89.55	86.60	85.72	82.51	81.42	75.30	93.45	92.46	87.41	85.60	83.25	79.24
16.	*Alternanthera philoxeroides*	88.45	87.00	86.85	85.40	81.90	80.00	84.66	85.93	84.62	84.40	83.30	78.85
17.	*Passiflora edulis*	86.05	85.10	82.20	80.24	77.60	76.20	84.24	82.60	81.38	80.10	78.40	76.20
18.	*Allium hookeri*	94.47	93.70	92.54	89.06	88.50	86.25	93.08	92.53	90.18	86.26	84.30	82.35
19.	*Rumex nepalensis*	90.28	89.20	88.18	85.24	83.40	82.72	89.65	87.81	87.60	85.50	84.30	80.23
20.	*Amaranthus viridis*	89.41	87.60	86.00	85.14	80.46	78.35	92.48	89.56	88.30	86.42	82.30	80.50
21.	*Justicia adhatoda*	85.21	83.20	80.52	78.60	76.18	73.25	86.30	84.00	82.65	80.26	77.32	73.50
22.	*Piper longum*	81.43	81.10	80.65	80.50	76.12	74.50	84.41	83.45	82.30	80.65	78.20	75.80
23.	*Rumex acetosa*	95.20	94.45	92.74	87.87	89.56	86.52	96.14	95.20	94.26	92.13	90.05	88.10
24.	*Brassica juncea*	92.10	91.80	91.15	89.51	87.30	86.32	92.82	91.60	90.72	89.60	88.98	87.25
25.	*Chenopodium album*	90.50	86.20	85.40	82.92	81.48	80.66	88.90	87.65	84.84	82.60	82.00	79.90
	SEM ±	1.67	1.77	1.72	1.88	1.77	1.75	2.39	2.26	2.27	2.21	2.07	2.06
	CD 5%	4.74	5.02	4.88	5.35	5.03	4.96	6.80	6.43	6.45	6.28	5.87	5.85

4.2.2.9 Cooking Quality

Scores for cooking quality are presented in Figures 81, 82 and Table 4.31 which revealed that the different types of vegetables and harvest stage greatly affected the cooking quality of the vegetables. The overall cooking quality scores were observed to be high in *Eryngium foetidum*, *Oxalis corniculata*, *Allium hookeri*, *Brassica juncea* and *Hibiscus sabdariffa*.





Figs. 81 & 82: Cooking quality scores of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order:** 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

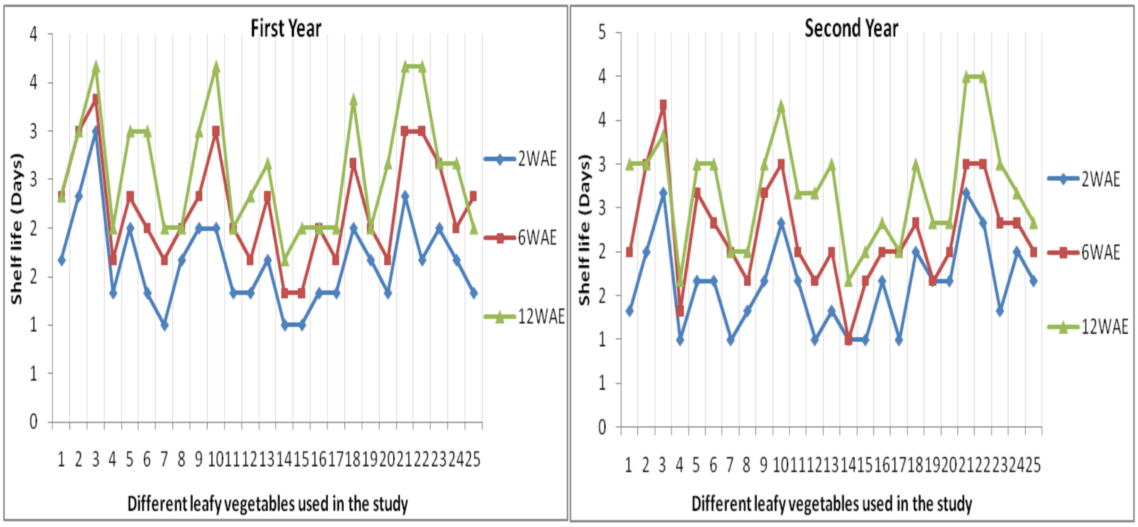
In general, scores for cooking quality were found to be high in initial growth stages which declined slightly as the plants mature. *Eryngium foetidum* was the most favoured leafy vegetable with a cooking qualityscores of 4.26 at 4WAE and 2WAE during the first and the second year of study respectively while *Colocasia esculenta* was found to obtain the least cooking quality score of 1.00 at 12WAE in the first year of the experiment.

Table 4.31: Cooking quality scores of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st Year						2nd Year					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	3.72	3.64	3.66	3.58	3.54	3.47	3.66	3.63	3.54	3.51	3.56	3.52
2.	*Plantago major*	3.44	3.16	3.12	2.97	2.93	2.83	3.39	3.19	3.07	2.92	2.96	2.74
3.	*Houttuynia cordata*	3.13	3.12	3.16	3.11	2.98	2.99	3.11	3.16	3.08	3.02	2.99	2.83
4.	*Fagopyrum cymosum*	4.00	3.87	3.89	3.82	3.77	3.62	4.08	3.90	3.82	3.83	3.69	3.71
5.	*Eryngium foetidum*	4.19	4.26	4.14	4.03	3.94	3.98	4.26	4.19	4.09	3.99	4.06	4.07
6.	*Commelina benghalensis*	3.24	3.23	3.09	3.10	2.92	3.01	3.27	3.20	2.96	2.99	2.96	2.77
7.	*Polygonum alatum*	4.01	3.82	3.88	3.86	3.78	3.81	3.98	3.93	3.86	3.88	3.89	3.74
8.	*Hibiscus sabdariffa*	4.17	4.21	4.14	3.89	3.72	3.57	4.00	4.18	4.09	3.84	3.74	3.69
9.	*Diplazium esculentum*	3.87	3.63	3.40	3.24	3.04	2.92	3.91	3.74	3.51	3.40	3.23	2.94
10.	*Colocasia esculenta*	2.79	2.22	2.01	1.55	1.37	1.00	2.44	2.31	2.00	1.47	1.13	1.08
11.	*Emilia sonchifolia*	3.96	3.53	3.47	3.10	3.14	3.03	3.80	3.61	3.51	3.34	3.19	3.11
12.	*Mentha arvensis*	3.70	3.47	3.50	3.63	3.61	3.62	3.50	3.39	3.42	3.37	3.39	3.60
13.	*Spilanthes acmella*	3.08	3.09	3.02	3.13	3.10	2.96	3.12	3.07	3.10	3.00	2.91	3.02
14.	*Oxalis corniculata*	4.11	4.10	4.00	3.96	3.98	3.90	4.14	4.06	4.08	4.03	3.98	4.00
15.	*Basella rubra*	3.90	3.71	3.70	3.67	3.67	3.54	3.87	3.67	3.61	3.58	3.53	3.29
16.	*Alternanthera philoxeroides*	3.52	3.56	3.54	3.47	3.26	3.23	3.61	3.53	3.49	3.46	3.34	3.26
17.	*Passiflora edulis*	3.19	3.10	3.07	3.04	2.97	3.00	3.30	3.19	3.11	3.06	3.00	2.96
18.	*Allium hookeri*	4.04	3.99	4.02	4.00	4.01	3.92	4.08	4.06	3.99	4.03	3.97	3.97
19.	*Rumex nepalensis*	3.32	3.34	3.23	3.22	3.17	3.13	3.29	3.28	3.16	3.18	3.14	3.07
20.	*Amaranthus viridis*	3.78	3.43	3.47	3.21	3.33	3.26	3.67	3.38	3.32	3.27	3.24	3.20
21.	*Justicia adhatoda*	3.25	2.96	2.68	2.28	1.85	1.36	3.09	2.88	2.53	2.13	1.73	1.41
22.	*Piper longum*	3.37	3.20	3.13	2.97	2.99	2.97	3.23	3.12	3.04	2.86	2.88	2.76
23.	*Rumex acetosa*	3.83	3.73	3.69	3.74	3.71	3.76	3.92	3.84	3.76	3.67	3.77	3.74
24.	*Brassica juncea*	4.02	4.00	4.04	3.87	3.92	3.86	4.11	4.08	4.09	4.06	3.99	3.91
25.	*Chenopodium album*	3.69	3.58	3.32	3.29	3.38	3.39	3.63	3.57	3.44	3.32	3.30	3.17
	SEM ±	0.16	0.12	0.11	0.13	0.12	0.12	0.11	0.12	0.11	0.12	0.10	0.11
	CD 5%	0.45	0.33	0.31	0.36	0.35	0.34	0.33	0.35	0.31	0.33	0.28	0.30

4.2.2.10 Shelf life

Shelf life of the vegetables as presented in Figures 83, 84 and Table 4.32 greatly varied among the different leafy vegetables under study. Generally, the shelf life of the vegetables was found to be low. *Houttuynia cordata*, *Justicia adhataoda* and *Piper longum* recorded higher shelf life than the other vegetables. Highest shelf life of 4.00 days was obtained in *Justicia adhatoda* at 10WAE during the first year, 12WAE during the second year, *Piper longum* at 12WAE during the second year and *Houttuynia cordata* at 8WAE during the second year of study.



Figs. 83 & 84: Shelf life (Days) of the leafy vegetables under study at different stages of maturity

(**Note: 1-25 represent the different leafy vegetables under study in the order**: 1 = *Centella asiatica*, 2 = *Houttuynia cordata*, 3 = *Plantago major*, 4 = *Fagopyrum cymosum*,5 = *Eryngium foetidum*,6 = *Commelina benghalensis*, 7 = *Polygonum alatum*, 8 = *Hibiscus sabdariffa*, 9 = *Diplazium esculentum*, 10 = *Colocasia esculenta*, 11 = *Emilia sonchifolia*,12 = *Mentha arvensis*, 13 = *Spilanthes acmella*, 14 = *Oxalis corniculata*, 15 = *Basella rubra*, 16 = *Alternanthera philoxeroides*, 17 = *Passiflora edulis*, 18 = *Allium hookeri* , 19 = *Rumex nepalensis*, 20 = *Amaranthus viridis*, 21 = *Justicia adhatoda*, 22 = *Piper longum*, 23 = *Rumex acetosa*, 24 = *Brassica juncea*, 25 = *Chenopodium album*).

Table 4.32: Shelf life (days) of the leafy vegetables under study at different stages of maturity

Sl. No.	Crop	1st						2nd					
		Week After Emergence						Week After Emergence					
		2	4	6	8	10	12	2	4	6	8	10	12
1.	*Centella asiatica*	1.67	2.00	2.33	2.00	2.00	2.33	1.33	2.00	2.00	2.00	2.67	3.00
2.	*Plantago major*	2.33	3.00	3.00	3.33	3.00	3.00	2.00	2.67	3.00	2.67	3.33	3.00
3.	*Houttuynia cordata*	3.00	3.00	3.33	3.67	3.33	3.67	2.67	3.00	3.67	4.00	3.67	3.33
4.	*Fagopyrum cymosum*	1.33	1.33	1.67	2.00	2.00	2.00	1.00	1.67	1.33	1.67	2.00	1.67
5.	*Eryngium foetidum*	2.00	2.33	2.33	3.00	2.67	3.00	1.67	2.00	2.67	2.67	3.00	3.00
6.	*Commelina benghalensis*	1.33	1.67	2.00	2.33	2.33	3.00	1.67	2.00	2.33	2.33	3.00	3.00
7.	*Polygonum alatum*	1.00	1.67	1.67	2.00	2.00	2.00	1.00	1.33	2.00	1.67	2.00	2.00
8.	*Hibiscus sabdariffa*	1.67	1.67	2.00	2.00	2.33	2.00	1.33	1.67	1.67	2.00	2.00	2.00
9.	*Diplazium esculentum*	2.00	2.33	2.33	2.67	3.00	3.00	1.67	2.00	2.67	3.00	2.67	3.00
10.	*Colocasia esculenta*	2.00	2.67	3.00	2.67	3.33	3.67	2.33	2.33	3.00	3.00	3.67	3.67
11.	*Emilia sonchifolia*	1.33	1.67	2.00	2.00	2.33	2.00	1.67	1.67	2.00	2.33	2.00	2.67
12.	*Mentha arvensis*	1.33	1.33	1.67	2.33	2.00	2.33	1.00	1.67	1.67	2.00	2.33	2.67
13.	*Spilanthes acmella*	1.67	2.00	2.33	2.67	3.00	2.67	1.33	1.67	2.00	2.00	2.67	3.00
14.	*Oxalis corniculata*	1.00	1.00	1.33	1.67	1.67	1.67	1.00	1.00	1.00	1.67	1.33	1.67
15.	*Basella rubra*	1.00	1.00	1.33	1.67	2.00	2.00	1.00	1.00	1.67	2.00	1.67	2.00
16.	*Alternanthera philoxeroides*	1.33	1.33	2.00	1.67	2.00	2.00	1.67	1.67	2.00	2.00	2.00	2.33
17.	*Passiflora edulis*	1.33	1.33	1.67	1.67	2.00	2.00	1.00	1.33	2.00	1.67	2.33	2.00
18.	*Allium hookeri*	2.00	2.00	2.67	3.00	3.00	3.33	2.00	2.33	2.33	2.67	3.00	3.00
19.	*Rumex nepalensis*	1.67	1.67	2.00	2.00	1.67	2.00	1.67	2.00	1.67	2.00	2.00	2.33
20.	*Amaranthus viridis*	1.33	1.33	1.67	1.67	2.33	2.67	1.67	1.33	2.00	2.00	2.00	2.33
21.	*Justicia adhatoda*	2.33	3.00	3.00	3.67	4.00	3.67	2.67	2.67	3.00	3.33	3.67	4.00
22.	*Piper longum*	1.67	2.67	3.00	3.00	3.67	3.67	2.33	2.33	3.00	3.33	3.33	4.00
23.	*Rumex acetosa*	2.00	2.00	2.67	2.67	3.00	2.67	1.33	2.33	2.33	2.67	2.67	3.00
24.	*Brassica juncea*	1.67	2.00	2.00	2.67	2.33	2.67	2.00	2.00	2.33	2.33	2.67	2.67
25.	*Chenopodium album*	1.33	2.00	2.33	2.00	2.33	2.00	1.67	1.67	2.00	2.00	2.67	2.33
	SEM ±	0.27	0.25	0.26	0.26	0.23	0.23	0.27	0.27	0.23	0.24	0.26	0.22
	CD 5%	0.76	0.71	0.73	0.73	0.66	0.66	0.76	0.76	0.66	0.68	0.73	0.63

4.2.3 Standardization of maturity indices of the collected vegetables

The maturity indices of the leafy vegetables are presented in Table 4.34. Based on some important physical, chemical and sensory attributes (plant biomass, leaf number, leaf color values for ‘a’, number of harvests, cooking quality, shelf life, vitamin C content, total calcium and magnesium contents, iron and manganese contents, crude fibre content and beta carotene content, shown in Table 4.33) maturity indices of the different vegetables were standardized. The maturity indices varied greatly among the different vegetables. For crops like *Plantago major, Fagopyrum cymosum, Commelina benghalensis*, *Colocasia esculenta*, *Emilia sonchifolia*, *Spilanthes acmella*, *Allium hookeri* and *Brassica juncea* the optimum stage of harvest was found to be 4-6WAE; while a high stage of maturity of 10- 12 WAE was found to be the optimum stage for *Centella asiatica* and *Eryngium foetidium*.

Table 4.33: Optimum stages for some important physical chemical and sensory parameters for standardizing maturity indices of the leafy vegetables under study

Sl. No.	Crop	Week after emergence												
		Plant biomass	Leaf number	Leaf color a	Leaf texture	No. of harvests	Cooking quality	Shelf life	Vitamin C content	Total Ca	Total Mg	Total Fe	Crude fibre	B-carotene
1.	*Centella asiatica*	8-12	8-10	8-10	4-6	10-12	2-12	6-8	6-8	6-8	6-8	8-10	8-12	6-8
2.	*Plantago major*	4-6	6-8	4-8	2-4	2-4	2-6	4-8	4-6	6-8	6-8	4-6	4-6	6-8
3.	*Houttuynia cordata*	6-8	6-10	4-8	2-4	6	2-8	2-8	6-8	6-8	6-8	6-8	6-8	6-8
4.	*Fagopyrum cymosum*	4-6	4-6	4-8	4-6	6	2-12	8-10	4-6	6-8	6-8	6-8	6-8	6-8
5.	*Eryngium foetidum*	8-10	8-10	4-6	2-4	8	2-12	6-10	6-8	6-8	6-8	8-10	6-8	4-6
6.	*Commelina benghalensis*	4-6	4-6	6-8	2-4	4	2-8	6-8	4-6	6-8	6-8	4-6	6-8	6-8
7.	*Polygonum alatum*	6-8	6-8	6-8	2-4	4	2-12	8-10	4-6	6-8	4-6	6-8	6-8	6-8
8.	*Hibiscus sabdariffa*	4-6	6-8	6-8	4-6	4	2-12	6-8	6-8	6-8	6-8	6-8	6-8	4-6
9.	*Diplazium esculentum*	4-6	8-10	4-6	2-4	8-12	2-10	6-8	6-8	8-10	8-10	6-8	6-8	4-6
10.	*Colocasia esculenta*	4-6	4-6	4-6	2-4	4-6	2-6	4-6	6-8	8-10	6-8	4-6	4-8	4-6
11.	*Emilia sonchifolia*	4-6	6-8	4-6	2-4	4	2-12	6-8	4-6	6-8	4-6	6-8	8-10	6-8
12.	*Mentha arvensis*	6-8	6-8	4-6	2-4	8	2-12	8-10	4-6	6-8	4-6	4-6	6-8	4-6
13.	*Spilanthes acmella*	4-6	4-6	4-6	2-4	2-4	2-10	4-8	4-6	6-8	4-6	4-6	8-10	4-6
14.	*Oxalis corniculata*	6-8	6-8	6-8	6-8	6	2-12	6-8	4-6	6-8	6-8	4-6	10-12	6-8
15.	*Basella rubra*	4-6	8-10	6-8	2-4	6	2-12	8-10	4-6	6-8	6-8	6-8	10-12	6-8
16.	*Alternanthera philoxeroides*	6-8	4-8	6-8	2-4	6	2-12	6-8	6-8	6-8	6-8	6-8	8-10	6-8
17.	*Passiflora edulis*	4-6	4-8	6-8	4-6	4	2-8	6-8	4-6	6-8	4-6	6-8	6-8	4-6
18.	*Allium hookeri*	4-8	6-8	6-8	2-4	4-6	2-12	6-8	4-6	6-8	4-6	6-8	8-10	4-6
19.	*Rumex nepalensis*	4-6	6-8	4-6	2-4	2-6	2-12	6-8	4-6	6-8	4-6	6-8	4-6	4-6
20.	*Amaranthus viridis*	6-8	6-8	6-8	4-6	6	2-12	6-8	4-6	6-8	4-6	4-6	6-8	4-6
21.	*Justicia adhatoda*	4-6	4-8	4-6	2-4	6-8	2-8	4-8	4-6	4-6	6-8	6-8	4-6	4-6
22.	*Piper longum*	4-6	4-8	4-6	2-4	6	2-6	4-6	4-6	4-6	4-6	6-8	6-8	4-6
23.	*Rumex acetosa*	4-6	6-8	4-6	4-6	6	2-12	6-8	4-6	6-8	4-6	6-8	6-8	6-8
24.	*Brassica juncea*	4-6	6-8	6-8	4-6	4-6	2-12	4-6	4-6	6-8	4-6	4-6	6-8	6-8
25.	*Chenopodium album*	4-6	6-8	6-8	4-6	6	2-12	4-6	4-6	4-6	4-6	4-6	6-8	6-8

Table 4.34: Maturity Indices of the leafy vegetables under study

Sl. No.	Vegetable	Maturity Indices
1	*Centella asiatica*	Fully grown leaves and stems should be harvested from well established plants 10-12WAE.
2	*Plantago major*	Young, tender leaves from well established plants of 4-6WAE should be harvested.
3	*Houttuynia cordata*	Tender young shoots and leaves are harvested from well established plants of 6WAE.
4	*Fagopyrum cymosum*	Tender leaves and young shoots are harvested from well established plants about 4-6WAE.
5	*Eryngium foetidum*	Fully mature outer leaves are harvested from plant of 10-12WAE
6	*Commelina benghalensis*	Young leaves and young shoots are harvested from well established plants of 3-6WAE.
7	*Polygonum alatum*	Young leaves and young shoots are harvested from well established plants of 4-6WAE.
8	*Hibiscus sabdariffa*	Tender leaves and stalks are harvested from plants of 6-8WAE.
9	*Diplazium esculentum*	Young fronds are harvested from well established plants of 8-10WAE.
10	*Colocasia esculenta*	Young leaves and stems are harvested from well established plants of 4-6 WAE are harvested.
11	*Emilia sonchifolia*	Mature and young leaves harvested from4-6WAE
12	*Mentha arvensis*	Fully mature leaves are harvested from well established plants of 6-8WAE.
13	*Spilanthes acmella*	Young shoots and leaves are harvested from well established plants of 4-6WAE.
14	*Oxalis corniculata*	Young shoots and leaves are harvested from plants of 6WAE.
15	*Basella rubra*	Fully mature leaves and tender shoots are harvested from plants of 8-10WAE.
16	*Alternanthera philoxeroides*	Tender leaves and shoots are harvested from plants of 6WAE.
17	*Passiflora edulis*	Tender leaves and shoots are harvested from plants of 6-8WAE.
18	*Allium hookeri*	Fully mature leaves are harvested from plants of 4-6WAE.
19	*Rumex nepalensis*	Tender leaves are harvested from plants of 6-8WAE.
20	*Amaranthus viridis*	Tender leaves and shoots are harvested from plants of 6WAE.
21	*Justicia adhatoda*	Fully mature and tender leaves are harvested from plants of 8WAE.
22	*Piper longum*	Tender leaves and shoots are harvested from plants of 6-8WAE.
23	*Rumex acetosa*	Fully mature leaves are harvested from plants of 6-8WAE.
24	*Brassica juncea*	Fully mature and tender leaves are harvested from plants of 4-6WAE.
25	*Chenopodium album*	Tender leaves and shoots are harvested from plants of 6WAE.

Chapter V

DISCUSSION

An experiment was conducted to identify and explore some of the underexploited leafy vegetables of Meghalaya. The present study consisted of three Experiments i.e. Experiment I, Experiment II and Experiment III. Experiment I consisted of collection of underexploited leafy vegetables from different locations of Meghalaya, which were propagated in the research Farm of the Division, Experiment II consisted of evaluation of morphological and physicochemical characters of the collected vegetables and Experiment III consisted of standardization of maturity indices of the collected vegetables. The salient findings of the present investigation are discussed together with logistic views under the following heads-

5.1 Collection of underexploited leafy vegetables in Meghalaya

For Experiment I planting materials of underexploited vegetables were collected from different parts of Meghalaya and out of them twenty five were selected on the basis of preference and survival rate and were propagated in the research Farm of the Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya.

The state of Meghalaya in the northeastern region of India is located between 20° 1' N & 26° 5' N latitude and of 85° 49' E & 92° 52' E longitude; and is endowed with unique physiography and enormous plant genetic resources and diversity. The state is blessed with remarkably unique and rich flora due to its wide variation in climatic and ecological diversity. It is considered to be the home of many leafy green vegetables, which remain underutilized and unexplored. Documentation of underexploited leafy vegetables of Meghalaya were done by several authors (Chetri, 2006, Sawian *et al.*, 2007, Kayang, 2007, Tynsong and Tiwari 2010, Jaiswal 2010, Singh *et al*., 2012 etc). Three principal tribes, the *Garos*, the *Khasis* and the *Jaintias* reside in Meghalaya. The people of Meghalaya consume different types of leafy vegetables which either grow in wild or are semi-cultivated. Some important leafy vegetables found and consumed in Meghalaya include *Houttuynia cordata* (Thunb.), *Centella asiatica* (L.), *Colocasia esculenta* (L.), *Commelina benghalensis* (L.), *Eryngium foetidum* (L.), *Amaranthus viridis* (L.), *Diplazium esculentum* (Retz.) Sw., *Brassica juncea* (L.) etc. Many of these vegetables are cooked as traditional delicacies. For instance, the fresh immature fronds of *Diplazium esculentum* are wiped with a cloth to remove the red petiolar hairs and boiled. Boiled fronds are cut and fried in cooking oil with spices such as seeds of *Cleome viscosa* L. (Misra *et al*., 2008). The tender shoot of *Fagopyrum cymosum* are cooked and eaten as vegetables and the young leaves are cooked with dry fish and eaten by local people (Kayang , 2007).

5.2 Evaluation of morphological and physicochemical characters of the collected vegetables

All the morphological parameters showed variations among the different leafy vegetables indicating the presence of high amount of genetic variability among them for all the studied traits.

5.2.1 Morphological Parameters

5.2.1.1 Whether annual or perennial

Among the 25 collected vegetables 19 were found to be perennial and six vegetables namely, *Polygonum alatum*, *Hibiscus sabdariffa*, *Emilia sonchifolia*, *Spilanthes acmella*, *Amaranthus viridis* and *Chenopodium album* were found to be annual. Though most of the vegetables under study were of perennial nature, many of them are grown and used as annuals. Plants like *Eryngium foetidum*, *Colocasia esculenta*, *Oxalis corniculata*, *Basella rubra*, *Rumex acetosa*, *Brassica juncea* etc. are grown as annual leafy vegetables.

5.2.1.2 Days taken from leaf emergence to maturity

The days taken from leaf emergence to maturity varied significantly among the different leafy vegetables. In general, *Diplazium esculentum* leaves took the maximum number of days, while *Mentha arvensis* leaves recorded the minimum number of days to attain maturity. It was observed that leaves in the initial stages of growth took longer time to attain maturity than the later stages in both the years studied. *Diplazium esculentum* leaves during 2WAE took the maximum number of days to reach maturity, while *Mentha arvensis* leaves at 12WAE during the first year took the minimum number of days to reach maturity. These differences in days taken from leaf emergence to maturity are probably due to the differences in duration of the crops with differential growth of the plants showing the presence of high amount of variability among the different vegetables under study.

5.2.1.3 Plant height

Plant height is considered as one of the traits for growth and vigour of the plants. In the present investigation, the different vegetables exhibited significant differences for plant height at different stages of growth. The differences in plant height among the different vegetables are due to their genetic variations. Plant height of the crops was found to increase with increasing age of the plants, with maximum values at 12WAE. *Passiflora edulis* recorded the maximum plant height of 148.65 cm at 12WAE in the second year of the experiment; whereas *Eryngium foetidum* recorded the lowest plant height of 5.81 cm at 2WAE during the first year. Similar results of increase in plant height with maturity were also observed by Aggrwal *et al*. (2013) in fenugreek, who observed an increase of plant height with increasing age of the plants. They explained that at some point photosynthesis is great enough to produce more sugar than is needed for plant growth. This results in an increase in the reserve carbohydrates and its utilization for growth and development of plant viz. plant height, leaf area, number of branches etc. Uddin *et al*. (2012) also reported an increase of plant height over time in different mutants of mustard.

5.2.1.4 Plant biomass

Plant biomass of the different leafy vegetables studied varied significantly with *Justicia adhatoda*, *Hibiscus sabdariffa*, *Piper longum* and *Basella rubra* recording higher values for plant biomass. For all the vegetables under study plant biomass increased with maturity and reached maximum at 12WAE. For both the first and second years *Justicia adhatoda* recorded the maximum plant biomass of 3105.50 g/plant and 3085.97 g/plant respectively at 12 WAE. Similar increase in plant biomass with maturity was also reported by Yommi *et al*., (2013) in celery who observed an increase in total weight from 309.00g to 2094.00g from 80 days to 129 days after transplanting. They concluded that this increase in plant biomass could be explained by the increase in leaf number and height increase, petioles thickening and floral stem elongation. According to Ewert (2004), biomass production is closely related to light interception, which is mainly determined by Leaf Area Index (LAI). Leaves with a higher leaf area index, have a larger photosynthetic area and they accumulate more biomass if all other factors are not limiting.

5.2.1.5 Number of leaves

Number of leaves per plant is an important yield contributing traits in leafy vegetables. This is because leafy vegetables are mainly grown for fresh leaves and so the numbers of leaves per plant along with leaf size determine the total yield. Leaf number varied significantly among the different leafy vegetables studied. *Passiflora edulis*, *Justicia adhatoda*, *Alternanthera philoxeroides*, *Commelina benghalensis* and *Piper longum* were found to have high leaf number/plant. A progressive increase in leaf number was observed with increase in maturity of the vegetables with plants at 12WAE recording the highest leaf number. For both the years of study, *Passiflora edulis* recorded the maximum leaf number/plant (255.33 and 240.00), followed by *Justicia adhatoda* (169.00 and 167.33) at12WAE. According to Fu (2008) this increase in leaf number with increase growth stages might be due to the reason that plants in the later stages of growth experience more thermal time and more days for growth and so more leaf production. He also reported a positive linear relationship between the accumulated leaf number/plant and thermal time in lettuce and rocket. He observed that leaf number/plant at the first harvest of lettuce and rocket increased as the harvest start was delayed. Kanthaswamy (2006) also observed a gradual increase in leaf number at different growth stages of amaranthus.

5.2.1.6 Leaf area index

Leaf area index is a measure of the photosynthetic area of the plant per unit area of land. For broad leaf plants, the higher the leaf area index, the more the ability for the plant to make and potentially store food (Msibi *et al*., 2014). The different leafy vegetables in the present study varied greatly with respect to their leaf area index. Values for leaf area index were found to be high in *Passiflora edulis*, *Justicia adhatoda*, *Piper longum* and *Diplazium esculentum*. The variation in leaf area index might occur due to the variation in number of leaves and their expansion (Uddin *et al*., 2012). The leaf area index was found to increase with maturity for all the crops under study. Highest leaf area index (10.04) was recorded in *Passiflora edulis* at 12WAE during the second year of the experiment; which was followed by *Justicia adhatoda* with a leaf area index of 6.85 at 12WAE during the first year. Lowest leaf area index of 0.01 was recorded in *Plantago major* at 2WAE during the first year and *Emilia sonchifolia* at 2WAE during both the years of study. This increase in leaf area index at later growth stages might be due to the fact that plants in the later stages had experienced more thermal time, and this resulted in greater leaf area index. Chapman *et al*., (1993) and Díaz-Ambrona *et al*., (1998) also showed similar relationships for leaf area index with maturity.

5.2.1.7 Leaf weight (fresh and dry)

Leaf weight is an important character which contributes greatly to the yield of leafy vegetables which are mainly grown for leaves. When the leaf weight is more, ultimately the yield of the leafy vegetables increases. Leaf weight is an important character which contributes greatly to the yield of leafy vegetables which are mainly grown for leaves. The fresh and dry leaf weights were significantly affected by the type of vegetables under study. Higher values for fresh and dry leaf weights were observed in *Justicia adhatoda*, *Piper longum*, *Basella rubra* and *Colocasia esculenta* etc. Leaf weight was found to increase with growth of the plants for both the years under study. At 12WAE, during the first year, *Justicia adhatoda* recorded maximum leaf fresh and dry weights (878.83 g/plant and 235.08 g/plant respectively) followed by *Piper longum* (267.75 g/plant and 68.30 g/plant respectively) during the first year of the experiment. This increase in fresh and dry weights was mainly due to enlargement of the cells as well as increase in the leaf number with maturity. Another reason for this increase could be due to the fact that at some point photosynthesis is great enough to produce more sugar than is needed for plant growth. This results in an increase in the reserve carbohydrates and its utilization for growth and development of plant viz. plant height, leaf area, number of branches, leaf weight etc. Aggrwal *et al*. (2013). A similar increase in physical parameters like of leaf fresh weight and dry weight with the age of plant in fenugreek was also reported by Aggrwal *et al*. (2013). They found that the average plant height, fresh weight and dry weight increased with maturity and were the maximum at 60 DAS.

5.2.1.8 Leaf color

5.2.1.8.1 Leaf Color values for 'L', 'a' and 'b'

Hunter L, a, and b values provide a quantitative basis for assessing leaf color differences. Color comparisons may also facilitate varietal selection in plant breeding (Townsend, 1977; Toy, 1966) or provide indication of plant disease, nutrient deficiencies, and maturity (Brearley and Breeze, 1966; Gates *et al*., 1965; Grime, 1961; Kozel, 1974). Among the different vegetables under study, the color values for 'L' were found to be high in *Brassica juncea*, *Commelina benghalensis*, *Spilanthes acmella* and *Chenopodium album*; whereas lowesr 'L' values were recorded in *Hibiscus sabdariffa*. It was observed that 'L' values decreased with increasing age of the crops. The decreasing 'L' values indicated a decrease in lightness with maturity. The 'a' values for leaf color were found to be negative for all the crops and the values increased with increasing maturity. The negative values for 'a' indicated the green colour of the vegetables which increased with maturity. In general, 'a' values were found to be high in *Justicia adhatoda*, *Eryngium foetidum*, *Rumex acetosa*, *Spilanthes acmella*, *Houttuynia cordata etc.* As regards to leaf color scores for 'b', higher values were obtained in *Polygonum alatum*, *Brassica juncea* and *Centella asiatica*, while lower 'b' values were recorded in *Hibiscus sabdariffa*. The 'b' values were found to decrease with age of the crops and lowest values were recorded at 12WAE in both the years of study for most of the vegetables. Chutichudet *et al*., (2011) and Rosalizan *et al*., (2008) also observed similar trends for 'L', 'a' and 'b' color values with maturity in *Lactuca sataiva* and *Centella asiatica* respectively.

5.2.1.9 Leaf texture

Texture is related to freshness, crispness, tenderness, and succulence of vegetables. They are terms that apply in varying degrees in assessing the quality of leafy vegetables. Flabbiness, excess softness, toughness, stringiness or pithiness manifest lack of freshness and therefore, poor texture (Chen, 1999). Leaf texture was found to be significantly affected by the different types of vegetables. Texture values showed an increasing trend with increasing maturity of the crops. Highest textural score (5.00) was recorded for *Plantago major*, *Houttuynia cordata*, *Allium hookeri*, *Amaranthus viridis* and *Piper longum* at 10 and 12WAE; *Eryngium foetidum*, *Basella rubra* and *Rumex nepalensis* at 8, 10 and 12WAE and *Justicia adhatoda* at 6,8,10 and 12WAE during the study. Yommi *et al*. (2013) also recorded increasing values for texture with increasing maturity in celery. Textural attributes of fruits and vegetables are related to the structural, physiological, and biochemical characteristics of the living cells. Changes that occur in the cell wall during the ripening of fruit, storage of produce, and cooking are critical for the texture of the final product. During the growth of some vegetative parts, especially stems and petioles, cell walls become lignified (Price and Floros, 1993), which could be the reason for increase in texture values with maturity of the crops. Also, changes in the collenchyma tissue during maturation could be responsible for the described changes of measured texture (Yommi *et al*., 2013).

5.2.1.10 Leaf shape

Each leafy vegetable has a standard shape or group of shapes. Any deviation from the expected shape detracts from the quality of the vegetable. Individual leaf shape is also important, as it is an indicator for cultivar identification (Chen, 1999). The vegetables under study varied greatly with respect to their leaf shape ranging from ovate to pinnately compound leaves. While *Centella asiatica* and *Piper longum* plants had reniform shaped leaves, *Plantago major* plants had oval shaped leaves, *Houttuynia cordata* and *Basella rubra* leaves were heart – shaped, *Diplazium esculentum* plants consisted of pinnately compound leaves etc. These differences in leaf shape are due to the presence of high amount of genetic variability among the different vegetables.

5.2.1.11 Number of harvests

The number of harvests is an indicator of yield of crops. Higher number of harvests during the crop season results in higher total yield. The different vegetables showed variations in the total number of harvests when harvesting was started at different maturity stages. This indicated that the optimum harvesting age should be identified for maximum production. In general, *Basella rubra*, *Justicia adhatoda*, *Eryngium foetidum* and *Passiflora edulis* recorded higher number of harvests, while *Plantago major* and *Oxalis corniculata* recorded lower number of harvests than the other vegetables. The number of harvests showed different trends for each vegetable with regards to maturity stages. While for crops like *Centela asiatica* and *Diplazium esculentum*, the number of harvests increased when harvesting age was delayed, for others like *Plantago major* and *Spilanthes acmella* number of harvests decreased with delayed harvest age. These differences in the number of harvests of the vegetables are mainly due to the different time taken for maturity as well as the differential growth of the plants. The timing of leaf removal has great effects on the plant's ability to recover from leaf harvesting (Barrett, 1987). At the early stage of maturity, leaves of most of the plants are either too young or at the right stage of leaf harvesting for consumption as leaf vegetables; thus, insufficient foliage is left after leaf harvesting to support subsequent biomass production. However, at a later stage of maturity the plants have formed lateral shoots and fully expanded true leaves with some of the leaves past the consumable stage as leaf vegetable. This leaves the plant with adequate foliage to support photosynthesis that can sustain recovery and sufficient growth after leaf harvesting. Further delay in initiating leaf harvesting, however, decreases the period between leaf harvesting initiation and flowering and the subsequent number of harvests that can be made. But for crops like *Plantago major*, *Spilanthes acmella*, and *Rumex nepalensis* number of harvests are reduced if the harvest age is delayed which is probably due to early maturity of these plants because of which most of the vegetative growths for these plants are completed within the early stages.

5.2.1.12 Yield/harvest

Yield/harvest of the crops at different stages of maturity showed significant variations among the different vegetables studied. Yield/harvest was found to be high in *Plantago major*, *Houttuynia cordata* and *Emilia sonchifolia*, while *Spilanthes acmella* and *Mentha arvensis* recorded the lower values for yield/harvest. The yield/harvest of the crops increased with growth of the crops. This is due to the fact that as the plants mature there is increase of biomass, leaf number and leaf weight, which in turn, increases the yield. For both the years under the experiment, *Plantago major* recorded highest yield/harvest (307.06 and 296.60 g/m^2 respectively) at 10WAE, which was followed by *Houttuynia cordata* (219.90 and 221.45 g/m^2 respectively at 10WAE); whereas *Rumex nepalensis* recorded a lowest yield/harvest of 32.95 g/m^2 at 2WAE during the first year. Though higher yield/harvest was observed in *Plantago major*, it does not represent higher values for total yield. As the number of harvests for *Plantago major* was low for each stage of maturity, the total yield (number of harvests x yield/harvest) is ultimately reduced.

5.2.1.13 Ratooning effect if any

Effects of ratooning on the leafy vegetables demonstrated that the different vegetables respond differently to harvesting stages and frequencies. While for crops like *Centella asiatica*, *Eryngium foetidum*, *Diplazium esculentum* and *Basella rubra* yield was reduced when harvesting was done at early stage, for *Plantago major*, *Hibiscus sabdariffa* etc yields were reduced in the ratoon crops. Again for crops like *Hottuynia cordata*, *Fagopyrum cymosum* no major effect was observed in the ratoon crops. These variations among the different types of vegetables indicated the significance of identifying optimum requirements of harvesting age before initiating any kind of economic production. According to Nassiri and Elgersma, (1998) faster recovery of some crops from reaping could be due to more photosynthetic leaf area. More photosynthetic leaf area means greater radiation interception and more photosynthate and therefore probably more carbohydrates for the start of regrowth, resulting in faster recovery. Amaglo *et al*. (2006) observed that fresh shoot or leaf yields reduced drastically with continuous harvesting in Moringa. Kassahun *et al*. (2011) reported that during the first harvest, performance of agronomic parameters such as fresh leaf yield, dry leaf yield, fresh above-ground biomass yield and dry above-ground biomass yield of peppermint increased with increasing harvesting age and reached a maximum at 120 DAP; thereafter, their value declined. In the second harvest, maximum values were recorded at 180 DAP for fresh leaf yield, fresh and dry above ground biomass yield.

5.2.2 Physicochemical parameters

5.2.2.1 Vitamin C content

Vitamin C is essential for the healthy formation of bones and teeth. It is a powerful antioxidant (Szeto *et al*., 2002). The patterns for changes in vitamin C content of the leafy vegetables at different stages of maturity showed significant variations among the different vegetables. Most of the vegetables were found to be rich sources of vitamin C. A gradual increase in vitamin C was observed in all the leafy vegetables at the beginning of growth period which reached peak values between 6WAE and 8WAE and declined subsequently for majority of the vegetables during both the years of the experiment. Highest vitamin C values of 155.00 mg/100g and 125.50 mg/100g were recorded in *Basella rubra* at 6WAE, during the two years under the study; while the lowest value for vitamin C (15.80 mg/100g) was recorded in *Emilia sonchifolia* at 2WAE during the second year of study. These results are within the range (3 – 295 mg/100g) reported by Gupta *et al*. (2005) for underutilized green leafy vegetables. The decrease in the level of vitamin C during maturation is probably due to biochemical oxidation (Rosalizan *et al*., 2008). Vitamin C is easily oxidized in the presence of oxygen by both enzymic and non-enzymic catalysts (Mapson, 1970). According to Seung and Kader (2000), conditions favourable to water loss after harvest result in rapid loss of vitamin C especially in leafy vegetables; which can be correlated with the decrease in moisture with increasing maturity of the leafy vegetables.

5.2.2.2 Minerals content

5.2.2.2.1 Calcium and Magnesium

The different leafy vegetables under study showed variations in the total calcium and magnesium contents. Calcium and magnesium have significant roles in photosynthesis, carbohydrate metabolism, nucleic acids, and binding agents of cell walls (Russel, 1973). Calcium is an important mineral as it is required for bone structure and function and in the proper functioning of the nervous system; while magnesium plays an essential role in many physiological functions of the body. Magnesium is also an essential constituent of chlorophyll (Tirasoglu *et al*., 2005).The vegetables under study were found to be rich sources of calcium and magnesium. The calcium and magnesium contents were found to be low during the initial phase of development which increased as the plants matured and then showed a gradual decline in most of the vegetables with different vegetables showing peak values at different stages; while for some crops like *Centella asiatica* and *Justicia adhatoda* the values showed a continuous increase. *Centella asiatica* recorded the highest calcium values of 2.85% and 2.75% at 12WAE during the second and first year of study respectively; while *Fagopyrum cymosum* and *Allium hookeri* recorded lowest calcium values of 1.08% at 2WAE during the second year of the study. As regards to magnesium content, *Houttuynia cordata* was found to contain maximum value of 2.55% at 8WAE during the first year of the experiment. A lowest magnesium content of 0.46% was observed in *Alternanthera philoxeroides* at 2WAE during the same period. These values of calcium and magnesium correspond to those reported by Imran *et al*. (2007). According to Khader and Rama (2003) during flowering stage the absorbed minerals are diverted to flower development. This may be the reason why the calcium and magnesium contents decreased after certain period in most of the vegetables. For crops like *Centella asiatica* and *Justicia adhatoda* the continuous increase may have been due to the relatively longer growing period and later flowering compared to the other vegetables.

5.2.2.2.2 Iron and Manganese Contents

Significant variations were observed among the vegetables in terms of their iron and manganese contents. Iron is a vital constituent of plant (Tirasoglu *et al*., 2005). Iron is also a crucial activator for enzyme–catalyzing reactions involving chlorophyll synthesis and for ferrodoxin nitrate reductase (Bowling, 1976). Manganese plays a structural role in the chloroplast membrane system. It may be responsible for color, taste, and smell. It is also a cofactor for fatty acids, DNA and

RNA synthesis (Gibbs, 1978). The leafy vegetables studied under the experiment were found to contain high values of both these minerals. The iron content of the vegetables increased during growth of the plants upto certain point and decreased thereafter; whereas the manganese content of the vegetables was found to increase with maturity of the crops. *Houttuynia cordata* was found to contain the maximum values for iron (9.66 mg/100g and 9.86 mg/100g) at 8WAE during the first and second years of study respectively. Among the crops, *Rumex nepalensis* recorded the lowest value (0.84 mg/100g) for iron during the first year of study at 2WAE. Similarly, for manganese content, highest values (2.54 mg/100g and 2.48 mg/100g) were obtained in *Basella rubra* at 12WAE during the first and second years respectively, while the lowest value (0.06 mg/100g) was recorded in *Oxalis corniculata* and *Alternanthera philoxeroides* at 2WAE during the first year. Lyimo *et al*. (2003) and Nasiruddin *et al*. (2012) also reported similar values of iron and manganese contents respectively for some traditional leafy vegetables. The variations in the iron and manganese contents of the different leafy vegetables is due to the fact that many factors such as soil composition, pH of the soil, water availability to the plant, weather conditions prevailing during growth of the plant, and variety of the plant affect the uptake of minerals by plants (Khader and Rama 1998). Khader and Rama (1998) also reported similar trend in iron and manganese contents in some leafy vegetables with increasing maturity. They concluded that iron may be an indissociable ion, and so it accumulates as age increases; but it decreases as the plant matured towards flowering, which may indicate diversion to flower development. Atta *et al*. (2010) also observed an increase in manganese content of roselle leaves at different growth stages. They reported that manganese accumulates in leaves as plant age increases.

5.2.2.2.3 Total Phosphorus Content

Phosphorus is essential for plant growth and it is also vital for early attainment of growth. Phosphorus has roles in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in the plant (Tirasoglu *et a*l., 2005). The total phosphorus contents revealed significant differences among the leafy vegetables studied. All the vegetables were found to contain appreciable amounts of total phosphorus in their leaves. The total phosphorus content of the different vegetables increased with increasing growth of the plants and then declined gradually for both the years of the experiment; which could be due to the partitioning of photosynthetic products which with age is directed to the reproductive growth. *Passiflora edulis* was found to contain a highest total phosphorus content of 0.96% at 8WAE during the second year; while a lowest total phosphorus value of 0.14% was found in *Plantago major* leaves at 2WAE during the same period. These values for phosphorus content correspond to those reported by Gupta *et al*. (2005) for some underutilized leafy vegetables. *Makobo et al*. (2010) reported that phosphorus contents of *Amaranthus cruentus* increased at the beginning and highest values were recorded at four weeks after emergence after which they declined. Acikgoz (2011) also observed similar increase of phosphorus content in kale from the first (18 weeks from planting to harvest) to the second harvest (21 weeks from planting to harvest), after which it declined.

5.2.2.2.4 Total Potassium Content

Data pertaining to the total potassium content of the leafy vegetables under study are showed that the different vegetables varied in their total potassium contents at different stages of maturity. Potassium has a key role in stomatal functioning and helps the plant use water more efficiently by promoting turgidity to maintain internal pressure of the plant (Tırasoglu *et* al., 2005). Furthermore, consumption of wild vegetables with high potassium content enhances the bioavailability of calcium in body and promotes bone health by preventing the occurrence of calciuria (Ng *et al*., 2012). The total potassium content increased at the beginning and then declined with maturity for all the vegetables during the two years under the experiment. Highest total potassium content of 2.92% and 2.85% were observed in *Diplazium esculentum* at 8WAE during the second and first years of study respectively; while the lowest total potassium content of 0.98% was recorded in *Spilanthes acmella* at 2WAE during second year. Gupta *et al*. (2005) also reported similar values for potassium content in some underutilized leafy vegetables. A trend of increase and decrease in potassium contents was also observed by Makobo *et al*. (2010) in *Amaranthus cruentus* at different harvesting stages. They reported that the optimum level of potassium in amaranth is obtained when it is harvested at six weeks after emergence. According to Marschner (1986), the level of potassium is expected to decrease with the increase in age. This could be due to the partitioning of photosynthetic products which with age is directed to the reproductive growth.

5.2.2.3 Total Chlorophyll Content

Leafy vegetables contain photosynthetic pigments that are chlorophylls and carotenoides. Chlorophyll is often referred to as the green blood of plants due to the identical molecular structure with hemoglobin with only difference in centre atom (iron or magnesium). This similarity makes chlorophyll so important to our health, it improves digestive, immune and detoxification systems of human body (Kopsell *et al.*, 2005). In addition, chlorophyll and carotenoid concentration correlate to the photosynthetic potential of plants giving some indication of the physiological status of the plant (Gamon and Surfus, 1999). The total chlorophyll content of the leafy vegetables at different stages of maturity showed great variations among the vegetables with regards to their total chlorophyll content. The total chlorophyll content was found to be low at the initial stages of maturity, but it increased rapidly with increasing age of the plants. *Justicia adhatoda* recorded the maximum total chlorophyll content of 2.13 mg/g at 12WAE during the second year of study, while the lowest total chlorophyll content of 0.34 mg/g was observed in *Alternanthera philoxeroides* at 2WAE during the second year of the experiment. Similar increase in chlorophyll content was also reported by Deveci and Uzun (2011) who reported that chlorophyll content increased as leaves grew from cotyledon stage and it reached the highest level at harvest stage in spinach. According to Taiz and Zeiger (2002), chlorophyll naturally increases as leaf surface area of a plant increases as a result of increase in mesophyllic cells including this pigment acting in photosynthesis. This might be the reason of increase in chlorophyll content of the leafy vegetables with maturity.

5.2.2.4 Crude protein content

Proteins are essential organic compounds of high molecular weight found in all living tissues (Osei, 2003). Protein helps in building and maintaining all tissues in the body, forms an important part of enzymes, fluids and hormones of the body and also helps form antibodies to fight infection and supplies energy (Jonhson, 1996). So the proteins have a considerable role in human nutrition. The different leafy vegetables under study varied considerably in their crude protein content. Maximum values for crude protein content were found in the leaves of *Centella asiatica*, *Brassica juncea*, *Rumex acetosa*, *Amaranthus viridis*, *Chenopodium album* and *Piper longum*. The higher crude protein content of these leafy vegetables suggests their richness in essential amino acids. These amino acids serve as alternative sources of energy when carbohydrate metabolism is impaired via gluconeogenesis (Iheanacho and Udebuani 2009). During the stages of development of the vegetables, the crude protein content declined with increasing age for all the crops. Highest crude protein content (35.35%) was observed in *Centella asiatica* at 2WAE during the first year of the experiment, while *Oxalis corniculata* was found to contain the lowest crude protein content of 7.27% at 12WAE during the same year. These values compared favourably with *Amaranthus caudatus* (20.59%), *Manihot utilisima* (24.88%), *Piper guineeses* (29.78%) and *Talinum triangulare (*31.00%) leaves reported earlier (Etuk *et al*., 1998; Akindahunsi and Salawu, 2005). Acikgoz (2011) also reported a decline of crude protein content from 35.00% for the first stage to 30.62% for the second and 26.87% for third harvesting stage in kale. Higher crude protein concentration in the young plants might be a result of nitrogen accumulation in the young tissues which receive soluble forms of nitrogen transported from elder leaves as well (Salisbury and Ross, 1992).

5.2.2.5 Crude Fibre Content

Dietary fibre has gained importance during the past two decades because of its beneficial effects in human nutrition: decreasing the risks from disorders such as constipation, coronary heart diseases, diabetes, diverticulosis and obesity (National Research Council, 1989; Roberfroid, 1993; Spiller, 2001). Fibre is an inseparable part of feeds of plant origin. It is composed of various components such as lignin, cellulose, hemicelluloses, pectic substances, gums, waxes, and indigestible oligosaccharides (Van Soest and McQueen, 1973; Trowell, 1974). Data furnished for crude fibre revealed that the different leafy vegetables varied greatly in their crude fibre content. It was observed that as the vegetables grow their crude fibre content increased gradually. In all the stages of maturity *Plantago major* was found to record higher crude fibre values than the other vegetables studied for both the years, with highest values of 34.52% and 33.65% at 12WAE during the second and first years respectively; while the lowest value (3.25%) was recorded in *Oxalis corniculata* and *Allium hookeri* at 2WAE during the first year. Bamishaiye *et al*. (2011) also reported increase in crude fibre content in *Moringa oleifera* leaves from early to late stage of maturation. The increase in fibre content of the mature and coarse leaves over the tender leaves was probably due to an increase in the content of insoluble as well as soluble fibre fractions such as cellulose, hemicellulose and lignin, during the maturation of the leaves. According to Punna and Paruchuri (2004) as the leaf matures from tender to mature to coarse stage, the lignification of cell wall constituents occurs and results in the increase fibre content of the leaf.

5.2.2.6 Antioxidant phytochemicals

5.2.2.6.1 β- Carotene

Carotenoids are natural pigments that provide the natural yellow, orange or red colours of vegetables and fruits. These colours are a result of the presence of conjugated double bonds, also providing carotenoids with antioxidant properties. Therefore the interest of carotenoids, which are found in vegetables, is not only due to their provitamin A activity but also to their antioxidant action by scavenging oxygen radicals and reducing oxidative stress in the organism (Rao and Honglei, 2002). Beta carotene is the most available and therefore important source of provitamin A in the diet of most people living in developing countries, providing about 66% of vitamin A in their diets (Sanusi and Adebiyi, 2009). The effects of harvest time on the beta-carotene content of the different leafy vegetables showed appreciable amounts of beta-carotene content in the vegetables studied. Higher beta-carotene values were observed in *Colocasia esculenta*, *Justicia adhatoda*, *Passiflora edulis*, *Rumex nepalensis*, *Mentha arvensis*, *Allium hookeri* and *Piper longum* etc. The beta-carotene content for both the years of study varied significantly among the different leafy vegetables at each stage of maturity. This may be due to the reason that carotenoid levels in the leaves of leafy vegetables depend on several factors, including species, variety, cultivar, production practice, maturity, as well as environmental growth factors such as light, temperature, and soil properties (Van den Berg *et al*., 2000). The vegetables were found to contain lower beta-carotene content at the initial growing period which increased with the age of the plants. *Fagopyrum cymosum* was found to contain the highest beta-carotene content of 96.70 mg/100g at 12WAE during the first year of study and a lowest value of 10.43 mg/100g was observed in *Emilia sonchifolia* at 2WAE during the same year. Similar values for beta carotene content were also reported by Della Lucia *et al*. (2008) who reported beta-carotene content of kale ranging from 4856 to 7409 μg/100g. Khachik *et al*. (1992) also reported a beta-carotene content of 8900 μg/100 g in spinach.

5.2.2.6.2 Total Phenol content

Phenols are one of the major groups of nonessential dietary components appearing in vegetable foods. They are a group of wide chemical compounds that are considered as secondary plant metabolites, with different activity and chemical structure, including more than 8,000 different compounds (Martinez, *et al*., 2000). It is reported that phenols are responsible for the variation in the antioxidant activity of the plant. (Cai *et al*., 2004). They exhibit antioxidant activity by inactivating lipid free radicals or preventing decomposition of hydroperoxides into free radicals. (Pokorny *et al*., 2001, Pitchaon *et al*., 2007). Data presented for the total phenol content of the leafy vegetables at different maturity stages showed significant variations. Maximum values for total phenol content were recorded in *Eryngium foetidum*, *Centella asiatica*, *Rumex acetosa*, *Mentha arvensis* and *Justicia adhatoda*. The results showed an increasing trend in the total phenol content of the vegetables with increasing age of the crops. The different leafy vegetables varied greatly in their total phenol contents at different harvest stages with *Eryngium foetidum* recording the highest values (24.90 mg/100g and 23.77 mg/100g at 12WAE during the second and first years under study respectively), while the lowest value (3.33 mg/100g) was recorded at 2WAE during the second year in *Rumex nepalensis*. It was reported that some phenolic compounds had a role in taste formation in fruits and vegetables. They were responsible for especially two significant taste factors like bitterness and acerbity (Turkmen *et al*., 2005; Proteggente *et al*., 2002). Oloyede *et al*. (2013) also reported an increase in the total phenol content of *Amaranthus cruentus* from 3rd to 6th weeks of age. Deveci and Uzun (2011) found that the total phenolic compound increased in 3 different growth stages of the spinach as the plants grew and the highest value (121.25 mg/100 g) was found in the harvest period. According to Delgado *et al*. (2011), phenolic compound concentration in the plant varies within a year depending on growth stages.

5.2.2.7 Titratable Acidity content

Acids play an important role in the post-harvest quality of vegetables, as taste is mainly a balance between sugar and acid contents which is important in evaluation of taste (Bainbridge *et al.*,1996). It was observed that the crops varied greatly as regards to their titratable acidity contents during the study period. *Hibiscus sabdariffa*, *Oxalis corniculata*, *Polygonum alatum*, *Houttuynia cordata* and *Rumex acetosa* were found to contain high titratable acidity contents. A progressive increase in acidity content was observed for all the crops with advancement of maturity, with highest values at 12WAE for both the years of the experiment. During both the years of the experiment, maximum titratable acidity contents (2.30% and 2.26%) were observed in *Hibiscus sabdariffa* at 12WAE; while the least titratable acidity content (0.18%) was found in *Rumex nepalensis* during the first year at 2WAE. The increase in titratable acidity contents of the vegetables correspond to the formation of organic acids during maturation. Similar results of increase in titratable acidity were also observed by Yommi *et al*. (2013) in celery with increase in the harvesting age from 80 to 120 days after transplanting; while Rosalizan *et al*. (2008) reported that the titratable acidity increased up to 0.18% at 60 days of harvest in ratoon crops of *Centella asiatica* but declined thereafter.

5.2.2.8 Moisture Content

Moisture content is a widely used parameter in the processing and testing of food. It is an index of water activity of many foods (Oduntan *et al*., 2012). In general the leafy vegetables under study were found to contain high moisture content. The high moisture content of the vegetables indicate that these vegetables may have a short shelf life since microorganisms that cause spoilage thrive in foods having high moisture content and also indicate low total solids (Adepoju *et al*., 2006).The moisture contents of the leafy vegetables at different growth stages showed that the different leafy vegetables varied greatly in their moisture contents at different growth stages. Higher moisture contents were recorded in *Rumex acetosa*, *Brassica juncea*, *Allium hookeri* and *Oxalis corniculata* etc. It is evident from the table that as the plants grow, the moisture content showed a gradual decline. *Rumex acetosa* was found to contain the maximum moisture contents of (96.14% and 95.20%) at 2WAE during the second and first years of study respectively, which was followed by *Allium hookeri* (94.47% and 93.08% at 2WAE during the first and second years respectively); while 72.15% was the lowest value for moisture content recorded at 12WAE in the second year in *Diplazium esculentum*. These values for moisture content correspond to those reported by Gupta *et al*. (2005) for underutilized leafy vegetables which ranged between 73.0 and 95.3g/100g. The decrease in moisture content with maturity was probably due to loss of water from the leaves and increase in the dry matter content of the plants as the maturity stage increased (Rosalizan *et al*., 2008). A decrease in moisture content (92% at 50 days of harvest to 88–89% at 60 and 70 days of harvest) in ratoon crops of *Centella asiatica* was reported by Rosalizan *et al*. (2008). Oduntan *et al*. (2012) also found a decrease of moisture content with maturity in *Sesamum radiatum* leaves.

5.2.2.9 Cooking Quality

Scores for cooking quality revealed that the different type of vegetables and harvest stage greatly affected the cooking quality of the vegetables. The overall cooking quality scores were observed to be high in *Eryngium foetidum*, *Oxalis corniculata*, *Allium hookeri*, *Brassica juncea* and *Hibiscus sabdariffa*. In general, scores for cooking quality were found to be high in initial growth stages which declined slightly as the plants matured. This is because leaves in the early stages are more tender and so were most liked. *Eryngium foetidum* was the most favoured leafy vegetable with a cooking quality score of 4.26 at 4WAE and 2WAE during the first and the second year of study respectively while *Colocasia esculenta* was found to obtain the least cooking quality score of 1.00 at 12WAE in the first year of the experiment. The low scores obtained for *Colocasia esculenta* leaves could be because of the oxalate content, which gives it a characteristics acrid taste; while higher scores for *Eryngium foetidum* could be attributed to the flavor and aroma of the leaves. Muthoni *et al*. (2010) evaluated the cooking quality of some African leafy vegetables organoleptically and observed great variations. They found that most of Amaranthus were either liked most or liked. *Amaranthus cruentus* was said to have the flavour of raw spinach and hence was disliked by most participants. Most of the *Solanums* were liked except *Solanum scabrum* which was disliked by all the participants since it was exceedingly bitter.

5.2.2.10 Shelf life

Shelf life of the vegetables greatly varied among the different leafy vegetables under study. Generally, the shelf life of the vegetables was found to be low. This might be due to the high moisture content of these vegetables as microorganisms that cause spoilage thrive in foods having high moisture content (Adepoju *et al*., 2006). *Houttuynia cordata*, *Justicia adhataoda* and *Piper longum* recorded higher shelf life than the other vegetables. Shelf life was found to increase slightly with advancement of maturity of the leafy vegetables. Highest shelf life of 4.00 days was obtained in *Justicia adhatoda* at 10WAE during the first year, 12WAE during the second year, *Piper longum* at 12WAE during the second year and *Houttuynia cordata* at 8WAE during the second year of study. The higher shelf life observed at the later stage of development could be due to the high dry matter as well as low moisture content compared to the initial stages. The possibility of spoilage reduces with maturity of the leaves as indicated by the decrease in moisture content which results in a longer shelf life.

5.3 Standardization of maturity indices of the collected vegetables

The maturity stage of a conventional vegetable is universally defined and a crop is normally harvested and consumed at a known stage of plant development, irrespective of environmental conditions for plant growth (Guarino, 1997). Maturity or harvest indices are visual, physical and chemical attributes that allow the grower to determine the best time to harvest a particular commodity. These indices are a compromise between a stage that is best for eating and a stage that is best for marketing (Durner, 2013). It is important to harvest a crop at the proper maturity stage because quality cannot be improved after harvest, it can only be maintained. Vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food. For different vegetables maturity indices vary e.g. in asparagus spear length, in broccoli compact flower heads, in lettuce firmness, in carrot root size are used as indicators of maturity. But unlike conventional vegetables, there is little documented information about the age of plant development to define harvest maturity for wild or indigenous leafy vegetables. Leafy vegetables are normally harvested based on appearance (fresh-looking, right size, right maturity, right colour, turgid or not wilted, free from rotting or other physical defects) and sensor attributes such as firmness, tenderness and taste etc. For example, vegetables like mustard greens are harvested when they have developed full size, but not so matured that leaves become tough and flavor is bitter. However, the nutritional content of leafy vegetables at a particular stage of plant development is also important to define harvest maturity because of their significant nutritional contribution in the diet of the people. So, based on some important physical, chemical and sensory attributes (plant biomass, leaf number, leaf color values for 'a', number of harvests, cooking quality, shelf life, vitamin C content, total calcium and magnesium contents, iron and manganese contents, crude fibre content and beta carotene content), an attempt has been made to standardize the maturity indices of the leafy vegetables under study. Since the maximum value for different attributes for a particular leafy vegetable varied greatly, an intermediate stage has been selected at which most of the attributes are at sufficient amount together with acceptable eating quality. For crops like *Plantago major* even though most of the parameters are higher at a later stage of development, leaves become fibrous and unsuitable for consumption. So, an early stage of harvest is preferred; while for *Colocasia esculenta*, cooking quality is an important factor as older leaves are not preferred for consumption. For most of the vegetables under study young tender leaves are selected. For *Centella asiatica* and *Eryngium foetidum* number of harvests are reduced if harvesting is done at an early stage, while for *Hibiscus sabdariffa* yield is reduced in older crops. So, keeping in view all the facts, maturity indices were developed for the vegetables under study.

Chapter VI

SUMMARY AND CONCLUSION

The findings of the present investigation are summarized and concluded below:

1. Twenty five underexploited leafy vegetables were collected from different parts of Meghalaya and were propagated in the research Farm of the Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya.

2. The vegetables were harvested at six different stages of maturity i.e., 2 WAE, 4 WAE, 6 WAE, 8 WAE, 10 WAE and 12 WAE and the different parameters were analysed. The experiment was conducted for two consecutive years. All the morphological and physicochemical parameters showed variations among the different leafy vegetables.

3. Among the 25 collected vegetables, 19 were found to be perennial and six vegetables were found to be annual.

4. *Diplazium esculentum* leaves during 2WAE for both the years took the maximum number of days (18.00) to reach maturity while *Mentha arvensis* leaves at 8WAE and 12WAE during the first year took the minimum number of days (6.67) to attain maturity.

5. Plant height, plant biomass, leaf number, leaf area index, leaf weight of the crops increased with increasing age of the plants.

6. *Passiflora edulis* recorded the maximum plant height (148.65cm) and leaf area index (10.04) at 12WAE during the second year of the experiment, maximum leaf number/plant (255.33 and 240.00) for both the years under study, while *Justicia adhatoda* recorded the maximum plant biomass (3105.50 g/plant) and leaf fresh (878.83 g/plant) and dry weights (235.08 g/plant) at 12WAE during the first year.

7. It was observed that leaf color 'L' and 'b' values decreased and 'a' values increased with increasing age of the crops. Highest 'L' value (46.44) was found in *Brassica juncea* at 2WAE during the second year of the experiment,

highest ‘a’ values were recorded in *Justicia adhatoda* at 12WAE for both the years (-8.85 and -8.82); while highest color value for ‘b’ (17.75) was observed in *Polygonum alatum* at 2WAE during the second year.

8. Values for texture showed an increasing trend with increasing maturity of the crops. Higher textural scores were observed in *Plantago major*, *Houttuynia cordata*, *Allium hookeri*, *Amaranthus viridis*, *Piper longum*, *Eryngium foetidum*, *Basella rubra*, *Rumex nepalensis* and *Justicia adhatoda*.

9. The vegetables vary greatly with respect to their leaf shape ranging from ovate to pinnately compound leaves.

10. Maxiumum number of harvests (9.00) was observed in *Basella rubra* at 6WAE.

11. The yield/harvest of the crops increased with growth of the crops. *Plantago major* recorded highest yield/harvest (307.06 g/m^2) at 10WAE during the first year of study.

12. Different types of vegetables responded differently to ratooning. While for crops like *Centella asiatica*, *Eryngium foetidum*, *Diplazium esculentum* and *Basella rubra* yield was reduced when harvesting was done at early stage, for *Plantago major*, *Hibiscus sabdariffa* etc yields were reduced in the ratoon crops.

13. The vitamin C, calcium, magnesium, iron, total phosphorus and potassium contents increased as the plants matured and then declined rapidly; while the manganese contents increased with increasing maturity.

14. Some plants containing high vitamin C content were *Basella rubra*, *Chenopodium abum*, *Brassica juncea* and *Colocasia esculenta* etc; while the calcium content was found to be high in *Centella asiatica*, *Oxalis corniculata*, *Piper longum*, *Houttuynia cordata* and *Eryngium foetidium*. For magnesium content, higher values were observed in *Houttuynia cordata*, *Hibiscus sabdariffa*, *Centella asiatica*, *Plantago major* and *Basella rubra*. High values for iron were observed in *Houttuynia cordata*, *Centella asiatica*, *Basella*

rubra, *Justicia adhatoda* and *Hibiscus sabdariffa*; while high beta-carotene values were observed in *Colocasia esculenta*, *Justicia adhatoda*, *Passiflora edulis*, *Rumex nepalensis*, *Mentha arvensis*, *Allium hookeri* and *Piper longum* etc

15. The highest vitamin C value (155.50 mg/100g) was recorded in *Basella rubra* at 6WAE during the first year, calcium (2.85%) in *Centella asiatica* at 12WAE during the second year, magnesium and iron (2.55% and 9.86 mg/100g during the first and second years respectively) in *Houttuynia cordata* at 8WAE, manganese content (2.54 mg/100g) in *Basella rubra* at 12WAE during the first year, total phosphorus (0.96%) in *Passiflora edulis* at 8WAE and total potassium content (2.92%) at 8WAE in *Diplazium esculentum* during the second year of the experiment.

16. The total chlorophyll and beta carotene contents increased rapidly with increasing age of the plants. *Justicia adhatoda* recorded the maximum total chlorophyll content of 2.13 mg/g at 12WAE during the second year, while *Fagopyrum cymosum* was found to contain the highest beta-carotene content of 96.70 mg/100g, at 12WAE during the first year of study.

17. The crude protein content was found to decline with increasing age of the crops; while the crude fibre content increased gradually. Highest crude protein content (35.35%) was observed in *Centella asiatica* at 2WAE during the first year of the experiment and *Plantago major* was found to record highest value for crude fibre (34.52%) at 12WAE during the second year.

18. An increasing trend in the total phenol and titratable acidity contents of the vegetables was observed with increasing age of the crops. *Eryngium foetidum* recorded the highest value (24.90 mg/100g) for total phenols at 12WAE during the second year, while the maximum value for titratable acidity (2.30%) was observed in *Hibiscus sabdariffa* at 12WAE during the first year of the experiment.

19. The moisture content of the plants showed a gradual decline with maturity. *Rumex acetosa* was found to contain the maximum moisture content (96.14%)

at 2WAE during the second year of study.

20. Scores for cooking quality were found to be high in initial growth stages which declined slightly as the plants mature. *Eryngium foetidum* was the most favoured leafy vegetable with a cooking quality score of 4.26 at 2WAE and 4WAE during the first and second year of study respectively.

21. Shelf life was found to increase slightly with advancement of maturity of the leafy vegetables. *Justicia adhatoda*, *Piper longum* and *Houttuynia cordata* recorded higher values for shelf life.

22. Based on important morphological and physicochemical parameters, maturity indices of the different vegetables were standardized. The maturity indices varied greatly among the different vegetables. For crops like *Plantago major*, *Fagopyrum cymosum*, *Commelina benghalensis*, *Colocasia esculenta*, *Emilia sonchifolia*, *Spilanthes acmella*, *Allium hookeri* and *Brassica juncea* the optimum stage of harvest was found to be 4-6WAE; while a high stage of maturity of 10-12 WAE was found to be the optimum stage for *Centella asiatica* and *Eryngium foetidium*.

CONCLUSION

From the results and discussion, it is evident that considerable variations existed among the different underexploited leafy vegetables in terms morphological and physicochemical parameters at different stages of maturity based on which, maturity indices of the leafy vegetables were standardized. These vegetables should be harvested at the proper stage of maturity to get higher yields as well as nutrition. It can be concluded from the present study that the underexploited leafy vegetables are rich sources of nutrients like vitamin C, minerals, crude protein, total chlorophyll and beta carotene contents etc. Based on the important morphological and physicochemical parameters, some prominent vegetables are *Basella rubra*, *Centella asiatica*, *Houttuynia cordata*, *Eryngium foetidum* and *Justicia adhataoda* etc. These vegetables can constitute an inexpensive source of these nutrients in the food and these vegetables can be domesticated to alleviate nutritional deficiencies of the local people.

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