DEBREMARKOS UNIVERSITY
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF HORTICULTURE


HAND OUT FOR

ADVANCED VEGETABLE CROPS PRODUCTION & PROCESSING (HORT 524)

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Feb, 2020
Debre Markos, Ethiopia

Chapter 1

Introduction

Chapter objectives

At the end of this chapter students will be able to:

1. *Classify Horticulture*
2. *Define the term Vegetable and Floriculture, root and tuber crops*
3. *Explain the major distinguishing futures of Vegetable Crops, root and tuber crops*
4. *Classify vegetable crops in to different categories*
5. *Recognize importance of classifying vegetables*
6. *Demonstrate different types of vegetable crops systems*
7. *Identify the importance of vegetables (Nutritional value of vegetables, Medicinal value, Ornamental value, Economic value and Social value*
8. *Analyze the prospects and constraints of vegetable production in Ethiopia*

1.1. Divisions of Horticulture

Activity 1.1. Make a distinction between divisions of horticulture

Generally, the horticultural industry consists of four major divisions

i. **Pomology**: - is the science and practice of growing, harvesting, processing and marketing of tree fruits.
ii. **Olericulture:** - It is the science and practice of growing, harvesting, processing and marketing of vegetables.
iii. **Floriculture:** - is the science and practice of growing, harvesting, processing and marketing of flowering plants.
iv. **Ornamental and landscape designing**: - is the science and practice of propagating, growing, maintenance and using grasses, annual plants, shrubs and trees in landscape.

1.2. Definition of vegetables, root and tuber crops

Activity 1.1. What is a vegetable?

Because of their diverse nature, it is very difficult to come-up with a single, acceptable, all-encompassing definition of vegetables. Definitions of the word "vegetable" are generally based on their use. A vegetable could thus be defined as an edible, usually a succulent plant or a portion of it eaten with staples as main courses or as supplementary food in cooked or raw form.

Activity 1.2. Make a distinction between roots, tubers and corms

a. **Roots:** - are underground vegetative organ of plants which is responsible for anchorage, absorption of water and minerals. The tuberous root includes several types of structures with thickened tuberous growth that functions as storage organs. Botanically, these differ from true tubers, although common horticultural usage sometimes utilizes the term “tuber” for all of them.

b. **Tubers**: - are enlarged storage organs which are found underground. The distinguishing factor of a tuber is the presence of nodes or ‘eyes’ on the organ. A classic example is the potato.
c. **Corms**: - is the swollen base of a stem axis enclosed by the dry, scale-like leaves. In contrast to the bulb, which is predominantly leaf scales, a corm is a solid stem structure with distinct node and internodes.

1.3. Characteristics of vegetable, root and tuber crops

i. Seasonality

Most vegetables are seasonal. They grow best during certain seasons or in certain places. Demand for certain vegetables are also higher during certain periods of the year. Several species of vegetables can be grown throughout the year, but here are others that can be grown only during certain times of the year. If irrigation is available, many species can be grown throughout the year.

ii. Perishability

Because of high water content (85-90%) of vegetables, they are perishable and although the shelf life of many root crops may extend over weeks, deterioration, particularly of the leafy salad crops, sets in soon after harvest.

iii. Bulkiness

They are bulky in relation to their volume and this is aggravated by the further needs of packing to protect them from damage.

iv. High capital requirements

Vegetables are intensively cultivated crops. They require intensive cultural practices and the financial and labor inputs involved are therefore greater than those needed for most staple food such as rice or maize.

v. Susceptibility to damage

Crops only be stored for relatively short period of time and utilized mainly when they are fresh. Vegetable crops may also suffer from wind damage when grown on exposed sites where some form of protection will be desirable. For example, runner beans are susceptible for such damage.

vi. Diversity

Considering their diversity nature, a plant may be a vegetable in one country but a fruit, a weed, an ornamental or a medicinal plant in another country, depending on the crop. For example, tomato is a vegetable in Asia but a fruit in Europe. The garland chrysanthemum, is a vegetable to some Asians, to others, it is an ornamental. Although melons are generally used for dessert, they are considered as vegetable; since many members of the cucurbits family are vegetables. In some cases, a plant could be a vegetable only at ascertains growth stage. The bamboo is a crop used for its wood but bamboo shoot is a vegetable. Some of the legumes can be used at various stages of development; the sprouted seeds, the tender shoots, the immature tender pods, and the mature seeds. Some fruits, such as papaya and jackfruit, are used as vegetable in south East Asia When they are immature.

Table 1.1 Difference between fruit and vegetable:

Fruit	Vegetables
i. Fruit is a mature ovary associated with accessory parts of the flower and developed after fertilization of ovule.	i. Vegetable may be any part of the plant such as root, stem, leaf, flower, fruit and seeds or the whole plant used for culinary/cooking purpose.
ii. Fruit plants are perennial in nature (growth habit) except some fruits like cape-gooseberry which is an annual	ii. Most vegetable plants are annual except some cucurbits (coccinia, pointed gourd), sweet potato and asparagus which are perennial.
iii. Fruit plants are generally woody	iii. Vegetable plants are not woody. They are herbaceous plants
iv. Fruit plants are mostly asexually or vegetative propagated plants.	iv. Vegetable plants are mostly sexually or seed propagated plants.
v. Fruit plants require special practices like training and pruning seasonally.	v. Vegetable production is seasonal and special practices not required.
vi. Only fruit from fruit plant is edible and mostly consumed as raw.	vi. All parts depending on the vegetables are edible and generally consumed after cooking.

Activity 1. Recognize the importance of Vegetables

1.4. Vegetable consumption in Ethiopia

In Ethiopia consumption of vegetables and fruits is very low as compared to international recommendation. FAO WHO (2003) recommendation = 400g/person/day. For balanced diet, Dieticians advocate intake of about 300 (125g leafy vegetables, 100g roots and tubers and 75g other vegetables) /person/day and 100 g fruits /person/day.

Table 1.2: Quantity of fruits and vegetables required a family

Person	Per day/ month/ Year	Present consumption in Ethiopia			FAO/WHO Recommendation		
		Fruits	Vegetables	Total	Fruits	Vegetables	Total
one	Day	6 g	118 g	124 g	100 g	300g	400g
	Month	0.195 kg	3.54 kg	3.37 kg	3 kg	9 kg	12kg
	Year	2.35 kg	42.5 kg	4.85 kg	36 kg	108 kg	144kg

Causes of low consumption:

1. The rigid traditional eating habit of the population.
2. Low awareness of the nutritional importance of vegetables and fruits.
3. Consumption of fruits and Vegetables are considered as luxury
4. Low income of the society.
5. High price of fruits and vegetables especially during off season.
6. Shortage of fruits and vegetables supply.

7. Lack of diversity of vegetables in the markets.
8. Vegetable and fruit cultivation is limited to home gardens.
9. Several vegetables are not known to the community people.
10. Lack of knowledge about the uses/ cooking of vegetables

1.4. Classification of vegetables

The relationships of vegetable crop are important to know. There are six general methods of classifying vegetables.

1.4.1. Botanical classification
1.4.2. Classification based on hardiness
1.4.3. Classification based on Life cycle
1.4.4. Classification based on Edible portion
1.4.5. Classification based on Photoperiod
1.5.6. Classification based on Cultural requirements

1.4.1. Botanical classification

It is a classification which is based on the biological relationship of the crops. Plants are divided into four great groups

i. Thallophyta (lichens, algae and fungi)
ii. Brophyta (mosses and liverworts)
iii. Pteridophyta (ferns and other allies) and
iv. Spertmatophyta (the seed plants)

The vegetables belong to the **spermatophyte**. This group or sub-community is sub group into two divisions.
Division I. **Gymnosperms** (ovules naked, not enclosed in an ovary)
Division II. **Angiosperms** (ovules in a carpel or ovary). This division is classified into two classes. Class I. Monocotyledons (one seed leaf) and Class II. Dicotyledon (two seed leaves).
No vegetables belong in the division gymnosperms. So we are concerned with Angiosperms.

It is exact or scientific way of classification. Growth habit and susceptibility to injury by insects and diseases are likely to be similar for members of the same species, genus and family. But in many ways it is of little value in giving principles of culture, since crops within a family may vary widely in their requirements. Therefore, it doesn’t completely satisfy the needs of the student interested in the production of vegetables, because he/she needs to have some orderly arrangement in mind which will helps him/her relate one crop to another in respect to their cultural requirements’ and uses as human food. For example, potatoes and tomatoes belong to the same family (*Solanaceae*) but their requirements are very different. However, other crops in this family, as tomatoes, eggplant and hot pepper have similar requirements. Likewise, most crops in the *Cucurbitaceae* have similar cultural requirements.

1.4.2. Classification based on Hardiness

In this respect vegetables are classified as hardy and tender plants. Hardy vegetables will endure ordinary frosts without injury. Tender classes would be killed by frost. Therefore, frost injury is the chief difference between hardy plants and tender plants. Other differences, hardy plants will not thrive well under hot dry conditions. Others will withstand frost and also thrive during the hot weather. Some tender vegetables do not thrive in cool weather even if no frost occurs. The terms cool season crops and warm season crops stand to mean hardy plants and tender plants, respectively.

The cool season vegetables are those of which the vegetative parts: stems, leaves and buds or immature flower parts are eaten, with two exceptions to this rules, sweet potato (roots used) and New Zealand spinach (leafy & stem used). On the other hand, those vegetables of which the immature or mature fruits are eaten are warm season crops. Pea and bean being exceptions as they are cool season crops. Cool season crops withstand light frost, they are crops in which the edible part is root, stem, leaf or immature flower part. Many cool season crops are shallow rooted and small in size. A few are moderately deep rooted. They need more careful and frequent irrigation than deep rooted crops. Cool season crops respond to nitrogen fertilizers because nitrification occurs slowly in cool soils. Warm season crops need relatively high temperature, hot& dry conditions. Their growth is checked when the air is cool and die when frosted. The edible portions of this group of crops is their fruit with few exceptions such as sweet potatoes. But there are some warm season crops with some other edible organs such as spinach with leaf and stem edible parts. Furthermore, these cool season fruit vegetable, for instance peas.

Cool season crops generally differ from warm season crops in the following respects;

i. They are hardy or frost tolerant
ii. Seeds germinate at cooler soil temperature
iii. Root systems are shallower
iv. Plant size is smaller
v. They respond more to nitrogen
vi. More attention must be paid to irrigation- usually plants must be irrigated more frequently
vii. Some of the biennials are susceptible to pre-mature seed stalk development from exposure to prolonged cool weather.
viii. They are stored at close to 0^{0}C, except the white potatoes. Sweet corn is the only warm season crop held at 0^{o}C after harvest.
ix. Harvested product is not subject to chilling injury at temperatures between 0^{0}C & 10^{0}C as the case with some of the warm season vegetables.

Table 1.2. Classification of vegetables based on hardiness

Cool season vegetables		**Warm season vegetables**
Artichoke	Celery	Tomato
Asparagus	Chard, Swiss	Sweet corn

Rhubarb	Chicory	Musk melon
Rutabaga	Kale	Water melon
Turnips	Leek	Cucumber
Bean, broad	Radish	Squashes
Broccoli	Lettuce	Pepper
Brussels sprout	Potato	Pumpkin
Chinese cabbage	Chive	Eggplant
Cabbage	Endive	Sweet potatoes
Collard	Onions	Bean
Carrot	Garlic	spinach
Cauliflower	Shallot	
Parsley	Peas	

This classification is of value in connection with a discussion of time of planting. By grouping all hardy crops together general principles regarding time of planting can be given for the whole group. However, it does not fulfill the interest of the Olericultures, because it lists those crops with different cultural requirements together, for example sweet potato and tomato.

1.4.3. Classification based on life cycle

With this method the crops are classified based on the length of their life cycle. Accordingly, there are: annuals which complete their life cycle within a year. Biennials, those which are completing their life cycle within two years (e.g. carrot, beet, cabbage). Crop of this group produce the vegetative parts during the first season and the reproductive parts during second season.

1.4.4. Classification based on edible portion/parts

a. Those grown for their leave or stems (cabbage, Swiss chard, celery, lettuce, asparagus and other leafy vegetables).
b. Those grown for their fruits (melons, squash, cucumber, pumpkin, peas, beans, tomato, pepper, eggplant).
c. Those grown for their flowers (cauliflower, broccoli)
d. Those grown for their underground parts (portions)
    i. Those grown for their bulbs (garlic, shallot, onion, leek).
    ii. Those grown for their roots (beet, carrot, sweet potato, yam, cassava, anchote, taro, tannia).
    iii. Those grown for their tubers (Irish potato)

1.4.5. Classification based on photoperiod

Photoperiod is the daily duration of light, which of course changes throughout the year. The rate of photoperiod encountered increases with latitude, thus at the equator the length of the day is almost constant throughout the year, but the extreme latitudes of the tropics, the day length varies from about 10 hours in winter to about 14 hours in summer.

Flowering and fruiting of certain crop species are affected by photoperiod. Some will flower as it increases. Bulbing and tuberization are other growth processes that are affected by photoperiod. The vegetable species affected by photoperiod and the classification according to their response is indicated in table4.2 below.

Table 1.3. Classification of vegetables according to photoperiod

Crop species according to photoperiod response	Phase of development sensitive to the photoperiod	Practical importance
Short day plants		
African eggplant	Flowering	Seed and crop production
Sweet potato	Flowering & tuber production	Crop production
Potato	Tuber production	Crop production
Onion (some Cultivars)	Seed & bulb formation	Seed and crop production
Cassava	Tuber formation	Crop production
Long day plants		
Beet root	Flowering	Seed production
Carrot	Flowering	Seed production
Chinese cabbage	Flowering	Seed production
Spinach	Flowering	Seed production
Lettuce	Flowering	Seed production
Onion (some cultivars)	**B**ulb formation	Crop production
Radish	Flowering	Seed production
Potato	Flowering	Seed production
Day neutral plants		
Asparagus, cucumber, cauliflower, cabbage, sweet potato, French bean, melon, chili pepper, tomatoes, maize, pea		

1.4.6. Classification based on cultural requirements

It is a very convenient method of classification, because it is based on the essential methods of culture. In this system all those crops that have similar cultural requirements are grouped together for discussion. This makes it possible to give the general cultural practices for the group without the necessity of repetition in the discussion of individual crops.

There are 13 (thirteen) groups of vegetables to be discussed based on their similarity in general principles of vegetable growing.

i. Perennial: - Asparagus
ii. Pot herbs and greens: - spinach, kale, chard
iii. Salad crops: - celery, lettuce
iv. Cole crops: - cabbage, cauliflower, broccoli, Brussels sprout
v. Root crops: - beet root, carrot
vi. Bulbs crops: - onion, leek, garlic, shallot
vii. Irish potato
viii. Sweet potato

ix. Peas and beans
x. Solanaceous fruits: - tomato, pepper, eggplant
xi. Cucurbits: - cucumber, pumpkin, water melon, squash
xii. sweet corn, okra
xiii. Yam, Cassava, Anchote

This system combines parts of the other three methods (Botanical, hardiness & consumable parts).

1.5. Types and systems of vegetable growing (gardening)

Vegetable crops production is an art which has been practiced for centuries. Its types of production have evolved through time base on improved methods of transportation, increase purchasing power (demand), changing food habit, and the discovery of the importance of vegetables in human diet.

Generally, it has been developed as a result of change in socio-economic conditions. Based on the objectives sought and the methods employed in producing and in disposing (marketing) of vegetables there are seven types of vegetable production.

The types of the production are:

1. Home gardening
2. Market gardening
3. Truck gardening
4. Production for processing
5. Vegetable forcing
6. Vegetable seed production, and
7. School gardening

All of the above types of vegetable production except that "home, and school gardening involve attempts to produce vegetables on a commercial scale for profit.

1.5.1 Home gardening:

As its name indicates home gardening is the growing of vegetables for family use in the diet. It reduces living expenses because the vegetables are grown for the home table. A wide selection of crops is grown though the local mate is not exactly ideal - for all of them. Land, fertilizer, and seed may be expensive compared to commercial growing, but the quality of the produce is usually more desirable. It should furnish an ample supply of fresh vegetables throughout the growing season.

Most of the work in carrying for the garden is done in spare time, and then the location selected should be as close to the house as is practicable. It is also important that since the gathering of vegetable is usually done by the women of the family, it should be nearby the house. In dry regions it is desirable to locate the garden where it can be irrigated easily and conveniently. In cold, exposed sections the location with reference to protection from the wind is important.

Varieties should be chosen to meet special requirements, such as: earliness, succession, adaptability to the region, disease resistance, productivity, and size of the area available. Where the area is large enough it is desirable to produce all the kinds of vegetables that the family likes, provided that they can be grown satisfactorily in the region. If the area is limited, it is wise to grow those crops that produce large yield per unit of area, considering the time they occupy. Tomatoes, cabbage, lettuce, beets, carrots are desirable for small garden. By proper selection and succession of these crops fresh vegetables may be obtained from the garden most of the growing season:

1.5.2. Market Gardening:

It may be defined as that branch of vegetable growing which has for its objects the production of vegetables for a local market. As cities and towns become larger and more congested, residents of the periphery increased their production and peddled the surplus to those who are living in the more fully occupied areas.

The production is to meet the need of those members of the population who had no land in the city, by providing fresh vegetables. This necessitates good transportation facilities. A variety of vegetables are grown inspire of high demand, expensive labour, and same times the lack of labour-saving devices. Low cost of transportation the possibility of quick adjustment of supply and variety to the demand of a local market have made this type vegetable growing profitable. The market gardener is producing those crops for which the climate and soil are suited. If production is increased competition may become intense between producers so that this leads to more specialization in production and too attention to the grade and appearance of the product.

1.5.3. Truck gardening

Tuck gardening may be defined as the producing of special crops in relatively large quantities for distant markets. Prior to the development of refrigeration and the refrigerator car, production of perishable vegetables for market was limited to regions relatively near the market. Due to the development of good transportation and refrigeration vegetables have been started to be produced extensively and specially, so that a large quantity of it is arrived for the consumers, even though the gardens are located several hundred miles away, and have removed the advantages of the market gardeners. In general truck farming is more extensive and specialized than market gardening, and the location of truck-growing regions is determined primarily by climatic factors and soils favouring the culture of special crops.

1.5.4. Production of vegetables for processing

It is a form of agro-industry which has the objective of producing vegetables for vegetable processing. Since most vegetable crops are highly perishable and cannot be supplied with continuously to the market in large quantities the need for processing fresh vegetables to differently preserved form becomes indispensable. Vegetables for processing are usually produced on a more extensive scale than those grown for market, and are generally grown in rotation with farm crops. Because of the necessity of low-cost production, the industry has sought areas of favourable climate and cheap labour. As a rule, processors contract for tonnage, with certain limitations on quality, at a figure lower than the market price for fresh vegetables. Many producers produce only one crop for ceasing. Favourable growing areas tend to be come leaders in the production of certain vegetables for processing. Cost of production per acre and per ton is usually less for processing crops than for the same crops gown for market, because of the generally lower land value, less labour, and lower cost of handling.

1.5.5. Vegetab1e forcing

It is the growing of vegetables out of their normal season or outdoor production season. It is accomplished by the use of artificial heat or in some cases by protection from cold in growing structures. This structure must admit light and produce favourable environmental conditions in order to permit the normal development of plants. Vegetable forcing was developed because of the demand for the fresh vegetables out of the normal season of production where growing season is too short or too cold for growing warm season crops in the open field. This type of vegetable growing is a highly specialized branch of agriculture. The cost of production is high and cannot compete with the same kinds grown under this type of production it should be produce when supply is less from the vegetables in the open and in best quality. Tomato, cucumber and pepper could be grown under this type of production. Growing structures suitable for the forcing are green houses, hot beds, and cold frames.

1.5.6. School gardening

It is a garden established for the purpose of education. Its main purpose is the demonstration and training of basic agricultural practices in school level. The activity is not done by family members but by students of a certain school for education. It is not based on family vegetable demand. In general, the establishment of any enterprise for the commercial production of vegetables should be based on a careful technical, economical, and commercial studies, related to the size of the proposed enterprise and to all local circumstances. The size should be as far as possible be located in the proximity either to the local market or the factory or, for export trade, to a suitable sea port; or air-port.

1.6. System of Vegetable Farming:

1. **Small scale vegetable farming** - Vegetables are grown by small holders nearby market for their own livelihood. Almost all family members work in the field and earn income to fulfil the requirement of the family.

2. **Large scale vegetable farming** - Specialized vegetables are grown on large farms away from the city and transported to big market. This is also called commercial vegetable farming

3. **Contract vegetable farming** - In this system some companies such as seed companies and processing companies and exporters undertake contract production of vegetable seeds or vegetables with farmers for export and also for domestic markets. The company and farmer have certain mutual agreements (terms and conditions) with regards to price and seed quality, time of seed supply before undertaking contract vegetable production.

4. **Cooperative farming** - In this system, cooperative societies of enterprising farmers undertake the production of vegetable crops for supply to distance market or in other regions. The farmer's cooperative societies supply vegetables at a pre-fixed price to enterprises.
5. **Organic vegetable farming**
6. **Off-season** or **Protected vegetable farming**

1.6. Constraints and future prospects of vegetable production in Ethiopia

1.6.1. Constraints/ Problems of Vegetable Crops Production

The major gaps that require research intervention in vegetable, root and tuber crops production and use can be grouped into the following areas:

a. Production technologies

- Adaptable high yielding and good quality varieties
- Improved agronomic packages
- Lack of improved seed sources/plant material and limited research activities, thus poor varieties are resulted into low quality and yield
- Improved soil fertility and water management
- Genetic resource conservation and utilization of indigenous vegetables, root and tuber crops
- Control of major diseases such as late blight and bacterial wilt of potato, bacterial wilt of enset, virus in sweet potato
- Lack of skilled manpower in the field of vegetable (olericulture)

b. Postharvest, processing and utilization

- ♣ Inadequate post-harvest handling, thus much of the yield is lost from the time of harvesting to the point of consumption as storage condition is poor and improper and vegetables are highly perishables.
- ♣ Storage, packaging and processing techniques
- ♣ Information and awareness on different recipes
- ♣ Lack of appropriate processing equipment
- ♣ Inadequate knowledge about the cultural requirement of each crop. Poor transportation facilities: Well-equipped transportation facilities are vital to move the products from the site of production to the area of consumption without much deterioration. Under our situation, transportation in hindered due to relief of the country, mainly in regions suitable for vegetable crops production.
- ♣ Poor knowledge of community about food and nutritional value of vegetables
- ♣ Inadequate appreciation of the food value of vegetable crops

c. Marketing and transportation

- ✓ Lack of capital
- ✓ Market problem (poor marketing system)

- ✓ Market information and distribution system
- ✓ Market linkages between producers and consumers

d. Protection

- ▪ Diseases and insect pests

1.6.2. Prospects for Vegetable, root and tuber Crops production

a. Favorable agro-ecology - grow vegetables with different ecological requirements

i. climate
ii. Soil: - favourable for different types of vegetables
iii. Ample water supply: - both RF & irrigation
b. Market: - Local & export
c. Cheap and abundant labour force

d. Proximity of the country to fertile markets of Europe and Middle East Asia

e. Vegetables are good sources of human diet and can obtained cheaply as compared to animal products

f. Vegetable production creates job opportunity for the citizens

Chapter Two

Factors Influencing Vegetable Crops Production

At the end of this section students will be able to:

- *Describe the climate and soil requirements for successful vegetable production*
- *Differentiate biotic and abiotic factors influencing vegetable production*

Since the yield potential of vegetables revolves around photosynthesis and respiration, directly or indirectly, all environmental factors that affects, the efficiency of these processes must be at optimum level. The factors can be grouped in to abiotic, referring to nonliving and living components of the environment, respectively.

2.1. A biotic Factor

2.1.1. Weather and Climate

In a given location, the daily condition of the environment can be described in terms of temperature, rainfall, light intensity and duration, wind direction and velocity, and relative humidity, collectively they comprise the weather. The weather changes each day and assumes a certain pattern, which repeats itself year after year. The pattern is a climate of that particular location.

Each crop has a certain climatic requirement. To attain the highest potential yield per unit of land, a crop must be grown in an environment, which meets these requirements. A crop that is well

matched to a particular climate can be grown with minimum adjustments. However, the high demand of some crops has led to their cultivation in areas that are less than ideal.
Unfavourable climatic conditions produce a stress or a strain on metabolic processes of the crops resulting in lower yields. In such a case the environment can artificially modified to meet the crop requirements. However, modifying the environment artificially can be very expensive, so it is done only when it is highly profitable or for experimental purposes.

In temperate zone where temperature changes constantly, temperature is the determine factor in crop production. In the tropics, rainfall is a key element of climate since temperature is more or less constant.

While climate determine what crop can grow best in a particular location, the rate of growth and development depends largely based on the weather. Weather conditions influences the basic crop physiological processes. The weather also determines when to undertake farm operations such as, land preparation, weed control, fertilization, harvesting and irrigation.

a) Temperature

There is a 0.6^0c decease in temperature for every 100 meter rise in elevation above sea level. Temperature usually the most important factor to consider in deciding what crops to grow in a place, it influences all physiological activities by controlling the rate of chemical reactions. It affects flowering and pollen viability, fruit, set, hormonal balance, rate of maturation and senescence, quality, yield, and shelf life and affect harvest time of vegetables. High temperature near harvest time hastens the time interval during which harvest can occur.

i) Optimum temperature

Each type of vegetable crop grows and develops most rapidly at a favourable temperature or range of temperature. This is the optimum temperature range, with in which photosynthesis and respiration occurs are rates that result in the highest marketable yields. The rate of photosynthesis is high and respiration is normal, so net photosynthesis is maximum. Temperature requirement are usually based on night temperature. At high temperatures, the night temperature may influence the amount of crop yield. While photosynthesis occurs during daytime, respiration occurs mostly at night, when respiration is right net photosynthesis is low thus potential yield is reduced usually night temperature is high during rainy season,

ii) Temperature extremes

Vegetable crops grow well in a narrow temperature ranges. At 0^0c crops are killed by frost, and at 40^0c they are killed by heat. When a temperature is lower or higher than what the crop can tolerate, photosynthetic, respiratory and metabolic processes become abnormal. Many crops are permanently, damaged at10^0c or even at 15^0c, and most cease to carry out photosynthesis efficiently above 30^0c. The abnormalities are expressed by the slowdown in growth and development and by some external symptoms. In tropics heat injury rather than low temperature injury is the bigger problem.

Chilling injure

Crops requiring high temperature are very susceptible to chilling temperature (10-12^{0}c or lower but above freezing). The metabolism of the crop is resulting in the appearance of discolored areas, poor color development, or sunken area on the surface of the leaves or fruits (surface pitting). Chilling injury is a result of interaction between temperature and time of exposure. A short period of exposure to 5^{0}c may cause as much damage as a long exposure to 12^{0}c.

Heat stress

Very high temperature is potentially injurious, so it is called heat stress. Reduction of temperature on leaf surface usually depends upon cooling by transpiration and by heat flow (Conduction) to the atmosphere. When heat not effectively removed, the temperature of leaves in fully sunlight may be higher by 10-15^{0}c than the ambient temperature.

Injury caused by a temperature higher than what a crop can tolerate occurs gradually and is expressed as reduction in growth rate. Its effects are seldom lethal. Heat injury can be due to starvation, toxicity, or reduction of protein structure, at a temperature above 30^{0}c, the stomata remain closed, this effectively preventing carbon dioxide from entering, when this occur for a long period, starvation results, since net photosynthesis is zero or less than zero. Toxicity may be possibly occurring when respiration is so rapid that eventually oxygen intake is reduced and the respiration process then become abnormal. This abnormal process eventually is called anaerobic respiration. The products of anaerobic respiration, among others, are ethanol and acetaldehyde compounds which can damage plant cells.

The structure of protein may be destroyed (denatured) by high heat. Destruction of proteins causes marked chlorophyll deficiency since enzymes, which are proteins, are necessary for chlorophyll synthesis. Cell membrane of heat stressed plants become more porous(Permeable) and thus release their cellular contests; so they become more susceptible to diseases, as the released substances serve as food for microorganisms.

Vegetables normally grow in the temperate regions cannot withstand the stress imposed by high temperatures and can rarely tolerate temperatures above 35^{0}c.

iii) Soil temperature

Soil temperature is a major factor that determines the rate of microbial growth and development, organic matter decay, seed germination, root development, and of water and nutrient absorption by roots. The higher the temperature up to a certain limit the faster are these processes. The size, quality and shape of storage organs are also greatly affected by soil temperature. Dark colored soils absorb more solar energy than light colored ones. The capacity of water to move heat from one area to another (conduction) is greater than that of air. Heat is therefore, released to the surface faster in wet coloed soil than in dry sandy soil.

iv). Vernalization

The biennials and some of cool season vegetables (Allium, carrot, celery, the crucifer) initiate flower formation after extended (several works or months) exposure to low temperature. Older plants respond better than seedlings and transplants. Flowering in the above plants is a quantitative response to low temperature; that is the duration of explore needed to initiate flowering declines as the temperature decrease. The lower the temperature, the shorter the exposure to vernalization temperature is necessary. Thus, at the same exposure duration, radishes will fowler sooner at 5^{o}c than a 100c. However, if a temperature during growth is high verbalized plants might fail to flower.

If is important to expose crops to low temperature when they are most responsive to it (inductive stage), so as to obtain flowers for seed production. However, the premature appearance of a flower stem, called blotting can cause substantial yield loss when these crops are grown for vegetables. This is particularly true in crops requiring relatively little cold exposure, like heat tolerant Chinese cabbage. This may be a problem in low temperature areas or during cool months of the year at low elevation.

b) Light

Light from the sun travels to earth is waves. The waves are measured by their length, which is expressed in a nanometers (nm). Each wavelength corresponds to a certain color, thus sunlight is composed of light of different colors (as in rain bow), though if appears white to the naked eye. They are three light factors that are important to normal growth and development of vegetable crops.

i) Light quality

Light quality refers to the predomination wave length. Photosynthesis uses light in the range of wavelength from violet with a wavelength of about 380nm, to red with a wavelength of about 670nm; light not used in photosynthesis is transmitted through the leaf or in reflected by the leaf.

Light is a shorter wave length. (Blue light about 450 nm) is absorbed by carotenoids and chlorophyll. In longer wave length (red light about 675 nm), it is absorbed by the chlorophyll only. Chlorophyll does not absorb green light but reflect it, so it appears green. Light quality becomes important only when plants are grown under artificial light. The lamp to be used should give light with the red and blue wave lengths in sufficient amounts. Otherwise, when there is a predominance of ultraviolet wave length, the plants will be dwarfed. Low light intensity (predominance of the red wave length) with cause the plants to be long and thin (spindly)

ii) Light duration

The duration of light is measured by the number of hours from sunrise to sun set. It is called photoperiod or day length. The length of light periods varies according to the season of the year and latitude.

Some vegetable crops are qualitative in response that is they flower when a specific day length threshold has been passed. Short day plants flower rapidly when the days get shorter and long day plants flower fast when days are longer.

In reality, it is the night duration that is important; thus, **short day plants** require daily prolonged darkness to induce flowering while long day plants require shortened darkness. Some plants are more sensitive to photoperiod than other. Short day plants flower with in a constant number of days when a day length shorter than critical photoperiod. There is no flowering at more than the critical photoperiods, the vegetative phase is promoted and the reproductive phase is suppressed.

On the other hand, a **long day plant** flowers within a constant number of days when the days are longer than its critical photoperiod. No flowering occurs at a shorter photoperiod in a sharp contrast to the response of short day plants. The vegetative phase of the plant is promoted and the reproductive phase is suppressed when the length of light period is less than the critical photoperiod.

Plants are not affected by day length are called **day-neutral** plants. These plants apparently can flower under any light period.

Knowledge of the critical photoperiod of photoperiodic plant will allow the grower to time his/her planting, so that flowering will occur after it has attained sufficient vegetative growth.

The length of light and dark periods also influence the formation time of certain storage organs. Long day hasten bulb formation in onion, short day hasten tuber formation in potato, root enlargement in sweet potato, corm formation in taro. In case of cucurbits, day length coupled with light intensity and temperature is known to influence sex expression. In general, long and high temperature tends to keep the plants in the staminate (male) phase.

iii) Light intensity

Total light energy from the sun is a net effect of the amount of light and length of the day. The amount of brightness of light which, is referred to as intensity, change with elevation and latitude. Therefore, the highest potential photosynthesis (productivity) for the growing period of annual vegetables would be high at high latitude (temperate region) due to long day length. On the other hand, the greatest potential growth for perennial vegetables would be high in the low latitude (tropical region) due to longer growing season.

The reaction of a crop to different light intensities differs, depending on weather the plant is a shade or a sun plant. Sun plants require high light intensities to maintain a high photosynthesis and respiration rate and consequently show lower rate of net photosynthesis at low light intensities. Shade plants have low photosynthetic rate than sun plants; but respiration rate is correspondingly low, so net photosynthesis is high low light intensity. Light intensity is much lesser during the rainy season than during the dry season due to cloudiness. Under continuous low light intensity of when the plants are greatly shaded plants become tell and thin (spindly), and are light green in color.

Leafy or salad vegetables, such as celery and lettuce, have generally better quality and tenderer when grown under partial cloudy skies. There are few vegetables that can tolerate shade, such as taro and ginger. They yield as much under partial shade as well as under full sunlight.

Table - Light requirement of vegetables

Light level	Vegetables
High	Corn, cucurbits, eggplant, legumes, potato, tomato, sweet potato, yam
Medium	Allium, asparagus, carrot, celery, Brassicas, lettuce, spinach, taro
Low to total darkness	Ginger, bamboo shoot, bean spout, mushroom

c) Water

Lack of water is the greatest single factor that lowers vegetable yield. Vegetables are composed of 80 - 95 % water and they have to produce the remaining 5-20% of their weight through photosynthesis. Aside from its importance for biomass, water also essential for plant growth and development.

A plant usually absorbs several times more water than amount incorporated in its cells. Most of its water lost through during transpiration. The water lost cools the leaf so that it will not be warm to inactivate the enzymes of photosynthesis and respiration. This loss through transpiration also acts as a drawing force pulling the water from the soil to the plant.

During the rainy months in many areas of the tropics, there is more water than is needed. During dry months, there is shortage of any water for growing crops, thus irrigation is necessary drought occurs when there is too little water that does down fast enough.

Too much rain falls causes direct damage to shoots, high incidence of pests and disease, physical destruction of flower, and less activity of pollinators. It is also nutrients down to a level beyond a reach of roots (leaching). Heavy rain fall also creates flooding or water logging in the poorly drained soil.

In terms of water requirement, vegetables can be classified as follows:

I. Great water user with poor penetration: these vegetables are shallow - rooted crops and possess large leaf area and tender tissues; thus they require plenty of water. e.g cabbage, chine's cucumber, leaf green and radish.

II. Economic water users with poor root penetration: these vegetable crops have small and waxy leaves that reduce transpiration. However, they also have poor systems with fewer root hairs of water uptake than most vegetables.

III. Economic water users with moderate root penetration: Solanaceous and root vegetables and legumes have less leafy area but with hairy leaves to reduce transpiration. They have a more vigorous root system than crucifers but poorer than that of cucurbits.

IV. Economic water users with vigorous root penetration: These vegetables are deep-rooted crops possess large leaf area but with hairy lobed leaves to prevent excess transpiration, hence they are slightly tolerant to drought. e.g. Melons &bitter gourd

V. Extravagant water users with poor root penetration: Most aquatic vegetables, such as water convolvulus, water chestnut, water cress, and some varieties of two. They have tender root systems. Their root system is usually poor without any root hairs for efficient water up take.

d) Humidity

Relative humidity has a great effect on condensation and evaporation. It is an important climatic factor affects the growth and development of vegetable crops, through its effects on evaporation of water from the foliage.
Relative humidity (RH) defined as the relation (in %) between the actual vapor pressure and the potential vapor pressure as saturation. at the same temperature.

The precise factor involved is the effect of saturation of the atmosphere in contact with the leaves, i.e. the difference between the saturation water vapor pressure and an actual water vapor pressure at the levels of the leaves. The dryness of air not only depends upon quantity of water vapor present in air but also on temperature of air. When there is high temperature the relative humidity of air low.

Naturally the evaporation is greatest during the hottest part of the year and least in the coldest period. Mean will, keep other things being equal, the relative humidity will be lowest during the hottest time of a day highest when it is coolest (during before sunshine).

In humid atmospheric conditions the stomata will be open, allow a better diffusion of Co_2. The negative effect of high relative humidity includes the germination of certain frugal spores and rapid spread of bacterial activity on crop foliage.

e) Wind

A slight wind in necessary to replenish co_2 near the plant surface. During rapid growth of the plants, Co_2 is rapidly depleted on the leaf surface. When there is no wind, the rate of resupplying the surface of the leaf is limited, so entry of Co_2 is too slow to maintain rapid photosynthesis. Wind also carries O_2 away from the plant. On other hand when there is less wind, there is less evaporation and less water requirement.

Wind is a limiting factor in vegetable production in countries where strong winds "(greater than the average wind speed of 7.2 km/hr/frequently occur. All vegetable crops except few are very susceptible to wind speeds greater than the ordinary. The use of windbreaks or shelterbelts will minimize damage by relatively slow wind.

2.1.2 Altitude

The effects of latitude are significantly modified by height above sea level, since increasing rainfall and reducing temperatures occur with increasing altitude. On average, a 100 m increase in altitude is associated with a 0.6° C in temperature which, in temperate regions, may result in a poor environment for vegetable production. In the tropics however the cooler moister conditions of high plateau regions can provide better conditions for many vegetables than the hotter and drier lowlands.

2.1.3. Slope and Aspects

When choosing a site, account should be taken of the relief, as far as possible preference should be given to fairly level, flat sites. The land will then be easier to work and to irrigate and will not be subject to erosion. Furthermore, land levelling or construction of terraces involves much scrapping and filling which is very costly and often decreases the agricultural qualities of the soil. This is because the microclimate of a site is greatly influenced by its slope and aspect. The problems of water runoff, soil erosion and pool of cold air increase significantly with steepening slopes. In the tropics the western and Eastern aspects of a hilly area are pronounced with relatively higher temperatures, in the afternoon and in the morning, respectively.

2.1.3 Soil/edaphic factor

The soil holds up the plant and acts as reservoir for water. It is also the main plant nutrient elements. Its physical and chemical characteristics greatly influence the nature and rate of vegetable crops growth.

i) Soil types

The solid part of the soil is composed of a mixture of broken down rocks (mineral particles) of different size and the remains of plants and animals at different stage of decomposition (organic matter).

Sandy soils are best suited for the root, bulb, and tuber crops provided rainfall is not a limiting factor of irrigation is available. It allows fast development and easy harvesting of storage organs. However, the soil for root or bulb crops should not be too sandy since too sandy soils cannot hold much water and nutrients and therefore production. They have good mixture of sand and clay. So they gave good nutrient and water holding capacities and provide good aeration. Clay soils are difficult to work and when dry but have very good water and nutrient holding capacity. Root penetration of vegetable crops is more difficult than in loamy soils.

iii) Soil fertility

When previously forested land area is used for growing vegetables for the first time, the soil usually contains all the nutrient elements that the plant needs. However, as it is continuously used for producing a crop, the amount of nutrients is reduced.

iii) Organic matter

Organic matter represents the remain of plants and animals at various stages of decomposition. It improves drainage, aeration, nutrient- and water- holding capacities of the soil. It binds soil particles in to different sizes and forms (structures). Soil which are high in organic matter are usually dark colored are ideal for vegetable production

2.1.4. Financial factors

Many enterprises fail in gardening, because they are not adequately financed (no credit access/ or facility).

2.2. Biotic factors

2.2.1. Crop: adaptability of the crop:

For successful vegetable production there should be well adapted, disease and insect pest resistance, high yielding and high quality varieties of crops.

5.5.2. Disease, insect and weeds:

The presence of agents will limit vegetable crop production and its adaptation.

5.5.3. Social factors:

Centre for crop production is determined by social factors such as demand, facilities (transportation and storage facilities are essential to success in vegetable production since it reach the market in good conditions); labour, since the success of many gardening ventures depend upon timely operations such as planting, weeding, harvesting.

5.5.5. Personal factors:

Vegetable production depends to a considerable extent on the aptitude of the individual producer. Some adapted to grow while others are slow to adjust themselves to such farming. Many farmers do not like to produce vegetables and they have-little patience with the intensive requirements of intensive vegetable production, referring to grow a crop that has a wider planting and harvesting range. Vegetable require more hand labour but other crops require machinery on large scale farm. But what could be considered for the successful economic production of the yield and then income which is higher in the case of table growing.

Chapter Three

General principles and practices of quality planting material production and management

At the end of this section students will be able to:

- ↳ *Identify criteria for nursery site selection*
- ↳ *Perform nursery site preparation and management*
- ↳ *Practice the methods of seedbed preparation*
- ↳ *Estimate the area required for nursery site*
- ↳ *Compare direct sowing and transplanting*
- ↳ *Discuss about optimum condition for pre planting & post planting care*

3.1. Commercial nursery establishment and quality seedling production

The quality of planting material is a major factor that determines the success of seedlings. Nowadays the entire vegetable production system has received attention and changes because the necessity to improve yield and vegetable quality. The production of good quality seedlings is very much essential for getting higher yield and quality of any crop.

In most advanced countries vegetable seedling production is undertaken by specialized companies or as a specialized activity. In Ethiopia, the vegetable seedling production system under open field nurseries in small scale level and under protected condition and trays, in commercial farms. At present, vegetable yields per unit area are generally very low.

Activity 3.1. How do we produce quality seedlings?

3.1.1. Nursery site selection & establishment

The first step in successful vegetable production is to raise healthy vigorous seedlings. Young plants whether propagated from seed or vegetatively require a lot of care particularly during the early stages of growth. They have to be protected from adverse temperatures, heavy rains, drought, wind and a variety of pests and diseases. If small seeded vegetables are sown directly in the field, germination is often poor and the young plants grow very slowly and require a long time to mature. Also the season may be too short for full development in the field. To overcome these problems many vegetable crops are grown in nurseries before being transplanted in the field.

Activity 3.2. Define Nursery site and the need for nursery site?

3.1.1.1. Definition and the need for nursery site

Nursery is a place where plants are cared for during the early stages of growth, providing optimum conditions for germination and subsequent growth until they are strong enough to be planted out in their permanent place.

A nursery can be as simple as a raised bed in an open field or sophisticated as a glass-house with micro-sprinklers and an automatic temperature control system. Although raising seedlings in a nursery has advantages, some vegetables do not transplant well, particularly root crops, and must be sown directly in the field for optimum results. It has to be noted, however, that transplanting seedlings interrupts their growth, which has the potential to reduce their vigour.

Advantages of raising seedling in nursery

1. **Intensive care**: Seedlings receive better care and protection (from animals, weeds and pests) in the nursery. The average garden soil is not an ideal medium for raising seedlings especially from the point of view of soil tilth. At an early stage of development most vegetable crops require special attention that is not possible in the main field.
2. **Reduction of costs**: Fewer seeds are used for raising seedlings in the nursery than for sowing directly in the field, because later seedlings have to be thinned to one, which is wasteful. When expensive hybrid seeds are used, transplants become more economically attractive. Pesticides and labour are also reduced under nursery conditions as compared to planting directly in the field.
3. **Economy of land:** More seedlings can be raised on small piece of land to transplant on a large area.
4. **Easily managed**: It is easy and convenient to manage the seedlings because they are raised in less area in the nursery.
5. **Easy Protection**: Effective and timely plant protection measures are possible to control the insect pests and diseases.
6. **More availability of time for field preparation**: More time is available for preparation of land when seedlings are still in the nursery.
7. **Opportunity for selection** - Raising seedlings in a nursery affords the grower an opportunity to select well grown, vigorous, uniform and disease free seedlings.
8. **Extend a short growing season for late maturing crops** - Seedlings can be raised in a nursery under a protected environment before conditions outside become suitable for growth & transplanted into the field when conditions allow, thus reducing the amount of time spent in the field.
9. **Forced vegetable production for an early market** - Generally prices of horticultural produce are attractive when production or supply is low. Vegetables can be grown ‘out-of-season’ in a nursery when conditions are not yet favourable. Such crops will thus mature earlier after transplanting and hence stand to fetch a higher price in the market.

3.1.1. 2. Factors considered during nursery site selection

The production of good seedlings in the nursery is largely dependent upon suitability of the nursery site chosen. Although the choice of site for vegetable crop production and seedlings rising are similar, for the later the following points should be emphasized during the site selection:

1. Environmental factors: This refers to natural features of the land, which may greatly influence the cost of operation and facilitate management of the nursery.

a) Proximity to planting site (main field): Some of the advantages of locating a nursery as close as possible to the main field are:

i) Cost of transporting the seedlings to the field is minimized.

ii) Less risk of loss of seedlings during transportation, and seedling failure after transplanting.

iii) Reducing the chances of transmitting or redistributing soil-borne pathogens through seedling roots or earth balls over long distances. When, however, particular diseases occur in the nursery area it may of course be advantageous to raise the seedlings outside the affected area in order to initiate new plantings with disease-free seedling materials.

b) Land gradient (steepness of the land): It is desirable to have the nursery on a level ground with good drainage. This will reduce the cost of establishing the nursery considerably. If the nursery is to be located on a sloping land, soil conservation measures are required, such as constructing terraces across the slope to conserve soil and moisture.

c) Nursery soils: Favourable soil conditions (good drainage, absence of toxicity, fertile, etc.) are indispensable for the success of a nursery. When nursery plants are raised in pots, poly bags, seed boxes or trays, it may not be necessary for soils on the nursery site to be fertile. But in this case, a source of high quality soil must be as close to a nursery site as possible in order to lower the cost of soil transportation.

d) Water supply: A nursery should be located where a reliable, abundant and inexpensive supply of uncontaminated water is available. Water supply could be from wells, boreholes, natural streams or irrigation channels.

2. Proximity to services

a) Labour supply: Nursery operations are labour intensive, therefore, it is very important that nurseries are sited in areas where a dependable and regular supply of experienced labour can be easily obtained.

b) Markets: The nearness of nursery sites to potential buyers is very important to commercial nurseries intending to raise seedlings for sale to growers. Such a nursery should be located as close as possible to these growers.

c) Supplies: It is desirable to have a nursery located close to sources of inputs (equipments or tools, and consumables such as seeds, pesticides, fertilizers).

d) Services: It can be advantageous to have a nursery located in an area where the services of agricultural experts (horticulturists, crop protection specialists, soil scientists, etc) can be obtained easily. Other aspects of services are the availability of good roads necessary for the transportation of supplies, seedlings and workers.

3.1.2. Seedbed layout and calculating area

The soil of the nursery should be carefully tilled and enriched with fine manure or compost. Roots, stones and bid clods of soils should be removed. Depending on the weather condition and the soil type seed beds in the nursery could be raised, flat or sunken. However, seedlings are raised on raised beds for they will favour better drainage and more root development of seedlings.

a. **Raised beds: high RF and RH area**

The level of this type of bed is raised to 15-20 cm above the natural level of the plot soil. It is prepared during rainy season to raise the seedlings of vegetable crops like tomato, chilli, Eggplant and Early cauliflower.

Merits:

1. No water stagnation in the nursery area which may cause damage to tender Seedlings
2. It provides proper drainage to drain out excess of water from the nursery area.
3. Surface of the nursery bed remains soft (not compact) and there is minimum injury to roots while uprooting the seedlings from the nursery.

Demerits:

1. It requires more labor to prepare the seed bed which increases the cost of preparation.

b. Sunken bed: : in less precipitated area

- The level of nursery bed is kept below the natural soil surface. It is prepared during winter season.

Merits:

1. Seedlings can be protected against frost by covering the beds with polythene sheet or providing thatch cover over the nursery.
2. When the nursery beds are covered, the proper temperature can be maintained for germination of seeds

c. Flatbeds: when containers are used

The level of its surface is equivalent to the soil surface of surroundings. It is prepared to raise the seedlings of winter season vegetable crops such as Cauliflower, Cabbage, Lettuce, and Onion and spring vegetables like Tomato, Chilli, and Eggplant.

Merits:

1. It is easy to prepare
2. Cost of preparation is less

Demerits:

1. There is more chance of getting excess of irrigation water which is harmful to plants or seedlings.
2. Sometimes soil becomes more compact which results in damage of roots when seedlings are uprooted for transplanting

However, seedlings are raised on raised beds for better drainage and more root development of seedlings.

Area estimation

Before a nursery site is prepared, the area for the nursery could be calculated taking in to account:

- ♣ Plant population required in the field

- Reserve plants needed
- Size of the bed and
- Spacing for the nursery

The following steps may help in the calculation of nursery area required.

1. Number of seedlings per bed = $\frac{10,000\ cm^2 \text{ X single bed dimension}}{\text{Intra-row spacing (cm) X inter row spacing (cm)}}$
2. Number of seedbed per hectare = $\frac{\text{Total number of plants needed + Allowance}}{\text{Number of seedlings per bed}}$
3. Net area of beds = number of beds X single bed dimension
4. Gross area of nursery = Number of beds X 7.56 (for 5x1m)

   Number of beds X 15.12 (for 10x1m)

Example

Suppose we want to plant 10 ha of tomatoes at a planting density of 40,000 plants per ha with 20% allowance, and if we have decided to prepare seedbed having a dimension of 10x1m with 2.5cm (intra row spacing) and 15cm (inter row spacing. What would be the area required for the beds and for the whole nursery?

Solutions

1. **Number of seedlings per bed**= $\frac{10,000\ cm^2 \text{ X } 10}{2.5cm \text{ X } 15cm}$ = **2666.67**
2. **Number of seedbed per hectare** = $\frac{40,000 + (40,000X20/100)}{2666.67}$ = **18 beds**

- Therefore, for 10 ha = 180 beds are needed

3. **Net area of beds** = 180 X 10m^2= **1800m^2**
4. **Gross area of nursery** = 180 X 15.12 (for 10x1m) = **2721.6m^2**

3.1.3. Seed preparation and sowing

5.1.3.1. Seed preparation

Before sowing, seeds are treated to prevent seed borne diseases and to enhance germination. Such treatments are Hot water treatment, soaking of seeds in water and chemical treatment.

a. Chemical treatment: Generally, seeds are treated before sowing with fungicide such as Captan or Thiram or Bavastin at the rate of 2.5g/kg seeds to control ‘Damping Off’ disease. Fungicide is mixed thoroughly with seed after wetting seeds by spraying few drops of water so that fungicide can stick with seed coat easily. After treatment seeds are dried under shade to remove moisture from the seed coat.

b. Hot water treatment: In this method seeds are deeped in hot water having temperature 50-55^{0}C for 30 minutes to control black rot in Cole crops and Phomopsis blight of Eggplant. Care should be taken that water temperature beyond 55^{0}C and duration beyond 30 minutes adversely affects the seed germination.

For Enhancement of germination: Germination can be enhanced by soaking seeds in water or in Growth regulator solution.

i. Seed soaking in water:

- ✓ Seed with hard seed coat is soaked in water for about 18-24 hrs at room temperature.
- ✓ It is advantageous to soak seeds in warm water.
- ✓ Soaking seeds in water make the hard seed coat soft which can be easily broken by germinating embryo.
- ✓ Care is taken while soaked seeds are sown the soil should have sufficient moisture and not become dry otherwise there will be absorption of water by dry soil from the seeds which results in poor germination.

ii. Seed treatment with Chemicals (Plant regulators):

- ✓ It has been observed that germination of seeds can be enhanced by soaking seeds in GA3 at 100-500 ppm and Thiourea at 0.5-5.0 percent solution for 10-12 hrs.
- ✓ After soaking seeds are washed with water dry under shade

3.1.3.2. Seed sowing

Seeds are usually sown in rows running across the width of the seedbed. The spacing between rows and within the row and the depth of sowing depends on the kind and vigour of the crop and the time of transplanting the seedlings. Usually rows are 10-15 cm apart and seeds are dropped at every 2.5 to 5 cm within the row. Seeds are then covered with sifting fine soil and pressed slightly to firm. Seedbed is then watered sufficiently and preferably covered with 5cm thick layer of mulch grass or straw. Regular watering is required for the successful germination of the seeds. As soon as the seeds germinate and break the crust of the soil, the mulch is removed and shade is constructed over the bed. The shade is 1m or higher above the bed and covered with grass or leaves; in such a way that sufficient light reaches the plants.

3.1.4. Seedling Management/ Post planting or sowing operations

3.1.4.1. Mulching

As soon as sowing is completed, mulching is done with a thin layer of manure or leaves or straws or dry grasses to conserve the available soil moisture for proper seed germination. After three days of sowing, observe the seed beds daily. As and when white thread like structure is seen remove the mulch from the nursery beds carefully to prevent any damage to emerging seedlings. Always remove mulch during evening hours to avoid harmful effects of bright sun on newly emerging seedlings.

Advantages of mulching in the nursery

- It reduces the loss of soil moisture.
- It suppresses the weed growth.
- It provides protection to the seeds from bird damage and beating effects of rain drops**.**

3.1.4.2. Watering

Watering of seedbed should not be neglected and watering is important and determines seedling vigor. Both under and over watering are harmful

- Seedlings which are water stressed shows stunted with poorly developed root and shoot. Such plants are less likely to establish well in the field.
- Excess watering: creates poor drainage, suffocation of roots and encourages the development of fungal disease (damping off).

3.1.4.3. Fertilization

Well decomposed FYM or 100g/5m^2 urea.

3.1.4.4. Thinning

This is a way of regulating plant density in rows and in holes. During thinning, weak, diseased plants are pulled out to allow healthy seedlings to grow well. It is normally done when Seedlings have formed a few true leaves.

3.1.4.5. Hardening off

Transplants must be 'hardened-off' so that they can withstand the transition from a relatively sheltered and protected environment to a sometimes harsh open situation. Generally, hardening is imposed from about 1 to 2 weeks prior to transplanting seedlings, by gradually exposing them to higher (or lower) temperature and the higher light intensity prevailing in the field. It should, however, not involve any treatment that may reduce the rate of photosynthesis, such as nutrient stress. Care should be taken not to over-harden plants, as this may delay maturity and in some instances even reduce crop yields.

3.1.4.6. Transplanting

Transplanting is the transfer of plants from one place to another without injuring the roots or tops, and to set the plants in moist soils so that the soil is firm around the live uninjured roots. Or Success in transplanting plants to the field or garden is dependent on good plants, good condition of the soil, and doing the work in the proper manner. The soil of the field should be thoroughly prepared prior to transplanting. It is very difficult to set plants properly in hard , lumpy soil and plants set under these conditions are likely to seriously checked in growth, or to become weak and die. Contact between the roots and soil is important because the roots cannot take up moisture unless they are in close contact with fine, loose soil. For the same reason it is essential that the soil be well firmed around the roots.

The best time to set the plants is just before, or just after a rain, especially if the weather is cloudy. Cool, cloudy weather is desirable because evaporation and transpiration are less under these conditions than in hot dry weather. When it is necessary to transplant in hot, dry weather, it is desirable to do the work in the late afternoon if possible in 'order that the plants may have time during the night to recuperate from the shock.

Although on large scale planting machines are used for transplanting, plants are commonly set out by hand. In any case, plants are uprooted from the seedbed with a ball of earth around the roots. The plants can be planted in furrows made by ploughing, or in holes made using dibble, trowel, shovel or spade. During transplanting care should be taken to see that the soil is firm around the roots and that no space is left unfilled at the bottom of the whole. Plants should also be set slightly deeper than they were in the seedbed.

The correct stage of transplanting varies with the density of sowing, or the size of the containers and with the vigour of the seedlings. For cabbage three week-old seedlings at about a pair of true leaf stage are convenient to handle, although much larger seedlings up to five weeks-old can also be planted and will establish very quickly. Seedlings of some fast, growing vegetables such as Chinese crucifers can be transplanted when two or three weeks old.
Seedlings of tomatoes, chillies and eggplants grow more slowly, and should be transplanted when the plants are fairly large (at least 15cm tall).
Advantages of transplanting:

a. Enhanced earlier harvest
b. Reduced impact of adverse environmental conditions during the early seedling growth
c. Reduces seed quantity needed for crop establishment
d. Enhanced plant stands and faster maturity
e. Eliminates thinning needs

Chapter Four

Management of Vegetable Farm

Chapter objectives

- *Explain principles field preparation and post planting operations*
- *Discuss cultivation and mulching of vegetable crops*
- *Explain water requirement and irrigation practices of vegetable crop*
- *Describe Manure and fertilizer requirements of vegetables*
- *Identify major diseases, insect pests and weeds of vegetables*

4.1. Field establishment and management

4.1.1. Field preparation

Soil is the source of plant nutrient, water for plant, anchor of plant roots. Crop productivity largely depends on the Physical and Chemical compositions of the soil.
Soil fertility: It is the status of the soil to supply nutrient elements in the required amount, form and proportion for maximum plant growth. It depends on the Physico-chemical properties and organic matter contents of the soil. Humus and other organic matters improve the hydro physical, chemical and biological properties of the soil and thereby increase soil fertility. Vegetable crops

are grown in a wide range of soils from Sandy loam to Clay loam. Heavy soils are not suitable because they cause splitting in onion and short and deformed roots in many tuber crops. The soils should be well drained and fertile with continuous supply of nutrients and moisture for vegetable crops cultivation. For vegetable production soil should be well prepared and having good tilth.

4.1.2. Time, method, depth, rate of sowing

Time of planting

No definite date can be given for planting vegetable seeds and plants, because climatic conditions vary widely within relatively small area, owing to differences in elevation, proximity to the large bodies of water, etc. The time of planting should be determined with reference to the soil and weather conditions to the kind of crop and to the time the produce is desired.

Vegetable crops may be grouped into three classes with respect to cold resistance:

1. Hardy, or those that will withstand hard frosts,
2. Half-hardy, or those that will withstand light frosts and the seeds of which will germinate at low temperatures,
3. Tender, or those unable to withstand any frost and the seeds of which will not germinate in cold soil.

When more than one planting is made of any crop, the second and the later plantings should be timed so as to have a continuous harvest for the period desired.

Methods of planting

Seeds can be sown by machines, known as drillers, or by hand. Of these two-methods hand sowing is commonly practiced in home gardens, as the expense of seed drilling in such gardens is not justifiable. In any case, the seeds should be distributed uniformly in the furrow and covered immediately to prevent loss of moisture from the soil.

Depth of planting seeds

No definite rules can be given regarding the depth to plant seeds of various kinds. The size of the seed, the kind of soil, and the amount of moisture in the soil should be considered. Larger seeds are planted deeper than small seeds, although it does not follow that the largest seeds should be planted the deepest. On light soils such as fine sand or sandy loams, seeds ate planted to a greater depth than on heavy soils. The more moisture there is present in the soil, the less need there is for deep planting.

Rate of planting

The possibility of successful vegetable growing is the result of the combination of practices from choosing and preparing the site to the last disposal of the product to the consumer.

The maintenance of optimum plant population and convenient plant arrangement is the consideration of a wise grower to get the desired type of crop in the desired quality at the right time and get a reasonable yield from the cultivated land.

Plant population and spacing, although their effect could be modified by many factors, are truly known to affect the yield per unit area, individual plant size and crop maturity. For most vegetables yield per unit area increases with population until a certain point, beyond which further population increases cause yield reductions. This is because the individual plant size decreases steadily as the population rises and thus at the point of maximum yield, plant size is only half that produced at the widest spacing (lowest population). When individual plant size maximized the yield per unit area is less than 50% of the optimum.

Different from this, some species show very little decrease in yield once their 'ceiling' level has been reached. This phenomenon is particularly true in the case of carrots, cauliflowers and onions and some growers use such effects to provide uniform sized vegetables to serve different purposes.

Population and spacing, besides their effects on size and yield can also influence the time to maturity. Vegetables as cauliflower, bulb onions, brussels sprouts, peas and French leans mature early than the conventional spacing, even promising the engagement of mechanical harvesting due to their uniformity.

Once the optimum population has been suggested then it is necessary to know how much planting material is required to cover a given known area of land. Different authors have suggested various types of formulae but the variation between the rate of planting arrived at is not much apart one from the other.

To calculate the amount of seed per unit length of row, the following formula can be used

$$\frac{\text{Average row spacing (cm)} \times \text{No. Plants required per m}^2 \times \text{No. seed/meter run}}{\text{Lab. germ(\%)} \times \text{Field Factor (Ff)}}$$

This formula, which is suggested by Fordham and Biggs (1986), however, does not apply for beet root because beet root has fruits not seeds which will develop into many plants. Therefore, the formula should be adjusted as follows:

$$\text{Kg/ha} = \frac{\text{No. plants required per m}^2 \times 1000}{\text{No. clusters per g} \times \text{No. plants per 100 cluster} \times \text{Ff}}$$

Note that it is necessary to know the number of fruits or clusters per gram by counting and the number of plants produced from 100 clusters from germination test. Not much different from this is the formula given by Hardy and Watson (1982).

$$\text{Seeds/metre run} = \frac{\text{Plants per metre run} \times 100}{\text{Lab. Germ.(\%)}\ \text{Ff}}$$

They also suggest that the number of plants per metre run could be obtained from the following formula:

Plants per metre run = No. plants/m^2 X Row width (mm)/1,000

The field factor used in the above formulae is to be decided by the grower based on his experience on how much of the plants are successful to establish. A field factor of 1.0 would mean afield germination equal to laboratory germination which would never be achieved in practice. At the other extreme a filed factor of 0.1 would suggest that only 10% of the laboratory germination would be achieved in the field. The working area of the scale is, however, between 0.8 for a very good seedbed condition and 0.5 for rather poor condition of tilth of temperature.

There is also another formula for use to calculate the amount of seed per ha of land, This is

$$\text{Seed (g)/ha} = \frac{\text{Plants needed per ha X Wt. of 1,000 seeds } (g)}{\text{Lab. Germ (\%) X (100 – RP) X 100}}$$

RP = reserve plants meant for calculated amount of plants to replace loses during transplanting and for re-transplanting (expressed in percent)

It is more-suggesting to use the last formula to quantify the amount of seed required to raise seedlings for covering a hectare of land by transplanting technique. Whereas, if direct sowing is to be practiced the formulae either by Fordham and Biggs(1986) or that of Hardy and Watson (1982) could be used to arrive at the amount (number of seeds) as well as the number of plants for a given length of row.

Among the points to be taken into account in regard to the quantity of seed to plant are:

1. The viability of the seed,
2. The time of planting,
3. The condition of the soil,
4. The size and the vigour of the young plants, and
5. The possible ravages of insects.

Seeds known to be of low viability should be planted more thickly that those having high percentage of germination. Seeds planted when the soil and weather conditions are unfavorable to quick germination should be planted at a heavier rate than when the conditions are favorable. The longer the time required for germination of any given kind of seed the heavier should be the rate of planting. Seeds that produce delicate weak plants, such as carrots and parsnips should be planted quite thickly to ensure a good stand so that any excess of plants may be removed by thinning to prevent crowding. In cases where insects are major problem for vegetables unless large numbers are started, the chances are against saving enough for good stand of strong plants.

4.2. Cultivation

Cultivation is a long-established practice and its benefits are well known by everyone. Cultivation also known as hoeing consists in moving the surface layer of the soil without turning it. Cultivation is an important cultural operation to vegetable crops for the following reasons:

1. Cultivation results in the destruction of weeds thereby conserving moisture and nutrients and eliminating competitions for light and air. Cultivation in general increases yields of crop

plants which due mainly to weed control, although the formation and maintenance of soil mulch by cultivation may be important factors under some conditions. In fact, mostly weed control is considered as the prime importance of cultivation.

2. It conserves moisture by the formation and maintenance of soil mulch. This benefit of cultivation is attributed to the decrease or the cessation of the capillary flow which in turn slows up the movement, of moisture to the soil surface since the moisture would then move by diffusion.
3. The effect of cultivation on conserving moisture favoring better aeration, and raising the temperature of the soil favors nitrification and aids other chemical changes in the soil. One cause increasing nitrification through cultivation is as result of improving the soil conditions for nitrification as by increasing aeration or providing better moisture or better temperature conditions for the growth of nitrifying bacteria.
4. Increasing the absorption and retention of heat. Absorption and retention of more heat by cultivated soils is probably due to the fact that by loosening the soil surface moisture, loss is minimized so that the heat energy required to evaporate the water, thus heat is preserved. However, this effect is more significant for sub soil than for top soil.

The aforementioned benefits from cultivation could only be obtained through and proper depth of cultivation of cropping fields with appropriate tools meant for the operation. Where possible, cultivation should be given as often as necessary to prevent weeds from injuring crop plants and the soil from forming a crust. Hoeing can also be carried out when a crust forms on the soil surface encouraging the loss of soil moisture through capillarity and evaporation. However, when cultivation is primarily meant for controlling weeds, it is recommendable that the operation be carried out at the time most favorable for killing the weeds without affecting the crop plants. This is accomplished most easily before the weeds have become established, and it is important to kill them before they have competed seriously with the crop plants for moisture and nutrients. The best time to cultivate is just as the weeds are breaking through the soil surface because at this time the roots are small and do not have much hold on the soil.

In vegetable gardens by cultivating deeper one can disk damaging the roots of the crops. Therefore, cultivation is preferable to deep cultivation vegetable crops under most conditions, especially after the roots have grown to any considerable extent. This is because while all the benefits of cultivation could be obtained by shallow cultivation deep cultivation could destroy many roots and prevent the plants from getting the full benefits of the surface soil.

Cultivation of vegetable fields could have done with hand hoe. For larger area, however, a wheel hoe is convenient; when dealing with mechanized farms a motor hoe or tractor mounted hoes are used.

4.3. Mulching

Mulching is one of the simplest and most beneficial practices used in the garden. Mulch is simply a protective layer of a material that is spread on top of the soil. Mulches can either be organic--

such as grass clippings, straw, bark chips, and similar materials--or inorganic--such as stones, brick chips, and plastic. Both organic and inorganic mulches have **numerous benefits**:

- ♠ Protects the soil from erosion
- ♠ Reduces compaction from the impact of heavy rains
- ♠ Conserves moisture, reducing the need for frequent watering
- ♠ Maintains a more even soil temperature
- ♠ Prevents weed growth
- ♠ Keeps fruits and vegetables clean
- ♠ Keeps feet clean, allowing access to garden even when damp
- ♠ Organic mulches also improve the condition of the soil. As these mulches slowly decompose, they provide organic matter which helps keep the soil loose. This improves root growth, increases the infiltration of water, and also improves the water-holding capacity of the soil. Organic matter is a source of plant nutrients and provides an ideal environment for earthworms and other beneficial soil organisms.

Time and Rate of Mulch application

When applying mulch, a two inches (5cm) layer is the commonly suggested thickness for it to be effective. It is best to apply mulch once seedlings have started to grow, and a proper weeding has been done. Always water the garden before applying mulch. Ensure that mulch is not built up onto the stem of the plant. They should have a breathing space of about one inch from the stem.

Time of application depends on what you hope to achieve by mulching. Mulches, by providing an insulating barrier between the soil and the air, moderate the soil temperature. This means that a mulched soil in the summer will be cooler than an adjacent un-mulched soil; while in the winter, the mulched soil may not freeze as deeply. However, since mulch acts as an insulating layer, mulched soils tend to warm up more slowly in the spring and cool down more slowly in the fall than un mulched soils.

4.3. Earthing up

It is heaping of earth (soil) around the base of plants, which gives them more resistance against wind and stimulates the growth of new roots, in turn, extra plant growth. In some plants like asparagus and leek earthing up is done with the object of blanching a certain part of the plant and thus improving its eating quality and commercial value. In the case of potatoes this operation supplements the planting depth, favours root development, inhibits the greening of tubers and protects them from the attacks of mildew and tuber moth.

Whatever the reason for the operation one must be careful to carry it out progressively according to the growth of the plants and after having tested its effect on a few of them.

Unless the earthing up is performed correctly crop losses could be encountered for several reasons. These are:

1. Damage to the root system
2. Working the soil too deeply
3. Injuries to the plant or

4. Development of diseases on the stems of plants.

Top dressing with the recommended rate of fertilizers should be applied before earthing up. The work may be carried out by hand hoe, or on sandy soils, even by rake. On larger areas, the ridging plough is usually employed.

4.5. Staking

There are some crop species that, for various reasons, require staking. If plants are fragile or if they are climbers, stakes can be placed in the ground to support them. Many tomato varieties need staking to produce high quality fruits and to avoid the rotting of fruits in contact with the soil. Climbers such as many of the beans, Ceylon, spinach and bitter gourd develop better when supported and this also makes harvesting easier.

In short, for certain crops, staking allows better aeration, reduces attacks of fungus diseases and exposure of the foliage to light, thus making for better photosynthesis. The shape and the size of the stake vary according to the plants cultivated. One method of staking often used for legumes and tomatoes is by the use of groups of two or three stakes of wood tied together at the top and connected with other groups by a light horizontal cane. An alternative means of support is an iron wire stretched horizontally at a suitable height, from which strings are suspended. The stems of the beans or tomatoes are twisted carefully around the strings.

Another system is the construction of shelf of twigs or bamboo about 20 cm above the soil surface. The crop foliage is spread along the shelf as it develops. For some cucurbitaceae and for Ceylon spinach, however, a firm construction can be made, about 1 to 1.5m high, resembling table. For some crops individual plants must be tied to a stake, but loosely, to allow room for the stern to grow thicker. In all cases the erection of stakes and support is best carried out before sowing or field transplanting of seedlings to avoid damage to the young plants.

4.6. Irrigation

Water is an essential environmental factor which should be controlled by drainage, storage, diversion, and irrigation. The wise use of water is obligatory for all farmers, as growing plants have a high demand for water. An optimum supply of soil water is essential for maximum root development. Well-developed roots in turn absorb optimal quantities of water and nutrients, producing healthy top growth and higher yields. Excess water, on the other hand, causes unhealthy roots due to poor soil aeration.

Some of the important functions of water in plants are given below.

- It is a normal constituent of all plant tissues.
- The rate of formation of carbohydrates and organic nitrogenous compounds is directly proportionate to the amount of water in plant tissues.
- Water must be present in the soil to encourage fixation and as a medium of transport for nutrient minerals.
- Water has a moderating effect on temperature.

- ♣ It keeps the plant cell turgid, which is essential for normal growth and cell division.
- ♣ Enzyme activity is adversely affected by a deficiency of water.

Methods of irrigation

With vegetable crops, appropriate irrigation practices vary for different species and from area to area, depending on agro-climatic conditions. Vegetable crops are irrigated through surface, subsurface, and spray systems, which are explained in the following paragraphs.

i. **Surface irrigation**: Surface irrigation is the application of water directly to the soil surface. This system is used on deep, compact, and uniformly-textured soils with a gentle slope. Surface irrigation is given to vegetable crops through the border and furrow systems. In the border system, after land leveling, borders 15-25 cm high are made around the field, which may be divided into sub-blocks for separate irrigation. In the furrow system, the land is thoroughly levelled and 15-20 cm deep furrows are made between the rows. This method is commonly used with vegetables grown in rows in the arid and semi-arid regions. Although surface irrigation is easy to do, it results in uneven water distribution and wastage of water through leaching on open and porous soils. It cannot be used efficiently on uneven or unleveled soils. Puddling and baking of the soil also occur with this method of irrigation. Making sub blocks in the field increases the cost of labor.

ii. **Sub-surface irrigation:** Water is applied under the soil surface in the root zone of the plants through emitters. It is continuously available; loss of water is minimized; there is no loss of water from the soil surface; and more soil can be utilized for vegetable raising. On the other hand, it is very costly and difficult to install and operate. It is not useful in porous soils or in those which have hardpan.

iii. **Spray irrigation (sprinkler)**: Spray irrigation is giving water to crops in the form of a spray similar to gentle rain. Irrigation by this method can be used for vegetable growing on all types of soils, and on both leveled and rolling land.

iv. **Drip or trickle irrigation**: Sprinkler irrigation wets a large land surface, whereas drip or trickle irrigation only wets a specific area surrounding the plant. The rate of application is so slow that little or no flow of water occurs on the surface. The system discharges the water onto the ground through one or more emitters adjacent to each plant (vegetables), which are usually connected to a narrow lateral plastic line that extends parallel to the tree row.

It may either be buried slightly between trees or lie on the surface. Since in this system there are a limited number of emitters, a large root area cannot be wetted. Frequent irrigations are needed, each of limited volume to avoid over-wetting the soil. Irrigation is generally done daily or every other day depending upon the needs of the tree. Though there are several advantages of drip irrigation, namely water savings, restriction of weed growth to wetted areas, utilization of problem soils, and saving in labor, there are also many disadvantages. It is very costly to install; the continuity of the flow of water through the emitters is unreliable; and salts accumulate around the root zones of the plants. As the root area becomes restricted to the wetted region only, problems of weak tree anchorage and unsatisfactory yield may arise because of the small root zone and small root volume. Therefore, drip irrigation must be tested under specific field conditions before its installation on a large scale in any region of the country is recommended.

4.7. Fertilization

4.7.1. Organic fertilizers

The maintenance of soil fertility is of prime importance in commercial agriculture. The organic matter present in the soil is originally derived almost entirely from green plants grown on the soil. When crop plants are grown, a portion or all of the plant can be returned to the soil, replenishing its organic matter. After a crop is harvested the roots decay in the soil adding organic matter. When the entire plant is returned to the soil, the process is called green manuring. Plant material after passing through animals may be returned to the soil as farmyard manure. The organic matter then decomposes and in turn supplies the soil with minerals important for its fertility.

The rate of decomposition of organic matter is generally affected by soil temperature, humidity, and aeration conditions. That is why at the same temperature clayey soils have more organic matter than sandy soils or sandy loams. There is usually more organic matter in the soils of the temperate zone than of the tropical and subtropical regions. The decomposed products of organic matter give soils their dark brown and black color. The product which gives soil a black color is called humus.

4.7.2. Chemical fertilizers

The rapid increase in human population and depletion of natural resources of cultivated lands has prompted the use of chemical fertilizer to replenish the soils and to increase crop yields per unit area. These chemical fertilizers supply the same essential elements as organic matter, but unlike organic manures, with chemical fertilizers the supply of nutrients to the crop is **immediate** and **effects are observed soon after application**. NPK is generally applied artificially in the form of fertilizer, nitrogenous fertilizers being the most frequently used.

4.8. Crop rotation and intercropping

Vegetable crop production is relatively intense and continuous which is by necessity on small farms where all the available space is usually cultivated to maximize yields. The objectives of crop rotation are to maintain and, as far as possible, to improve soil fertility. Fertility in this context includes soil nutrients and soil physical structure.

This objective may be achieved by:

- Including a legume crop in the rotation sequence;
- Ploughing or digging crop residues into the soil;
- Sowing a fodder crop the remains of which are incorporated in the soil;
- Sowing a grazing crop which will be grazed *in situ* thus providing both a break from vegetables and also the advantage of additional organic material from the livestock and subsequent turning in of the crop remains; and
- Growing a sequence of unrelated vegetable species using different soil horizons (i.e. crops with shallow or deep root systems).

Other advantages of growing crops in rotation are:

- To reduce infestation of soil borne pests and pathogens (e.g. nematodes, *Verticillium* and *Fusarium* wilts) by growing a sequence of unrelated crops with no common soil borne pests or pathogens. Other advantages can be obtained by following vegetables by so called 'trap crops' such as groundnut. A 'non host' crop such as *Tagetes* spp. is reputed to be a non-host of *Meloidogyne spp*. and is used as a break between susceptible crop species; and

- For farm management, by organizing a satisfactory work schedule through all the consecutive growing seasons and making optimum use of available land, man power and other available facilities.

Advantage of intercropping

- ✓ Satisfactory competition with weeds.
- ✓ Making a more uniform and even labor input pattern over the cropping periods.
- ✓ An insurance of food supply – it has long been believed that intercropping provides an assurance over failure of a single crop, in the sense that if one crop fails as a result of pests, pathogens or adverse weather, the companion crop or crops will provide a food supply.
- ✓ The potential for a higher cash return per unit area – researchers in Africa during the 1950s and 1960s generally found that appropriate intercropping gave higher cash return per unit area than growing the two crops in separate plots. Later work in Nigeria (IITA, 1974, 1975) and in India (ICRISAT, 1974) demonstrated that maize with soybeans and also mung bean, sweet potato, or groundnut with irrigation yielded a 30–50% increase compared with pure stands of each crop. It is important to bear in mind that the optimum population of each species is less than the population density would be in a single species stand.

4.9. Protection of Vegetable crops

4.9.1. Control of diseases and insect pests

Understanding crop protection measures for the important diseases and insect pests is essential for successful vegetable production because of the increased ravages from such agents. Insect pests and plant diseases cause losses to the vegetable grower in quality and quantity terms. This increase the cost of production due to the incurring costs of controlling the diseases and insect pests. This is due to the fact that it is impossible to produce satisfactory crops of certain vegetables in many areas without measures being taken to control diseases or insect pests or both.

Diseases and insect pests are so serious that, oftentimes, without the application of chemicals little or no harvest is achieved in some crops. For instance, growing of tomatoes in the rainy season is not profitable due to serious attack from blight.

As in the case of damage by insect and other pests, the development of diseases in a growing crop may result in both lower yields and reduced quality. Viruses, bacteria and fungi can all cause serious crop losses although the later group are more diverse and represent the most serious threat to vegetable production.

4.9.2. Weed control

Weed is a plant growing where it is not wanted. Plants are classified as weeds because they compete for moisture, soil nutrients, and light and may additionally harbor insects carrying viruses or disease. It is quite possible for a plant to be considered a weed in one situation but a desirable plant in another. Certain plants such as pig weed are essentially always weeds, but others such as Bermuda grass, which is a very undesirable weed in a vegetable field, can be classified as a turf and pasture crops.

Chapter Five

Principles and practices of post-harvest handling and value addition

Chapter learning objectives
At the end of this chapter students are expected to:

- Define harvesting and Post-harvest handling
- Give details on maturity and maturity determination
- Discuss the techniques of harvesting

5.1. Introduction

The quality and condition of produce sent to market and its subsequent selling price are directly affected by the care taken during harvesting and field handling. Whatever the scale of operations or the resources of labour and equipment available, the planning and carrying out of harvesting operations must observe basic principles.

Small-scale producers have the option to **harvest earlier**, when vegetables are more delicate and valuable; **harvest later**, when fruits are at a riper, more flavorful stage; **or harvest more often** (taking advantage of multiple harvests to gather produce at its optimum stage of maturity). All these options can lead to higher profits due to the higher value of the produce you have to offer for sale.

One of the most common mistakes growers make is to harvest fruit crops **too early**, when they are under-ripe and have not yet developed their **full flavor**. Some vegetables, if allowed to grow large, will be too **fibrous or full of seeds** for good eating quality. With many horticultural crops, if you harvest all at once you are sure to have many items that are either under-mature or over-mature. Using a maturity index as a standard will greatly reduce pre-sorting losses. For some crops this involves using a refractometer to measure sugars or a penetrometer to measure firmness.

Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiratory and ethylene production rates leading to quick deterioration. In general, harvesting by machine will cause more damage than harvesting by hand, although some root crops can be severely damaged by careless hand digging. The containers used by pickers in the field should be clean, have smooth inside surfaces and be free of rough edges. Stackable plastic crates, while initially expensive, are durable, reusable and easily cleaned.

Post-harvest losses in fruits and vegetables are very high (20-40%). About 10-15% fresh fruits and vegetables shrivel and decay, lowering their market value and consumer acceptability. Minimizing these losses can increase their supply without bringing additional land under cultivation. Improper handling and storage cause physical damage due to tissue breakdown. Mechanical losses include bruising, cracking, cuts, microbial spoilage by fungi and bacteria, whereas physiological losses include changes in respiration, transpiration, pigments, organic acids and flavour.

5.2. Definition of harvesting

Activity 5.1. What is harvesting?

Harvesting is the harvest is the process of gathering mature crops from the fields or it is the process of detaching a produce from the mother plant at the proper stage of maturity, by an appropriate technique, as rapidly as possible, with minimum damage or loss imparted to the commodity and at relatively low cost.

- ***When we harvest wheat or teff, little harm is done***
- ***While in vegetables, fruits and ornamentals the damage is painful***
- ***In human terms it is "murder" (Ramswamy, 2005)***
- ***So harvesting marks the beginning of deterioration process!***

The harvest marks the end of the growing season, or the growing cycle for a particular crop and the commencement of market preparation or conditioning for fresh products. Harvesting in general usage includes an immediate post-harvest handling, all of the actions taken immediately after removing the crop-cooling, sorting, cleaning, packing-up to the point of further on farm processing, or shipping to the wholesale or consumer market.

Harvest timing is a critical decision that balances the likely weather conditions with the degree of crop maturity. Weather conditions such as frost, rain (resulting in a "wet harvest"), and unseasonably warm or cold periods can affect yield and quality. An earlier harvest date may avoid damaging conditions, but result in poorer yield and quality. Delaying harvest may result in a better harvest, but increases the risk of weather problems. Timing of the harvest often amounts to a significant gamble.

Harvesting can be performed by hand or mechanically. However, for some crops e.g. onions, potatoes, carrots and others-it is possible to use a combination of both systems. In such cases, the mechanical loosening of soil facilitates hand harvesting. The choice of one or other harvest system depends on the type of crop, destination and acreage to be harvested. Fruits and vegetables for the fresh market are hand harvested while vegetables for processing or other crops grown on a large scale are mainly harvested mechanically.

Harvesting at the proper stage of maturity, the method of harvesting, and the handling operations are crucial aspects which determine the shelf life and quality of produce. In Ethiopia, harvesting of vegetables is generally done by hand, by people who are not aware of the principles upon which the best harvesting dates should be determined. This factor adds to post-harvest losses. Prediction of correct harvesting dates may depend upon the number of days from flowering, temperature-time values called' heat units, physiological criteria like pressure testing of fruit, ground color of the fruit peel, or percent total soluble solids (TSS) of the pulp juice.

5.3. Maturity and maturity determination

Activity 5.2. When is fresh produce to harvest?

A critical time for growers of fruit and vegetables is the period of decision on **when to harvest** a crop. Normally any type of fresh produce is ready for harvest when it **has developed to the ideal condition for consumption**. This condition is usually referred to as **harvest maturity**. Confusion may arise because of the word maturity since, in the botanical sense, this refers to the time when the plant has completed its active growth (vegetative growth) and arrived at the stage of flowering and seed production (physiological maturity). Harvest maturity thus refers to the time when the "crop" is ready to harvest and must take into account the time required to reach market and how it will be managed en route. This time lag usually means that it is harvested earlier than its ideal maturity.

Activity 5.3. What is maturity? Do you think all horticultural crops have the same maturity period?

Maturation is the stage of development where the plant is capable of shifting from vegetative to reproductive growth. Matured when it meets the requirements for harvest which vary with the plant produce involved. Within a given crop, optimum maturity is highly subjective determination varying with whom in the production-storage-marketing-utilization chain. Optimum harvest maturity for the grower is a function of both product and marketing conditions. With most crops optimum maturity is determined by specific physical or chemical characters of the plants or plant parts to be harvested.

Physiological maturity: is a stage or point in the development of an organ (e.g. fruit, leaf) or organism (e.g. ornamental plant) when maximum growth has been achieved and the organ organism as matured to the extent that the next development stages can be completed.

Horticultural maturity or **Commercial maturity:** is the timing of the harvest to meet a particular market requirements or the characteristic state of a plant organ required by a market. It commonly bears little relation to physiological maturity and may occur at any stage during development, maturation, ripening or senescence. The terms immaturity, optimum maturity and over-maturity can be related to the market requirements. At optimum consumer quality, or able to achieve optimum consumer quality.

Determination of maturity

Activity 54. How is harvest maturity identified?

Commercial maturity indices generally involve some expression of the stage of development (growth, maturation and ripening) and usually require determination of some characteristic known to change as the plant material develops. They may involve taking decisions about levels of market and consumer acceptability, and generally necessitate making objective measurements, subjective judgments or both. The time of harvest is often judged by growers based on their experience with their own crops in terms of calendar date, and various subjective judgments in relation to market requirements. Cut rose are a good example. Many criteria for judging maturity are based on a variety of characteristics, including: time from flowering or planting (calendar date); accumulated heat units; size and shape; skin or flesh colour; light transmittance or reflectance; flesh firmness; electrical conductance or resistance; chemical composition (e.g. starch, sugar, acid); respiratory behavior and ethylene production; and time to ripen.

Most growers decide when to harvest by looking and sampling.

Judgments are based on:

- **Sight**-colour, size and shape
- **Touch**-texture, hardness or softness
- **Smell**-odour or aroma
- **Taste**-sweetness, sourness, bitterness
- **Resonance**-sound when tapped.

Experience is the best guide for this kind of assessment. Newcomers to fresh produce-growing may find that learning takes time. Harvest maturity can readily be observed in some crops: bulb onions when their green tops collapse and potatoes when the green tops die off. Other crops can be more difficult: avocados remain unripe off the tree after maturity.

Some maturity Indices of fruits and vegetables

Onions/Garlic (Size, Drying and collapse of the "neck", drying of leaf scales)

Potatoes (Death of the plant, Size of tubers, Starch content; specific gravity, Periderm development

Asparagus (Size, Apex closed)

Broccoli/Cauliflower (Size, Florets closed)

Lettuce, head (Size, Firmness, solidity, Flavor-sweetness, bitterness)

Lettuce, Romaine (Size, Number of leaves)

Beans (Size, Seed development

Summer Squash & Cucumber (Size, External color)

Peppers (Size, Color, Firmness, Seed development)

Tomato (External and Internal color, Development of locules (jelly), Firmness, Size, Development of cuticle)

5.4. Postharvest handling

Postharvest handling is the stage of crop production immediately following harvest, including cooling, cleaning, sorting and packing. The instant a crop is removed from the ground, or separated from its parent plant, it begins to deteriorate. Post-harvest treatment largely determines final quality, whether a crop is sold for fresh consumption, or used as an ingredient in a processed food product.

The most important goals of post-harvest handling are keeping the product cool, to avoid moisture loss and slow down undesirable chemical changes, and avoiding physical damage such as bruising, to delay spoilage. Sanitation is also an important factor, to reduce the possibility of pathogens that could be carried by fresh produce, for example, as residue from contaminated washing water. After the field, post-harvest processing is usually continued in a packing house.

5.5. Processing and Value Addition

In Ethiopia, current economic intensification and changes in dietetic patterns have made both the production and consumption of fruit and vegetables progressively more important. The fruit and vegetable sector has a fundamental role in farm revenue improvement, poverty mitigation, food security, and sustainable agriculture.

This sector, however, suffers greatly from postharvest losses. Some estimates suggest that about 30–40% of fruit and vegetables are lost or dumped after leaving the farm gate. Huge postharvest losses result in diminished returns for producers. International markets discard fruits and vegetables containing illegal pesticides, with pesticide residues beyond permissible limits, and with inadequate labeling and packaging (FAO, 2006).

Value addition is a process of increasing the economic value and consumer appeal of a commodity. It is a production/ marketing strategy driven by customer needs and preferences. Produce is changed from its original form to a more desirable form e.g. apple pie, jams, jellies and pickles etc. The primary reason for processing fruits and vegetables is to extend the shelf life beyond the period when there is plenty into the bend or away of season period. For instance, when a scrupulous produce comes in season, there may be a loads of it, and if the excess is not conserved it will decay and go to waste. Usually when there is excess, supply outweighs demand and product fetches less money. Value is added to the particular produce item: when the product is still available. when the season is out and the demand for the product outweighs the supply accessible Produce is packaged to make it easier to prepare and serve, for example: Chopping and packaging green beans and peas. Freezing/cooling fruits and vegetables as in salads. Steam/cook in bag. Vegetables produce is processed in such a way that is becomes easier to incorporate into other foods, like sauces; it is processed in such a way that the predominant component (s) desired by the consumer is captured, as in fruit and vegetable juices.

Too much of the food harvest is lost to spoilage and infestations on its journey to the consumer. In countries like Pakistan, where tropical to subtropical weather and poorly developed infrastructure contribute to the problem, losses are sometimes of staggering proportions (Abdullah, 2010). Losses occur in all operations from harvesting through handling, from harvest to consumption would reduce losses and increase profitability margins of the produce. Proper evaluation of post-harvest technologies includes technical, economic and social components and is being increasingly focused in agricultural research.

Ways to Add Value to Food: Considerable volumes of unmarketable and physically damaged fruits and vegetables that are without infection can be converted into value added products by processing. By products of fruit and vegetable processing could also be gainfully utilized. In the past, the consumer's preferences were limited to taste and flavour only, after 50's the priorities changed into safe nutritious foods. In 21st century considerable emphasis has been placed on functional, nutraceutical food products and these products gain popularity among the consumers.

Previously, fruits and vegetables were processed primarily into jams, jellies, chutneys, etc. Canning and dehydration were considered to be the most sophisticated methods of processing, prior to the discovery of rapid freezing (Abdullah, 2010). Cold storage has considered the only method suited to extending the shelf life of fruits and vegetables, until the development of modified and controlled atmosphere storage. Relatively little emphasis was placed on the handling of fresh fruits and vegetables.

Chapter six
Production technology of fruity vegetables
(Tomato, Pepper and Eggplant)

Tomato, pepper and Eggplant belonging to the large Solanaceae family (nightshade family) which contains ~3,000 species distributed in some 90 genera. Out of these *Solanum* L. is the largest one, with around 1,500 species including globally important crops such as potato (*Solanum tuberosum* L.) and tomato (*Solanum lycopersicum* L.), as well as many other minor crops. Most *Solanum* genus have a basic chromosome number of $n = 12$.

6.1. Tomato (*Lycopersicon esculentum* Mill) / (*Solanum lycopersicum* L.)

Origin, Taxonomy and Botany

- Originated in Peru, Ecuador or Bolivia (South America)
- Belongs to the family: - *Solanaceae* (night shade family), Genus: - *lycopersicon, and* species*: esculentum and pimpinellifolium. The* two species are edible and grown throughout the world.
- Chromosome number 2n=24

Use and Composition

- Second in importance to potato in many countries
- It is regard as one of the most "protective food". Because of its special nutritional value and widespread production.
- It tops the lists of canned vegetables
- A very good source of income
- Tomatoes are important source of minerals, vitamin C, sugar, lycopene, organic acids and protein etc
- Ripe tomato fruit is consumed fresh (salads), in cooked form and processed products (ketchup, sauce, juice, paste and whole peel-tomatoes)

- Recently the crop has expanded to commercial production for home use, export and processing industries. Small-scale farmer produces the bulk of fresh market tomatoes. Processing types are mainly produced in large-scale farms.
- It is an important cash-generating crop to small-scale farmers and provides employment in the production and processing industries.

Botany: The tomato cultivars currently produced in Ethiopia vary in growth habit such as determinate (0.9 - 1.2 m), semi-determinate and indeterminate (2.1 -4.5 m)

1.The indeterminate types are:

- High in stature (of height)
- Produce fruits for extended period
- Need plant support and produce high fruit yield

2. The Determinate types (cultivars) are:

Bush like, compact and fruit mature in a relatively short time as compared to determinate ones. It is favorable for concentrated fruits production for early market and for processing industries. The genotypes also differ in several aspects such as**:** stem strength, leaf type, foliage coverage, fruit set, plant size, response to various stress depending on the cultivars (Marglobe or cherry) or growing conditions about 3-8 fruits are produced per cluster.

Tomato varies in visible fruit characteristics important for fresh market and Processing Values; these include shape, size, color, flesh thickness, number of locules, blossom end shape and fruit quality (TSS%, pH, acidity, juice viscosity. juice volume, flavor, nutritive values, etc.).

The fruits may be globe-shaped (Marglobe), oval or flattened (Marmande) and Pear shaped (Roma VF) which differ in acceptability in the local market, quality, and storability. Red skin tomatoes are the most preferred in local markets. High TSS % (4.5 - 6.0) is responsible for high yield of processed products. Intensive red colors of skin and flesh, low acid content are some of the attributes favored by processing industries. The sugar and acid ratio has important contribution to the flavor of tomatoes. The content of glucose, fructose, citric acid and their inter relationships influence the taste and aroma of fruits.

There are special fruit characters that the local market demands from tomatoes. The most reorganized ones are: fresh market types, round, large, free from defects, good flavor, and attractive red colored fruits. Fruit should also be firm, healthy, evenly colored, good appearance and good keeping quality and high vitamins content. The tomato fruit currently produced differ in size from small cherry types (20g) to extra-large of beefsteak (180 g). The fruits that are commonly available in the markets can be categorized as small (less than 50g), medium (70-100g), big (100 -170) and Very big (>170g) sized. The small ones are tolerant to environmental hazards than large ones. The two extremes have low acceptance in the market.

Cultivars for processing should be: firm with thick wall, high retaining capacity, high processing quality i.e. high TSS (4.5-6.0), pH >4.5, intensive red color of both skin and flesh, better tolerant to diseases and physical damages, and high yielding. Fruit quality, especially TSS% is negatively related to fruit yield. Therefore, high solid cultivars are little value unless they have high yield potential**.** Currently, the demand for fresh market tomatoes is changing to the processing cultivars (Pear or cylindrical) because of their thick flesh and ease of transportation, Storability and fitness for multipurpose use.

Climatic Requirements

Though tomato is produce in different regions currently exact agro-ecological information is not sufficiently available to locate production belts. Altitudes between 700 and 2000 m.a.s.l. which characterized warm and dry day and cooler night are favorable for optimum growth and development.

A temperature range between 21^0 c and 27^0 c night temperature favorable for plant development and fruit Set. The cultivars that are currently in production failed to set fruits when the day and night temperatures were above 32 ^{0}c and 21^0c respectively.

Soils: A well-drained, friable sandy loam soil with pH of 6-7 is preferable for early and high fruit yield

Rainfall; Tomato is produced mainly under irrigation. Production under rainy season needs intensive management.

Plant establishment

Tomato may be produced either by direct sowing of the seed in the field or transplanted from seed bed

Transplanting has the merit of: economic use of seeds, 300 /ha instead of 400g/ha, selecting superior and vigorous seedling, easiness for field establishment and early harvest

Nursery Management

To produce vigorous and healthy seedlings close attention must be given to the seedbed.

- Seedbed should be sited in a location where frequent visit can be carried out.
- Seedbed should be away from obstructions affecting the availability of light and close to water source
- Preference should be given to well drained sandy loam soils
- The beds should not be on field previously used to produce related crops
- Seedbeds should be rotated with non-related species
- Seedbed be protected from strong winds

Seedbed preparation and seed sowing

1. **Flat seedbed** - Prepared where the land level with adequate drainage system
2. **Raised bed** - Used in rainy season / when water logged soil conditions expected

3. **Sunken bed**- For areas with a prolonged dry season and help to conserve and economize water.

The nursery field should be carefully, tilled; Roots, /stones, Clods should be removed; Seedbed should be easy for Cultivation, irrigation and hardening off operations. A suitable basic design for a seedbed should be 1m x 5 or 10m and 40 cm between beds to allow a person to work half the seedbed from each side.

- About 250 - 300 g seed with over 90% germination potential is required for one ha.
- About 15 beds (3000 seedlings /bed) of 300 m^2 are needed to produce seedling for 1ha
- Seed should be mixed with equal ratio (1:1) of sand or soil to facilitate even distribution of seed.
- It is sown in the row at 15cm row apart at the depth of about 0.5 - 1 cm covered with fine soil, and lightly firmed.
- The whole bed is mulched with grass/straw to protect seeds from washing a way during watering and removed after the seedlings have emerged.
- The seedling are then thinned at 3-5 cm spacing at the first true leaf stage and
- Proper management (weeding, watering) practice are followed to produce health and vigorous seedlings

Fertilizer

Experience at Malkasa showed that amount of fertilizer applied on seedbed on sandy loam soil, 200g DAP at seeding and 100g urea at thinning (at first true leaf stage) could be applied to enhance growth. Incorporating well decomposed manure is also good practice.

Irrigation

The soil should be kept moist, but not wet. Keeping the surface wet/ over watering is favorable for damping-off diseases. Watering is preferred in the morning or late in the afternoon.

Seedling Protection

- Damping-off is the most common seedbed diseases
- The causal agent is *Pythium Spp, Phytophtora Spp* that are soil born fungi are common in tomato production field.
- At pre- emergence, the disease decays germinating seed before it pushes through the soil and cause poor seedling stand.
- At post emergence, affected seedling shrivels and the entire plant will be lost
- Excess amount of moisture, dense seedlings, excess amount of nitrogen, carelessly handling of plants, and the presence of weeds favor damping off disease.
- Control measure: use 0.1kg Thiram at the rate of 50kg of seed.

Hardening Seedlings

Seedlings need to be hardened before transplanting to the field to enable them with stands the field conditions. This should be done by reducing frequency of watering and allowing the soil to low moisture status when it is ready for field planting. With holding the irrigation water for 2-3 days before uprooting the seedlings from seedbed facilitates the removal of transplants.

Transplanting Seedlings

- Health, Vigorous, stocky and succulent seedlings should be selected for transplanting.
- Seedlings will be ready for transplanting 28 -35 days after sowing at 2 -3 true leaf stages or at 12 -15 cm height for field transplanting.
- Too young seedlings resulted in stunted growth
- Too tall and leggy will be poor in field establishment
- Prior to transplanting, Pruning/ trimming roots or leaves or both parts facilitate good establishment
- At transplanting, hole should be made with dibbles enough to accommodate roots.
- Seedlings should be placed in the holes about the same depth as they were in the seedbed.
- The soil is pressed around the plant by hand or foot to prevent air pockets near the roots and protect the plant from dry
- Transplanting is better done during late in the afternoon or in the morning to reduce the risk of poor establishment
- Missing plants should be replaced with in seven days after transplanting
- Seedlings have to be protected with shade or wet straw from sun and dry wind till they are established

Field Operation

- Good Ploughing, disking, leveling and cultivation are important for better field and crop management.
- Early and timely ploughing is helpful to expose the soil to reduce diseases and insect pests
- Proper leveling contributes for even distribution of water. Tomato should be grown on the same field once every 3-4 years to reduce disease build-up.

Sowing / Planting date, Choice of Variety

Rain free, clean dry warm conditions and moderately uniform temperatures are favorable for high fruit set, clean fruits, less disease incidence and for high quality fruit production. Merti Agro-industry and similar locations were planting tomato from September to April. Werer area adopt June to July planting. At Jimma high marketable fruit yield of 1.2 to 1.5t/ha was produced from April to July sowings. The lowest yield was obtained in January to March sowings (0.3 to 1t/ha). At Bako, August to January sowing dates gave high marketable (17.3 to 28.1 t/ha); while February to July sowings gave low marketable (1.3 to 5.3 t/ha).

Spacing and Population

The distance between plants and rows depends on the methods and purpose of production, soil fertility, plant structure vine types and farm equipment.

Row spacing	Plant spacing	Population
80 cm	30 cm	41,625
100 cm	10 cm	100,000
120 cm	30 cm	27,639

Crop spacing of 100 to 120 cm between rows and 10 to 30 cm between seedlings (42,000 to 100,000/ha) could be used. In processing tomatoes, where total yield per unit area is more important than fruit size and appearances, high plant population is common practice in commercial production.

Varieties released in Ethiopia

Table Average seed yield and some other characters of Tomato variety

Variety	Year of release	Area of adaptation		Maturity days	Yield (Qt/ha)	
		Altitude (m)	Rainfall(mm)		research	Farmers
Marglobe	1976	700-1800	Irrigated	100-110	320	120-170
Melka shoal	1998	700-1800	" "	100-120	430	140-180
Melka salsa	1998	700-1800	" "	100-110	450	130-170
Roma VF	1977	700-1800	" "	95-100	400	120-140
Napoli VF	1977	" "	" "	100-110	370	120-140
Money Maker	1980	" "	" "	110-120	300	110-130
Heinz-1350	1978	" "	" "	75-90	350	110-140
Person A-1	1985	" "	" "	100-120	325	120-160

Source: Melkassa Agricultural research center

Direct Seeding: 100 cm between rows, 1-4 plants/ hole between 10, 20, 30 and 40 cm seedlings (25000 to 40000 plants/ha).

Staking and Pruning

Staking has the merit of protecting fruits from soil contact; ease of fruit harvest, chemical application, less disease incidence, early yield, and clean fruit, extended harvest and less fruit and crop damage by wind and other hazards.

Pruning

It is the removal of auxiliary leaves or stems or suckers. Pruning reduces the amount of foliage and the number of tomatoes the plant produces; it increases the size of fruit produced and facilitates disease control as well as tying and harvesting of staked tomatoes.

The short stake system requires:

- One major pruning and
- Second light ground sucker pruning in this system.

The large sucker produced directly below the first fruit cluster is located and all suckers below this are removed. During the second pruning, new ground suckers missed during the first pruning are removed. Allowing suckers to become too large before pruning makes them harder to remove, increase possibility of damage to the plant and delays maturity. All pruning practices tend to delay maturity. Ground tomatoes are not usually pruned, but trellis tomatoes are pruned continuously.

Water Requirement

Insufficient watering during flowering and fruit development leads to flower and fruit drops, physiological disorder, low fruit yield and quality. Yield increased with an increase in amount of irrigation water. On light soil, water is applied every 3 to 5 days for the first 3-week after transplanting and every 7 days subsequently.

Fertilizer

- Application of 60 t/ha manure could give higher marketable and total fruit yield
- 200 kg/ha DAP (18N and 46 P_2O_5) is used to be broadcasted at transplanting and
- 100 kg/ha urea (46N) is side dressed at early flowering stage.

Cultivation

- Removing weeds around the plants
- Early cultivation should be fairly close to the plant, but it should be followed by shallow and far away from the crops.

Physiological Disorder

These disorders occur due to nutritional deficiencies, extreme temperature and moisture stress. The most common ones currently observed in the main production region are:-

Sunscald: Immature fruits when exposed to the sun they become yellowish. This is common on crops with spare foliage or those crops that has lost their foliage due to leaf diseases. The exposed spot changes to dry paper like surface, w/h affect the color of fresh fruit. Cultivars tolerant to leaf disease or that have good foliage coverage is preferred.

Misshaped; Poor pollen tube growth and poor fertilization of ovules result in bulged fruits, which affect the quality of marketable fruit, yield. Following standard production practices can minimize this.

Blossom end rot; Small discoloration spot appear at the blossom end of tomato fruit, which is caused due to moisture fluctuations in soil and low calcium content in the fruit.

Control: Avoid fluctuation of soil moisture and poorly drained soils, and supply crops with necessary nutrients.

Cat face: Deformed deep cavity penetrating the fruits and result in malformation of the fruit.

Control: Find and plant tolerant cultivars

Puffiness: - It is the cavity between the outer wall and the central portion of the fruits where it becomes empty. This is caused by any conditions interfering with normal pollination, excess N or heavy rainfall.

Control: Plant tomatoes under optimum growing conditions

Cracking: There are two types of cracking.One radiating out from the stalk and the other is in concentric order. These are common in round tomatoes.

Control: - Use crack - resistant cultivars. The pear or cylindrical fruit with think skin are relatively tolerant than thin-skinned round or globular fruits.

- Maintaining a uniform water supply
- Keeping good foliage and nutrient balances and
- Picking fruit before full ripening can reduce the incidence of cracking.

Harvesting

The stage of maturity at which tomato fruit are picked depends on:

- The purpose for which they are grown (fresh or processing)
- The distance they are transported from production to retailer or consumers; and
- Availability of storage facility

Depending on cultivars, fruits could be ready for harvest at about 75-90 days after transplanting. The duration of the harvest for fresh market is about 5- 7 times (30 to 40 days), while it is 3 to 5 times (15 to 20 days) for processing types.

The commercial industry and growers recognize the following changes in color as indicator of maturity required for specific market

Ripeness stage	Description of tomato surface
Green	Surface is completely green
Breaker	Definite in tan, pink or red color up to 10% of surface
Turning	10 - 30% tan, Pink, or red color (Fresh market better be harvested)
Pink	30 - 60% pink or red color
Light red	60 -90% Pink or red color
Red	More than 90 % red color- processing harvested

Post-harvest handling ; The loss is high due to moisture losses, over ripening, mechanical injury, rough handling and packaging, bruises and transportation. It is important that fruits be harvested at the right stages, selected, cleaned, properly graded, packed in container, and carefully transported to the final destination. So, avoid injury and reduce decay and softening of fruits that affect the attractiveness of fruits in the market.

Tomato seed production

Tomato is a warm season herbaceous perennial that requires 3-4 month from seedling to production of fruit. It grows best at temperature between 18^0c and 29^0c. It is often killed at temperatures below freezing and does not grow at temperature above 35^oc. It is a self-pollinated crop. Insects may cause some degree of crossing. A large no of varieties have been developed for fresh fruit market and processing (canning) purposes.

<u>Requirements</u>

Tomato seeds should be obtained from breeder's and/or basic seeds from a recognized source (e.g. EARO, ETFRUIT). The seed is sown at rate of 60 gm/25m$^2 \approx$ 720 gm/ha. The seed is preferably sown on raised nursery beds (15-20 cm height form the ground). Optimum spacing on nursery bed is 4-5 cm between rows. A total of 12 nursery beds (1 x 5m) are needed to raise enough seedlings to transplant 1 ha. Application of Farm Yard Manure (FYM) during land preparation and recommended rate of DAP fertilizer is very important.

Pest, disease and weed management (leaf spot, damping-off, cut worms) should be performed with maximum possible care. Watering should be performed by following recommended amount and frequency by taking in to consideration the weather condition, stage of plants and soil condition. Transplanting is performed at 30-35 DAS (days after sowing) at the time seedling reaches 12-15 cm height.

Isolation distance required for basic seed production is 50 m where, as 25 m isolation is required for certified seed or less than 10 m may be used if pollinating insects absent. Spacing in the field is 100 cm x 30 cm (33,330 plants/ha).

Field operations

Following integrated insect & disease control is advisable to optimize the seed production and minimize cost of production. Plants with off-type foliage should be removed before blossom (flowering). Evaluation for overall performance should be performed when the fruits begin to mature, by examining the plants and fruits. Plants affected by leaf spot, early blight and mosaic (TMV) (Tobacco Mosaic Virus) should be removed from the field.

Harvesting & extraction of seed

Tomato fruits ripen about 50-60 days after pollination, but may take longer if temperatures are cool. Keep the fruits on the vine until they are fully mature, preferably to the pink or red ripe stage. This enables the seed to develop normally and fully. If fruits are harvested at an earlier stage, place them in a covered, cool dry place for three or four days until they become red ripe. Be sure to check for the clipped sepal before harvesting fruit. Collect fruits in non-metallic containers, such as nylon net bags, plastic buckets, or crates. Metal containers may react with acids in the tomato juice and affect seed viability. Hence, they should not be used.

Seed Extraction: The two tomato seed extraction methods are manual and mechanical.

Manual Seed Extraction*:* Harvest the ripe fruits and keep them in nylon bags. Crush the fruits by trampling with feet. Put the bags of crushed fruits into big plastic containers and ferment to separate the gel mass embedding the seeds. To hasten the fermentation process, put weights over the bags or keep the fruits submerged in the liquid fruit mass. The time of fermentation depends upon the ambient room temperature. If temperature is above 25°C, one day of fermentation may be sufficient. If cooler, two days of fermentation may be needed. Fermentation for more than three days may spoil the seeds' quality.

To wash the seeds, put them in an open plastic container. Then fill the container with water and stir the seeds to allow the pieces of flesh and skin sticking on the seeds to float. Incline the container and gently remove the floating refuse, making sure that the seeds remain at the bottom. Repeat the washing several times, adding fresh water to the container every time until all the flesh and gel are completely removed, leaving clean seeds at the bottom.

Mechanical Seed Extraction: Mechanical seed extraction is used by large-scale operations. Put ripe fruits into a mechanical seed extractor for crushing and separation of the seeds and gel from the pulp. Gather the seeds and gel mass in a suitable container such as plastic tub or bucket. Instead of fermentation, treat the seed-gel mass with 0.7% hydrochloric acid (HCl) at a rate of seven milliliters of HCl per kilogram of seed-gel mass. Stir the seed-gel mass while the acid is being added. Continue stirring for 40 minutes until the gel is visibly softened or dissolved. Do not use a higher concentration of acid nor a longer treatment time, otherwise will you injure the seeds.

When the seed is separated from the gel, pour the acid-treated seeds into a clean fine-mesh bag. Wash the bag with tap water thoroughly so that no acid is left on the seeds' surface. While washing, step on the bag to squeeze out the remaining gel. Place the seeds into a plastic container, filling it to one-third capacity. Then, fill up the container with tap water. Stir the seeds to enable the small pieces of flesh and skin to float. Incline the container and remove the floating debris. Make sure the seeds remain at the bottom of the container. Repeat the washing procedure several times until all the debris is gone and the seeds are clean. Collect the seeds that remain at the bottom of the container and dry the seeds

Seed drying: Excess water can be removed by hanging the seeds in the shade for a day. An even quicker way to remove water is to place the seeds in a spin dryer. After the excess water is removed, uniformly spread the partially dried seeds in a flat plastic container or aluminum pan. Loosen any clumps of seeds. Enclose this container with its seeds into a net nylon bag. Place the container into an air drier. Drying continues for three to four days, maintaining a temperature of 28-30°C. Higher temperatures at the time of drying may cause seeds to germinate. Stir the seeds two to three times daily so that seeds dry uniformly. Loosen any seeds that clump together. These procedures will get the seeds to the desired 6-8% moisture content.

Seed Packaging and Storage: Pack and deliver the dried seeds according to specifications of the Seed Company or contract agency. If necessary, tomato seeds can be safely stored for at least three to five years. Place seeds in manila envelopes, cloth or mesh bags, plastic containers, or foil envelopes. The best containers are airtight, such as a sealed glass jar, metal can, or foil envelope. Label each container carefully. Note the names of the hybrid and parents, the date, and any other information you feel is valuable. Store seeds in a cool, dry place. Small quantities can be kept in an airtight container inside a refrigerator. For larger quantities, a special room with controlled humidity and temperature should be used. If possible, the temperatures should not exceed 20°C and relative humidity (RH) in the storage area should not exceed 30%.

Disease and insect pests

1. Late blight (*Phytophthora infestans*)

- Encouraged by rainy or humid weather
- It damages leaves and branches, and causes brown dark spot on the fruit

2**. Early blight (*Alteraria solani*)** is also encouraged in dry warm conditions

Control: Crop rotation,

- Use of clean seed
- Removing all infected residuals
- Use weed free fields to prevent disease build up in the soil

Insect Pests

- Potato tuber moth (*Phorimaea operculela*)
- Africam ballworm (*Helicoverpa armigera*)
- Whitefly (*Bemisia tabaci*)

Control: Cyper methrin (10% a.i.) 100 g a.i./ha in about 500 - 700lt of water every two weeks at early flowering and early fruiting stages

Weed management:

Brume rape (*Orobanche spp*) - Parasitic weed

Control: Deep ploughing and flooding of tomato fields for two consecutive months can reduce *Orobanche* seed in the soil.

2. Pepper (*Capsicum species*)

a. Use and composition

- The world's third most important vegetable after potatoes and tomatoes
- Excellent source of vitamin A, C and B_2, minerals (K, P and Ca)
- Are major ingredients of curry powder (for flavoring, coloring food and pungency)
- Pepper fruits are used in salads, pickles, stuffing, spices, sauce and dried powder
- Coloring agent and pharmaceutical ingredient

b. Origin and Botany

- Originated in latin America (Peru, Chile, Bolivia)
- Columbus introduce to Europe then to Africa and Asia.
- A member of *Solanaceae* family
- The genus *Capsicum* which consists of 22 wild species and five domesticated species
  - Capsicum annuum
  - Capsicum frutescens
  - Capsicum chinense
  - Capsicum baccatum
  - Capsicum pubescens

  } the five domesticated species
- The species annuum, however is the most commonly cultivated
- Diploid species with 2n=24 chromosome number
- Perennial herb usually grown as annual
- Both cross-pollinated and self-pollinated occurs
- Pepper fruits vary in their pungency, color, shape, flavor, size and their use
- The pungent material found in all Capsicum species is known as **Capsaicin** ($C_{18}H_{27}NO_3$)
- Carotenoids control pod color (red color comes from the carotenoids **capsanthin** and **capsorubin, while** yellow to orange color is from **beta-carotene** and **violaxanthin**.

Among the five species grown on the world the two important types grown in Ethiopia are:

1. Hot pepper
2. Sweet pepper

Hot pepper, because of its extensive use in the Ethiopian diet, the chilly is an important traditional crop. It is used industrially in the dry state for production of color oleoresins by a solvent extraction process. Hot pepper has high content of capsaicin which makes the fruit very pungent and the Sweet pepper with a very low content of capsaicin. Fruit of hot pepper are relatively small compared to sweet pepper. Hot pepper is used fresh and dried as a spice. Some of the hot pepper varieties grown in Ethiopia include: Bako local, Marako fana and long red cayennes. The yield for dried hot pepper ranges from 0.8 - 1.5 t/ha of dried fruit. In Ethiopia, sweet pepper is only produced for fresh export to Europe. The most popular variety is California wonder, which yields 10-15t/ha the bird's chilly (*C.frutescens*) is the most pungent of the chilly and has smallest fruits. The crop plants are generally perennial.

Varieties

D ifferent types of hot pepper (capsicum sp.) are produced in Ethiopia. It varies in mode of growth and in fruit characteristics such as fruit size, shape, color and pungency. The degree of pungency vary considerably from very mild to hot. The fruits are erect or hanging, depending on the variety

- ✓ Bako local } Bako Agricultural research center
- ✓ Oda haro
- ✓ Dube Medium } Jimma Agricultural research center
- ✓ Dube short
- ✓ Mareko fana
- ✓ Melka zala } Melkassa Agricultural research center
- ✓ Melka shote
- ✓ Melka awaze

Melka dima

Soil and Climatic requirements

Pepper tolerates slightly higher temperature than Tomatoes. The optimum growing temperatures are 21^{0}c to 29^{0}c for hot pepper and 21^{0}c -24^{0}c for sweet pepper. The optimum germination temperature is between 21^{0}c -24^{0}c. Hot pepper can be grown as a rain fed crop as well as under irrigation.

Rain fed cultivation is more economical and the dried product can be stored and distributed during the dry season. Sweet pepper should always be cultivated under irrigation to obtain good quality and high yields. The soil requirements are the same as for tomatoes. Pepper is sensitive to wind.

Growth Requirement Hot pepper (berbere) grows well under womi and humid conditions, but it requires dry weather at the time of maturity. It give best green fruit yield and better seed set at 21 to 27'C during the day and 15 to 20°C at night. High temperature in combination with low humidity (40 to 50%) cause abscission of buds and flowers of poor fruit and subsequent low seed set. Hot pepper adapts well in sandy loam soil and well drained good clay loam.

Sowing and Transplanting

The seed rate is 0.6 kg per hectare and the required seedbed area to transplant one hectare is 300 square meters. Seedlings will be transplanted when they have reached a height of 10-12 cm.

Sweet pepper under irrigation is planted in double on flat- topped ridges. Double row spacing is 40cm.

The spacing between double rows is 80 cm. Spacing within the row is 40 cm. Plant population per hectare is 42000 plants. Hot pepper under rain fed conditions is planted in double rows 40 cm apart. The distance between the double rows is 60 cm and spacing within the row is 40 cm.

Fertilizer application: - It is similar to the recommendation for tomato.

Irrigation

Sweet pepper crops susceptible to diseases, which develop under water logged soil conditions. It is, therefore, necessary that seedling should always be planted on top of the ridge and about 10 cm away from the edge. Adequate drainage should be provided at furrow outlets. Water should always be admitted to furrows by siphon.

Cultivation:-Cultivation to control weeds should also be aimed at building up the ridges, particularly if they become washed down by heavy rain.

Crop rotation:- Three to five years must elapse before pepper can be grown on the same land.

Diseases

Virus diseases

Virus diseases on pepper are caused mainly by cucumber mosaic virus (CMV), Tomato mosaic virus (TMV), and Alfalfa mosaic virus (AMU). Measures taken to prevent virus diseases are the same as for tomato.

Powdery mildew (*Loveillula taurica*): it occurrs both on hot and sweet pepper.

The symptoms are chlorotic blotches on the upper side of the leaves and powdery blotches on the lower side. Recommended control measures are spraying with Topsin M 70% at a rate of 0.05% or spraying with colloid sulphur at a rate of 0.25% at weekly intervals.

Bacterial leaf spot / **Bacterial blight**: - *Pseudomonas vesicatori*

The first symptoms are small dark, greasy-looking spots on leaves and stem of young plants. These enlarge, become drier-looking and grayish brown, and in severe cases looking cases attack leaf tissues, especially tips and margins which shrived or and die.

On fruit, the symptoms are dark, water soaked spots.

Control measures are crop rotation, seed treatment and spraying of copper oxychloride at rate of 0.5 %.

Bacterial soft rot (*Erwinia Caratovora*): Persists in the soil and is plant debris. Infection through wounds caused by mechanical injury, bruises or insect damage. The bacteria are spread in packinghouses by contaminated equipment, trimming knives and wash water. This disease is a major cause of loss during storage and transit of many vegetables.

Control measures: -1) Avoiding harvest and handling in juries 2) Sterilization of trimming knives, field boxes and clothes, and 3) Immediate refrigeration after grading and packing.

Bleaching: - The causes of bleaching, in hot pepper fruits have not yet been identified. It may be a physiological problem.

Insect pests: Egyptian leaf worm and American bollworm attack pepper plant and fruits.

Recommended control measures against Egyptian leaf worm are spraying Metamidophos at a rate of 0.25% and against American bollworm spraying Endosulfan at a rate of 0.25%.

Harvest and Post-harvest handling

Harvest maturity

Sweet pepper is harvested when the fruits have reached full size but are still green. However during the later stages of the crop, fruits may be breaking color or be fully red. Harvesting frequency is usually once weekly. Chillies are normally harvested after they have fully or partly dried on the plant. This is a traditional practice, which should be investigated to determine whether it is the best method.

Grading and Packing Sweet pepper for export

The market demands either green or fully colored red fruit. Fruit, which is breaking color sometimes, develop full red color if stored for a few days in field boxes at ambient temperature and high relative humidity. Fruit, which is breaking color, should not be exported, as there is no demand for it. For size grading and packing the UN/ECE standard for sweet pepper, FFV- 28, should be adhered too. Sweet pepper may be waxed to reduce moisture loss. It is stored cool at 10^0c and 90 -95% relative humidity for a period of two to three weeks. At the time of packing, the cut end of the stalk may be dusted with sulphur as a protection against decay

Capsicum (hot peppers) seed production

Seed Production

The requirements for producing pure, high-quality seeds include favorable climatic conditions, a suitable field, the proper equipment, and good management practices. Peppers grow best in the dry season with temperatures in the range 18–27^{0}C for sweet peppers, 21–33^{0}C for chili peppers. The night temperature is especially critical in seed production. Generally, peppers will not set fruits if night temperatures remain above 24^{0}C (for sweet peppers) or above 30^{0}C (for chili peppers).

Field requirements: Ideally, select a field where the previous crop was a legume or a cereal. Avoid fields where the previous crop was pepper. This prevents the new seed crop from being contaminated with pollen or seeds from *volunteer* pepper plants. Volunteer plants are seedlings that emerge from unsown seeds. Avoid fields where the previous crop was sweet potato or a solanaceous crop (tomato, pepper, eggplant, and white potato). This prevents the build-up of diseases and insects.

Isolation requirements; although pepper is classified as a self-pollinated crop, it's out-crossing rate may sometimes exceed 90%. Cross-pollination is primarily caused by bees; therefore isolating the crop from bees is very important. Cross-pollination is less often caused by other insects (thrips and ants), and rarely by wind. Optimum isolation can be achieved by growing the crop at least 200 meters away from other pepper lines, by covering the pepper plants with 16-mesh nylon nets to keep out bees, or by growing plants inside an enclosed greenhouse or screen house. Sweet and chili peppers will cross with one another.

If optimum isolation is not possible, plant the crop on a large plot (at least one hectare). Plant tall barrier crops such as sugarcane, maize or sorghum around the pepper plot to restrict the movement of bees into and out of the plot. Collect fruits only from the central part of the plot. Even so, some contamination is likely.

Seed impurities can also occur from off-type plants with in the seed production field. Inspect the field at least twice - before flowering and before harvest. Remove any off-type plants**.** These off-types can arise from volunteer plants from previous crops, cross-pollination in the previous seed crop, seed mixtures, mutations, or damage to the plant. Plants suffering from viral and some other types of diseases should also be removed.

Harvesting; Harvest pepper fruits when their color indicates that they are ripe (usually red, but this varies depending on variety). Keep harvested fruits in a cool, dry place (25^0C and 50% relative humidity is ideal) for a week to allow any slightly immature fruits to ripen fully. If you have more than one variety, keep fruits of each variety separated to avoid mixing the seeds during the seed extraction process.

Seed extraction: *Sweet* pepper seeds should be extracted from fresh fruits. *Chili* pepper seeds may be extracted from fresh fruits, or from fruits that have been dried for 1 week at 40^0C. Seeds may be removed by hand or by grinding the fruits (with dull blades to minimize seed damage). Separate the seeds from fruits with a series of water washes.

Seed drying: Spread the seeds on a screen for drying at 25^0C and 40% relative humidity for one week. Use an air dryer if available. If one is not available, dry the seeds in a warm, well-ventilated placed out of direct sunlight. Stir the seeds occasionally and/or use a fan to hasten drying.

Seed storage: Pepper seeds can be safely stored for at least 3-5 years. Place seeds in manila envelopes, cloth or mesh bags, plastic containers, or foil envelopes. The best containers are airtight, such as a sealed glass jar, metal can or foil envelope. Label each container carefully. Note the names of the hybrid and parents, the year, and any other information you feel is valuable. Store seeds in a cool, dry place. Small quantities can be kept in an air-tight container inside a refrigerator. For larger quantities, a special room with controlled humidity and temperature should be used. The temperatures should not exceed 20^0C and relative humidity (RH) in the storage area should not exceed 30%.

Capsicums are important both as vegetable and spice crops. In Ethiopia bell pepper, chilies and hot pepper are produced for home consumption, industrial use and for export. It is also produced commercially as well as in home gardens but is mainly a small farmer and a rain fed crop grown in every region. The crop is mainly cross pollinated by insects (up to 90%). However, there are also some degrees of selfing. Hot peppers in general follow the breeding methods developed for cross pollinated crops.

5.3. Eggplant (*Solanum melongena* L.)

5.3.1. Origin

Vavilov (1951) considered *S. melongena* as being native to the "Indo-Chinese center of origin"and is now generally grown as a vegetable throughout the tropical, sub-tropical and warm temperate areas of the world. It is an important vegetable in India, China and Japan. In recent years, it has increased in importance as a protected crop in Northern Europe. Eggplant is berry-producing vegetables and known by a host of other names such as eggplant, brinjal, melongene, garden egg and guinea squash, but is distinguishable by its vibrant dark purple colour and stretched egg-like shape.

6.3.2. Nutritional importance and health

Eggplant is very low in calorie, loaded with beneficial nutrients, with a distinctive taste and sponge-like texture, it was once believed to be poisonous and actually contains more nicotine than any other vegetable. Eggplant is not the only vegetable that contains traces of nicotine however; tomatoes, potatoes, cauliflowers and green peppers also contain very small amounts. Ten kg of eggplant has the same nicotine content of a stick of cigarette. This only means that the nicotine content of eggplants is negligible compared to passive smoking. Nicotine content is insignificantly low especially compared to tobacco. Aside from that, other factors may affect the absorption of these nicotine alkaloids. Ingestion is different from smoking. Proper cooking may diffuse nicotine alkaloids in the water, careful picking of the time (ripeness) and method of eating or decreasing the dietary intake are ways in reducing the nicotine content.

Eggplants are a good source of dietary fibre, calcium, antioxidants and vitamins including vitamin C, vitamin K, vitamin B6, thiamin and niacin. They are virtually fat free and low in calories, sodium and cholesterol and high in folic acid. Eggplants also come loaded with a host of minerals essential for the effective functioning of the body, including magnesium, phosphorus, copper, and potassium.

Eggplant skin is the most prominent natural source of nasunin; a potent antioxidant which neutralizes free-radicals, giving it anti-ageing properties. Nasunin also protects lipids (fats) in brain cell membranes and has cancer-fighting properties since it restricts the growth of new blood vessels, whilst keeping present blood vessels clear and relaxed.

The flavonoids found in eggplants play an important part in heart health, whilst the presence of phenolic compounds can actively reduce blood pressure, lower cholesterol and help to prevent the formation of blood clots. Regular consumption of eggplant is recommended as a natural way to manage type 2 diabetes, as it can help to control glucose absorption and reduce associated high blood pressure, as well as being a high-fibre, low fat food. Juice made from the leaves and roots of the eggplant can be effective in treating throat and stomach disorders, asthma, toothache, rheumatism and skin problems.

6.3.3. Ecological requirements and Crop husbandry

Climate

A long growing season of about 120 days is required for successful production. Eggplant is a warm-weather plant that grows best under temperatures of 21° to 29°C. It cannot tolerate frost, and the growth of young plants will be retarded when night temperatures are below 16°C. Cool temperatures and cloudiness can reduce fruit set. Eggplant can tolerate drought and excessive rainfall, but struggles to grow when temperatures exceed 30°C. When temperatures and humidities are high, eggplant becomes more vegetative

Soil

Eggplant prefers a soil that is deep, fertile, well drained, high in organic matter, and has a pH of 5.5 to 6.8. A sandy loam soil is ideal when an early yield is desired. Heavy clay and saturated soils should be avoided due to the build-up of root-rotting diseases. Eggplant should not follow other Solanaceous crops (tomato, pepper, potato) since these crops share many of the same disease and insect pests. The incidence of bacterial wilt and nematodes can be reduced if eggplant is planted after paddy rice. Timely and appropriate applications of fertilizer can make a significant difference in the quality and quantity of fruit and can promote earlier harvests.

Irrigation

Irrigation is essential for eggplant cultivation wherever little or no rain is available during the growing season. The most critical period for irrigation is during flower and fruit formation. Any stress related to lack of water during this period can lead to the development of blossom- end rot and malformed fruit. Fruit size and yield are reduced by moisture stress.

6.3.4. Eggplant Varieties/Types

Eggplants are a botanically diverse and classified into four cultivar groups (Gilo, Shum, Kumba, and Aculeatum) based on morphological characteristics and use. The Gilo group has edible fruits with different shapes, color, and size, and hairy, inedible leaves; the Shum group has glabrous and small leaves that are eaten as a green vegetable but the fruits are inedible; the Kumba group has glabrous leaves and flattened large fruits, which are edible; the Aculeatum group, on the other hand, has more prickliness than other groups with flat-shaped fruit, and are used as ornamentals.

36.3.5. Harvesting and post-harvest handling

Most common eggplant varieties are harvested when they reach a dark, glossy, uniform purple-black color. Overly mature fruit becomes pithy and bitter, reducing market value. The fruit is hand cut from the plant leaving the calyx intact. Eggplant is picked frequently for higher yields. A crop may be harvested at least five to six times in a season (7- to 10- day intervals). Because the fruit is delicate and bruises easily, it must be handled very carefully. Fruit must be wiped clean or washed after harvest and then held at a temperature of 45 to 50 degrees F and 90 to 95 percent relative humidity to extend shelf life. Even under ideal conditions, eggplant should not be stored longer than 14 days.

Pest management

Colorado potato beetle is a key insect pest of this crop. Other insects include flea beetles (which can be devastating to transplants), aphids and mites. Phytophthora blight, which affects stems and fruit, can be a problem in wet, poorly drained soils. Phomopsis blight, early blight, Verticillium wilt and tomato spotted wilt virus can also cause crop losses. Disease management involves crop rotation, sanitation, planting in raised beds, and the use of protectant fungicides. Few eggplant cultivars have resistance to diseases other than tobacco mosaic virus (TMV).

6.3.5. Seed production methods

Environmental factors are important in the production of eggplant seed. Eggplant is a warm season crop. It requires a long and warm growing season for successful production. It is more susceptible to lower temperatures than tomato and pepper. A day temperature of 25–32 °C and a night temperature of 21–27 °C are ideal for plant growth and fruit development. Comparatively it is a hardy crop, it can tolerate drought and heavy rainfall. However, it is advisable to select a dry climate or at least a season with a low air humidity, which discourages fruit rot and other diseases.

Cultural practices and crop management for seed production are almost same as for market fruit production except that fruits are harvested when they are ripe and the skins become yellow. Furthermore, seed crops require special attention in terms of isolation, roguing, harvesting, and seed extraction.

In general, studies indicated that higher levels of P and K fertilizers result in greater seed yield and better quality. The importance of nitrogen on accelerating flower formation in eggplant has been reported and practiced. Special techniques are also used to train and support the plants. Eggplants are susceptible to many of the soilborne pests and diseases associated with other members of Solanaceae.

Appropriate isolation of the seed-producing field from other varieties of the same crop is generally required. Since there is considerable amount of natural cross-pollination in eggplant, isolation is essential to seed production. An isolation distance of 200 m and 100 m for foundation and certified seed production, respectively, is recommended.

Harvesting

For seed production, fruits are allowed to ripen fully to ensure complete seed development and maturity. In general, the color of fully mature fruit fades and turns normal color to yellow. For open-pollinated varieties, only the ripe yellow fruits are harvested.

In case of hybrid seed production, the seed fruit fully matures about 50–55 days after pollination depending on the maternal parents. Only the marked pollinated fruits are harvested.

Seed extraction and drying

The harvested fruits are stored for three to four days until they become soft. This allows the seed to mature fully. The top one-third of the fruit is removed since it contains almost no seed. In most cases, seeds are extracted by cutting, crushing or macerating with a mechanical extractor. After extraction, seeds are washed and cleaned with extra water in a container. Some seed extracts are also capable of separating the seed from the pulp through a screen. In the case of very small-scale seed production, dry extraction of seeds is used, however, this is time consuming and laborious.

Seed drying is done by spreading the wet seeds, either in the sun or in an electric dehydrator. Stir the seed with hands at least 2–3 times a day, turning them over to dry uniformly. Seeds that stick together should be disaggregated. The seed should be completely dry to about 8% moisture content.

Seed yield

The seed yields of eggplant vary with different varieties or parents and production conditions. Generally, the standard of seed yield is between 600–800 kg/ha. The cost of hybrid seed production of eggplant is not as high as compared to other vegetables because each fruit contains a large number of seeds. The cost can be further reduced by the use of male sterile line in hybrid seed production.

Chapter 7

Production technology of major root/tuber vegetables

Potato, Sweet potato, Cassava, Carrot, Beet root, Yam

7.1. POTATO (*Solanum tuberosum L.*)

7.1.1. Introduction

The potato is the **fourth** most important food crop in the world after **wheat, maize and rice.** In 2014/2015, area under potato crop has increased to 67,362 ha and its productivity is about 921,832 tonnes in Ethiopia (FAOSTAT, 2013). Its national productivity is 13.7 t ha^{-1} in the production years of 2014/2015**.** Potato is a staple food the potato is grown as a vegetable for table use, is processed into French fries and chips (crisps) and is used for dried products and starch production. Processing is the fastest growing sector of the world potato economy, and today, processors are building factories in countries where the potato is primarily grown as a staple food.

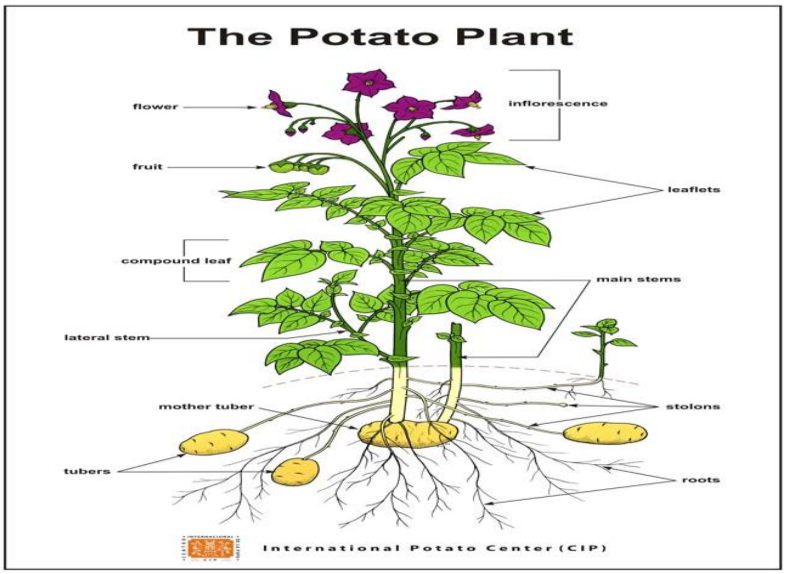
7.1.2. Origin

Potato has its **origin** in the high **Andes of South America** and was first cultivated approximately **Lake Titicaca** near the present border of Peru and Bolivia. It was introduced to Ethiopia 1858 by the Germen botanist schimper. Since then, the potato has become an important crop in many part of the country.

7.1.3. Botany

Potato (*Solanum tuberosum L.*) family; *Solanaceae*; genus; *Solanum;* section *Tuberarium* and chromosome number; 2n=48 is one of mankind's most valuable food crops. There are four diploid species; *Solanum stenotomum, S. phureja, S. goniocalyx* and *S. ajanhurri.* There are also two triploid species; Solanum *chaucha* and *Solanum juzepczukii;* and one pentaploid cultivated species called *S. curtilobum.* There are two sun species of *Solanum tuberosum*; Andean and tuberosum or Chilean. Today, over 99% of all cultivated potato varieties worldwide are descendants of the Chilean subspecies. There are about five thousand potato varieties (3 thousand of them are found in the Andes alone, mainly in Peru, Bolivia, Ecudar, Chile and Colombia). Apart from the five thousand cultivated varieties, there are about 200 wild species and subspecies.

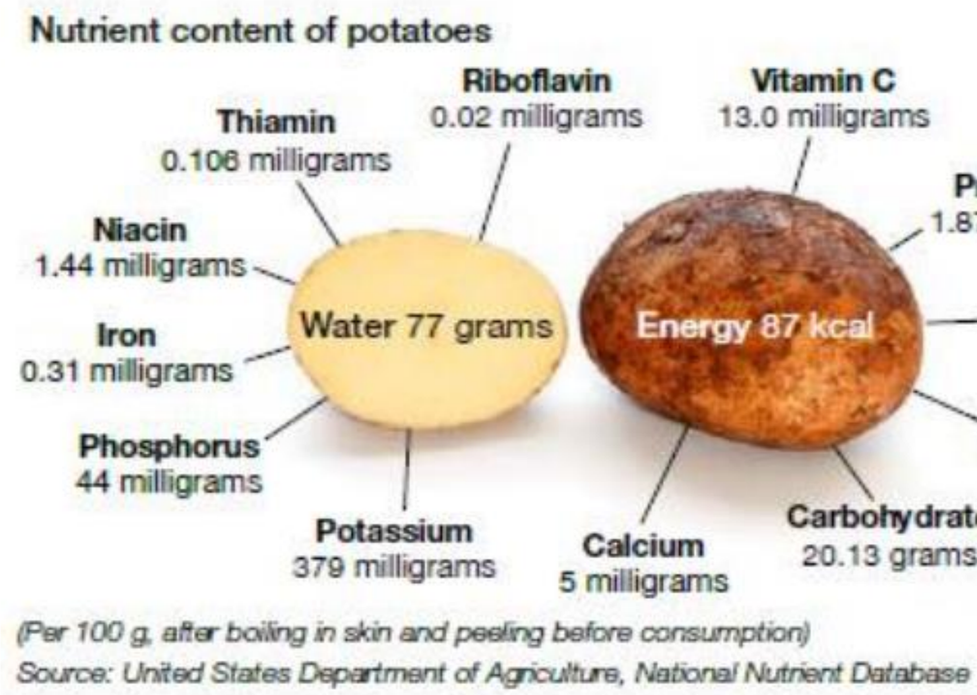
The potato is perennial but as crop, it is treated as an annual. It is vegetative propagated by the mean of tuber. The tuber is an enlarged underground stem produced on the end of a stolen and not on the roots proper. These tubers are morphologically stems. The possess eyes that is bud. Many potato cultivars produce flowers and fruits in cultivation. Potato is a self-pollinated plant. The flower of the potato plants is in terminal cluster. Each flower normally has five stamens, two-celled pistil, five sepals and five petals united for about half their length. Most varieties of potatoes bear infertile pollens and hence fruits or berries are not generally formed. In some of the varieties fruits or berries are formed. One inflorescence can contain variable number of flowers (1 to 40), depending on the cultivar and time of the flowering season. Usually there are more flowers in a cluster but maintained six to eight flowers are recommended. The stigma is receptive for pollination just before the flower buds open, or shortly thereafter older flowers may become self-pollinated.



7.1.4. Economic importance, use and composition

- ✓ Important food & cash crop in Ethiopia (especially on high & mid-altitude area)
- ✓ Potatoes are best known for their rich carbohydrate content (starch and fiber). Cheapest source of energy.
- ✓ Potatoes contain a number of important Vitamins (Vit. C, Vit B_1 (thiamine), Vit B_2 (riboflavin) and Vit B_6).
- ✓ Provides significant amount of proteins with a good amino acid balance.
- ✓ Source of minerals (K, P, Ca, Mg, Fe and Zn).
- ✓ Potato is rich in antioxidants comprising polyphenols, carotenoids and tocopherols.
- ✓ Fresh potatoes are free of fat and cholesterol.
- ✓ Staple food in western countries

Potato is an important food security and a hunger reliever crop in several parts of the country by virtue of its ability to mature earlier than most other crops at time of critical food need. In recent years, the production of this crop is expanding rapidly owing to the presence of improved technologies and expansion of irrigation culture.



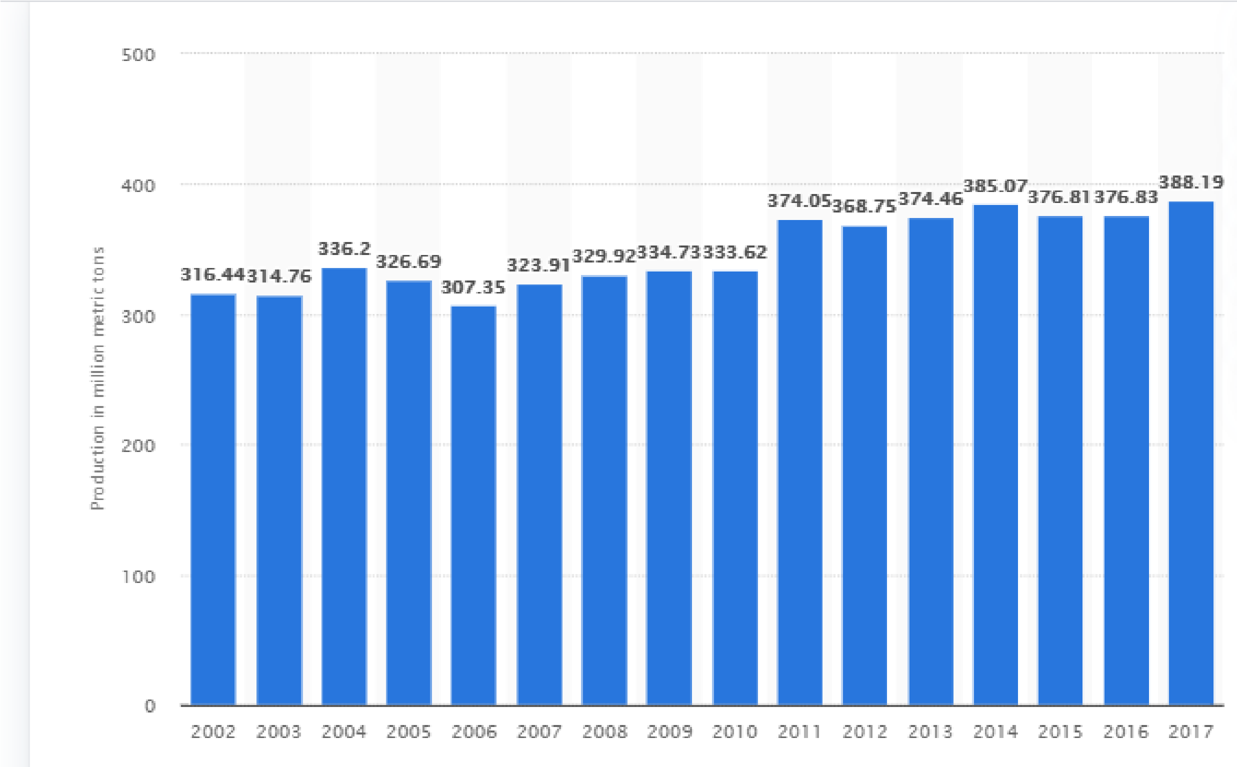
7.1.5. Production trend, Marketing and Utilization

The world potato production had increased from time to time. China is the biggest producer of potatoes worldwide, with about one third of the world's potatoes produced in China and India. According to FAO estimates, over 388 million metric tons of potatoes were produced worldwide, a substantial increase from 333.6 million tons in 2010.

Table 7.1. Potato production by region in 2006 (source FAOSTAT)

	Harvested area (ha)	Quantity (tonnes)	Yield (tonnes/ha)
Africa	1,499,687	16,420,729	**10.95**
Asia/Oceania	**9,143,495**	**131,286,181**	**14.36**
Europe	7,348,420	126,332,492	17.19
Latin America	951,974	15,627,530	16.42
North America	608,131	24,708,603	**40.63**
World	**19,551,707**	**314,375,535**	**16.08**
China	**4,901,500**	**70,338,000**	**14.35**
Russia	2,962,420	38,572,640	13.02
India	1,400,000	23,910,000	17.08
USA	451,430	19,712,630	43.67
Ethiopia	**73,095**	**525,656.8**	**8.03**

Source: - Singh and Kaur, 2009



Source; Shahbandeh, (2020)

Fig . Potato production worldwide from 2002 to 2017*(in million metric tons)*

Production trend in Ethiopia

In Ethiopia, nowadays many improved potato varieties have been released by research centers and universities for production. These improved potato varieties together with improved management proved to give three to four-fold yield advantage as compared to local varieties together with traditional production and management practices.

In the last three decades, the land under potato had increased from 30,000ha in the mid-1970s to 50 thousand in the mid-1980s, and since then there has been a steep rise to about 160,000ha by 2000. Moreover, in the year 2013/14, about 1,437,697 private peasant holders participated in potato production, on the total area of 66,745.61 hectare (having 31.80% distribution) covered by potato, and 7,849,934 quintals of potato was produced, yielding 117.61Qt/ha in Meher Season. The total area coverage of potato in the year 2012/13 in national level was 74,934.57 hectare, and for the year 2013/14 became 66,745.61, and its percentage change showed a decrease by 10.93% of the areal coverage. Regarding its total production, it was 8,633,477.92 quintals in the year 2012/13, and 7,849.934 quintals in the year 2013/14, and its percentage change showed 9.08% decrements. However, the amount of yield per hectare of the year 2012/13 and 2013/14 was 115.21 and 117.61 quintals respectively. Its percentage change showed an increment by 2.08%. (CSA,2014)

7.1.6. Marketing and Utilization

The utilization of potato in Ethiopia has been very conservative. In recent years, however, the consumption of potato in the form of crisps, chips and mixture of salads, stew, porage, enjera, local arekie…. has dramatically increased. The increase in urban development and improvement in infrastructure such as road has opened a growing opportunity for potato growers to sell their potatoes to nearby towns and distant cities. Some quality of potatoes is also exported to Djibouti from eastern and central parts and to the Sudan from the northwestern part of the country.

7.1.7. Climatic and soil requirements

a. Temperature

High temperatures encourage the growth of the haulm, whereas lower temperatures are more conductive to that of the tubers. The temperature, then, affects the distribution, in one way or the other, of the dry matter formed. For example, temperatures higher than 25 to 30° C are unfavorable for tuber production. It is not only the average temperature that is important; the maxima and minima are even more so. Low night temperature may do a lot to restore the balance. Regions with maxima as high as 30°C and minima of about 15°C are much better for potato growing than regions with temperatures that are fairly constant at around 25°C.

At about 30° C dry-matter production drops to roughly two thirds of what it is at 20°C. At 10° C it is considerably higher of what it is at 30° C. No wonder then that this crop grows best in temperate climates or at high altitudes in the tropics or sub-tropics. Needless to say, the temperature given is that in the crop. This may differ considerably from that measured at a height of 2m (i.e. the air temperature).

b. Light

Areas with plenty of sunshine, therefore, have a certain advantage over areas where it is often cloudy. Moreover, an abundance of light tilts the balance of the haulm/tuber growth relationship in favor of the tuber. This is one of the reasons why, in tropical and sub-tropical regions, it is possible to achieve high yields at high altitudes, where there is a high light intensity, even when day temperatures are fairly high, provided that night temperatures are rather low.

c. Moisture

Insufficient water supply to the crop reduces foliage growth and the efficiency of, that foliage to use intercepted light by reducing the rate of photosynthesis; moreover. Water deficiency Stimulates maturity and call even cause death of the leaves. Under Conditions prevailing in the Netherlands, shortage of water has a greater effect on the efficiency of the foliage in producing dry matter than it has on total light interception, although on

d. Soil

The potato develops best on deep, fertile, sandy to, clay loams with good water retention capacity. Because the potato has a relatively weak, shallow root system, impermeable layers in the soil limit rooting depth, which restricts water availability to the plant in dry periods. Thus soil compaction can greatly reduce potato yields. Aeration of the soil has a great effect on the set and development of tubers.

7.1.8. Potato Variety

In Ethiopia 36 potato verities were released so far.

Table 7.2. Average yield & some other characteristics of potato varieties released during 1987-2015

variety	Release year	Area of adaptation		Maturity	Yield (t/ha)		Releasing research centers or university
		Altitude (m)	Rainfall (mm)		On station	On farm	
Alemaya 624	1987	1000-2000		90-100	25.9	-	AU
Awash	1991	1500-2000	>750	90-100	25.4	20.0	Holetta
Tolcha	1993	1700-2000	>750		33.1	22.5	Holetta
Menagesha	1993	>2400	>750		27.0	25.0	Holetta
Wechecha	1997	1700-2800	>750		21.8	19.0	Holetta
Chiro	1998	1600-2000	700-800		36.0	27.5	AU
Bedassa	2001	1700-2000	700-800		40.5	-	AU
Zemen	2001	1700-2000	700-800		37.2	-	AU
Zengena	2001	2000-2800	1000-1500		30.0	23.5	Adet & Holetta
Guassa	2002	2000-2800	1000-1500		22.4	23.5	Adet & Holetta
Degemegn	2002	1600-2800	750-1000		46.7	35.6	Holetta
Jalenie	2002	1600-2800	750-1000		44.8	29.1	Holetta
Gorebella	2002	2700-3200	800-925		30.1	28.0	Sheno & Holetta
Gera	2003	2700-3200	800-1000		25.9	20.6	Sheno & Holetta
Bule	2005	1700-2700	980-1398		39.3	38.3	Awassa & Holetta
Marachere	2005	1700-2700	980-1398		33.3	28.4	Awassa & Holetta
Shenkolla	2005	1700-2700	980-1398		31.5	29.1	Awassa & Holetta
Gudenie	2006	1600-2800	750-1000		29.2	21.0	Holetta
Belete	2007	-	-		-	-	Holetta
CAESAR	2009	-	-	-	-	-	Solagrow plc
Mondial	2009	-	-	-	-	-	Solagrow plc
Red scarlett	2010	1800-2400	800-1200	70	50	40	Solagrow plc
Bubu	2011						Haramaya University
Moti	2012						SARC/OARI
Milki	2012						SARC/OARI
Dagim	2013						AARC/ARARI
Rumba	2015						Kartoffelzucht Bohm GmbH & Co.KG Europlant Pflanzenzucht GmbH Gibagri farm PLC.
Jelly	2015						Bohm-Nordkartoffel Agrarproduction GmbH & Co. OHG / Europlan

							Pflanzenzucht GmbH, Gibagri farm PLC.
Laura	2015						Europlant Pflanzenzucht GmbH Kartoffelzucht Bohm & Co KG Gibagri farm pic.
Horro	2015						Bako ARC/OARI.

Source: - MoARD, 2016; EARO, 2004

6.1.9. Propagation

Planting material can be seed tubers, stem cuttings and botanical seeds (true potato seed).

i. **Botanical seeds (true potato seed):-** widely used in other countries to reduce the incidence of virus disease.

ii. **Seed tubers**

- ⇒ Most commonly used
- ⇒ Potato tubers have dormancy period (8-10 weeks)
- ⇒ Should be planted after the dormancy period is over & when tuber starts to sprout
- ⇒ Tubers has to be free of viral disease
- ⇒ Can be planted whole or cut in to pieces

To overcome dormancy

- ♣ Dip the tubers in 1ppm solution of Gibberelic acid (GA_3)
- ♣ Treat the tubers with potassium triocyanate

iii. **Stem cutting**

Need hormones for sprout initiation

Table 3. Comparison of true potato seeds (TSP) and potato seed tuber

True potato seeds (TSP)	**Potato seed tuber**
Amount required is small (200g/ha)	Amount required is large (18-20q/ha)
Free from diseases	Infected materials may be planted
Require much labor (extra time to rise seedlings)	Require less labor
Take long time to maturity	The tubers are almost uniform (suitable for processing)
Difference in tuber size, shape (lack uniformity)	Mature early
Low cost of transportation and storage	High cost of transportation and storage

Dormant period

Under normal conditions the eyes of a potato will not sprout during the first few weeks after harvest, even if temperatures are favourable. This is called the dormant period. Normally it is defined as that between harvesting and the time when, at normal temperatures, the eyes begin to sprout in earnest.

The length of the period depends on:

1. **Variety**
2. **Degree of maturity when harvested**: - Potatoes harvested immature have a rather longer dormant period, but it must be remembered that such tubers have usually been lifted earlier and will in consequence start to sprout at an earlier date than those harvested when fully mature.
3. **Temperatures during the growing season**: - Potatoes start to sprout earlier after a warm summer than after a cool summer. Variations due to this factor can be observed even in a small country like the Netherlands. Day length may also affect dormancy; a short day during the growing season shortens the dormant period. Warm storage speeds up the physiological processes in the tuber and shortens the dormant period but with some varieties a fluctuating temperature or a low temperature for some weeks after harvesting has an even more marked effect in this direction. It follows from the foregoing that the dormant period is far shorter in hot countries than in cooler climates.
4. **Temperature during storage**
5. **The presence of tuber injury** caused mechanically (deliberate cutting or accidental damage) or disease (e.g. blight).

Planting

- ⇒ **Planting method: -** ridge & furrow method is most popular. The seed tubers should not come in contact with fertilizer.
- ⇒ **Planting time: -** for the main/rainy season (June to September) . Planting time is early June. For off-season/irrigation (October-February). Planting time is early October. But planting can be done any time when there is no frost problem.
- ⇒ **Planting depth: -** depends on soil moisture and soil temperature. Widely used planting depth for potato is 10-15cm deep.

Spacing

- Ware potato: - 75cmX 30cm (between rows and between plants, respectively).
- Seed potato: - 60cmX20cm (between rows and between plants, respectively).

Fertility management

Urea 165 Kg/ha (split: half at planting and the rest during flowering), DAP 195 Kg/ha Side dressing at the time of planting.

7.1.10. Irrigation

Soil moisture determine yield. Irrigation is essential especially at critical stages; such as sprout formation and establishment, stolon formation, tuber initiation and tuber development. Potato requires uniform moisture throughout the growing season. Erratic soil moisture results in: development of misshapen tubers, bitter taste tuber and rough skin texture tubers. Irrigation frequency must be reduced after tuberization to avoid rooting of tubers.

7.1.11. Earthing up (ridge) cultivation

Ridging refers to the practice of hilling or earthing up the soil around the potato plant; it is a normal practice in potato production areas. Proper ridging increase tuber yield by creating favorable conditions for tuber initiation and development and also reduce yield loss. Frequency and optimum of ridging may depend on variety, soil structure and workable soil depth. As compared to non-ridging of the crop at least twice during the growing period may increase yield by 10-20%. First round ridging maybe done in 2-3 weeks after emergence

Have the following benefits;

- ⇒ Means of wed Control mechanism
- ⇒ Prevent greening of tubers when exposed to sun by covering with sufficient layer of soil
- ⇒ To control PTM (potato tuber moth) because larva will be exposed to sun
- ⇒ To increase tuberization (by increasing aeration**).**

7.1.12. Harvesting

The size of the tuber increases until the vines become dry. In developed countries, potatoes are harvested by mechanical harvesters. In Ethiopia, they are manually harvested by digging up the ridges with a spade. Care must be taken that tubers are not injured during the process. After harvesting, the crop should be kept in the shade.

Early potatoes may be harvested before maturity when the skin may flake off readily. Potatoes for storage should be allowed to mature and develop a thick skin and a layer of suberin to reduce moisture loss. Top die down as the tubers mature. Maturity may be hastened by killing the tops with chemicals. Commercial harvest is accomplished by mechanical diggers which dig one or more rows at a time and may deliver the crop direct to trucks driven alongside. Storage is in well-insulated and ventilated storage houses where, after a preliminary curing period, the temperature may be held at about 40°F. Lower temperature will result in starch in the tubers being changed to sugar. The reaction is a reversible one, and so tubers which become sweet from chilling should be held at 40 to 50°F for about two weeks before marketing.

7.1.13. Potato postharvest management

Postharvest management in potato is a set of operations and functions between crop production and consumption. Potato in inherently perishable. During the process of harvesting, storage, distribution and marketing substantial losses are incurred which range from a slight loss of quality to substantial spoilage. Postharvest losses may occur at any point in the marketing process, from the initial harvest through assembly and distribution to the consumer. The causes of losses are many: physical damage, physiological decay, water loss. The tuber, once harvested, is susceptible to environmental influences and requires proper handling and processing in to value added products that have long shelf life.

Major postharvest losses

- ⇒ Physical, biochemical and physiologically
- ⇒ Respiration
- ⇒ Loss of moisture
- ⇒ Loss in dry matter content
- ⇒ Sprouting

⇒ Pathogenic losses

Storage methods

1. **Cold storage**
   - ➢ Most effective to maintain tubers in good condition
   - ➢ Rarely used in most tropical countries
   - ➢ Temperature and relative humidity should be adjusted to 2-4^{0}C and 75-80%, respectively.
   - ➢ Temperature below 0^{0}C cause: internal tissue break down due to chilling injury and sugar formation which reduce quality.
2. **Sack/gunny storage: -** sprouting and rotting is a problem.
3. **Diffused light storage:-**
   - ♣ Unlike cold storage it is very economical
   - ♣ Recommended in most potato growing areas
   - ♣ It avoids direct light and potato can be stored for quit long time in such storage.
4. **Pit storage**
   Dig an area that is cool and under shade to 75cm depth, 2.5m long and 1m wide. After storage cover the surface with leaves or dry grass and provide ventilation by providing tubes of bamboo.
5. **Field storage**: - leave the matured tubers in the field un-harvested for some times.
   Drawbacks
   - ✓ Risk of rain
   - ✓ Amount of tubers are not known
   - ✓ Difficulty in harvesting if extremely dry weather
   - ✓ Total weight of tuber will decrease especially if the soil is dry

7.1.14. Protection of Potato

a. Potato Disease Management

Both early and late blight are major fungus diseases. Fusarium wilt, ring rot, scab, rhizoctonia, and virus diseases such as leaf roll and mosaic may be troublesome. Aphis, wireworms, leaf hoppers, and Colorado potato beetles are insect pests. A complete spray program is usually required.

Late blight (LB) and tuber moth are the most significant disease and pest among the others which constraint the production of potato across the major production areas of the country.

N.B. Currently, among some constraints the absence of improved seed tuber production and its delivery system have resulted in the wide spread use of disease susceptibility, low yielding and poor quality of seed tubers country.

b. Potato Pest Management

Potato tuber moth (PTM):- the young caterpillars mine the leaves producing brown blotches. If infected tubers are planted there will be serious problem in the field. It attacks stem and tuber.

Other pests: cutworms, leafhopper, Aphid, ants.

7.2. Sweet Potato (*Ipomoea batatas* (L) lam)

7.2.1. Introduction

Sweet potato (*Ipomoea batatas* (L) lam) is is a dicotyledonous plant that belongs to a member of the morning glory or bindweed family, the convolvulaceae. It is the only member of the genus Ipomoea whose roots are edible and is undeniable one of the world's most important food crops due to its high yield and nutritive value. It is the only hexaploid (6x = 90) in this section and its origin is unknown. Section Batatas continues to undergo revision but contains approximately 12 other species, most of which are diploid (2n = 30), with a few tetraploids (4x = 60). Sweet potato, like cassava, was also domesticated in Central America but now is basically a crop of Asia which accounts for about 93% of world production. Other very important centers of diversity exist in sub-Saharan Africa, Papua New Guinea, and Indonesia. Sweet potatoes are a vine - like training perennial, but plants are typically grown as an annual from stem cutting called slips. Sweet potato, being heterozygous, exhibits a wide variety of morphological traits and nutritional qualities with differences in dry matter, fibre, ash, vitamin B_2 and oxalate contents. The shoot tips provide and excellent source of vitamin B_2. In the temperate areas sweet potato is commercially propagated asexually y sprouts from the tuberous roots, in the tropics; by shoot cuttings (slips) from the growing plants. Sweet potato among other root crops plays an important dietary role in many parts of tropical Africa. It is grown over a wide range of environments, from sea level up to 2400 m.a.s.l, mostly by small farmers. Its compatibility with various types of limited input farming systems and reliability under such conditions as drought, high rainfall and low soil fertility levels have made it an attractive crop to farmers. On steep slopes where sweet potatoes cover the ground they prevent erosion better than most other crops. Furthermore, after planting sweet potato can cover the ground quickly and suppress weeds. In addition to being important human food as a source of carbohydrates and vitamin A, sweet potatoes provide animal feed and raw materials for industrial purposes. Hence, with these desirable characteristics of tolerance to adverse environmental conditions and its multipurpose uses, sweet potato contributes greatly to framers food and income security. Food security is a major problem in Ethiopia largely caused by poverty, in adequate food production and ecological changes brought about by increasing population pressure and continuous degradation of productive soil. Root and tuber crops have the potential to tolerate drought and can yield ten folds than cereal crops. As judge from their potential and actual yields root crops including sweet potato have the potential to more than double their production and thus bring about food self-sufficiency. Among root and tuber crops, sweet potato is one of the world's major crops, especially in developing countries, where it is ranks third in value of production and fifth in caloric contribution to family food self-sufficiency, income generation and soil based resource conservation is indispensable.

The features of the root crops, which favor their production for food security in include:

- Low production cost and tolerance to adverse condition

- Produced twice a year with proper management
- Perform under marginal soil conditions
- Play in environmental protection by checking by erosion
- Surplus products (both toots and leaves) may not be wasted.

Sweet potato is large, starchy, sweet tasting tuberous roots are an important root vegetable. The young leaves and shoots are sometimes eaten as greens. It is one of the major root crops of Ethiopia, which is cultivated around home for several years and is used for food and feed. This crop has high starch and low amount of vitamins and proteins. Even though eating its leaf part at green stages is not accustomed in Ethiopia, it has high starch and protein contents. In 2015/16 cropping season, the total area under production reached 41,039.31 hectares and the production is estimated to be over 13,723,268.22 quintals.

7.2.2 Adaptation of sweet potato

Sweet potato grows in tropical, sub-tropical, and warm temperature regions of the world, but the crop is essentially a warm weather crop, which perform best in temperature above $24/25^0$c. When temperatures fallow below 10^0c, growth is severely retarded. The crop is damaged by frost, and this fact restricts its cultivars in temperate regions to areas with a minimum frost free period of 4-6 months. The optimum temperature for tuber growth is 25^0c. The crop is a sun loving crops and does best where the light intensity is relatively high. Moisture in the form of rain fall or irrigation water must be available during the dry season (especially during the first 6 weeks to 8 weeks after planting) because the time when tuber initiated-soil of Sunday loam with food aeration is suitable for tuber growth poorly drained and poorly aerated or saline soils tend to retard tuber development growth is best at altitude from sea level to 2100 m.a.s.l.

7.2.3 Phonology of sweet potato

Sweet potato is a perennial plant but it is normally grown as an annual. The growth of such plant occurs in three more or less district phases;

1. **Initial phase** – when the fibrous roots grow extensively and there is only moderate growth of the vine;
2. **Middle phase** – when the vines make extensive growth and the tubers are initiated; a tremendous increase in leaf area occurs during this phase;
3. **Final phase** – when tuber bulking occurs and very little further growth of the vines and fibrous roots takes place; total leaf areas stays constant early in this phase, and then begins to decline;

The respective duration of these three phases in sweet potato may vary with cultivars and environmental conditions.

- First phase from planting to 9.5 weeks.
- Second phase from planting to 9.5 weeks to 16 weeks, and

- Third phase for the rest seasons.

Until 2016, 26 sweet potato varieties were released in Ethiopian agricultural research institutes and universities.

Table 7.3. Recommended sweet potato varieties in different production areas, 1983 - …..

Varieties	Year of release	Maturity group	Maturity Period/days	Adaptation Zone/alt	merits	Root yield
Kudadie	1996/7	Early	90-120	Low and mid	TSPW@	24.08
Fallaha	1996/7	Early	90-120	Low and mid	TSPW@	16.66
Guntute	1996/7	Intermediate	121-150	Low and mid	TSPW@	35.35
Damota	1996/7	Inter mediate	121-150	Low and mid	TSPW@	30.68
Bareda	1996/7	Inter mediate	121-150	Low and mid	TSPW@	29.59
Awassa-83	1998	Late	151-160	Mid	TSPW@	36.61
19200-vIII	-	Early	90-120	Low and mid	TSPW@	17.343
Belella	2002	Early	90-120	Low and mid	TSPW@	17.62
192026-II	-	Medium	120-150	Low and mid	TSPW@	17.42
192009-IX	-	medium	120-150	Low and mid	TSPW@	17.3
Koka-6	1987	medium	120-150	Low and mid	TSPW@	26.91.
Koka -12	1987	medium	120-150	Low and mid	TSPW@	25.4

Source: Assafa-2001, training manual @TSPW-to sweer potato weevil

Varity	Year of Release	Yield (t/ha)	Adaptation Zone/ Altitude (m.a.s.l)	Released by (Breeder/Maintainer)
Koka 12		13.95	1400-1800	
White star		13.39	1400-1800	
Cemsa (Bako)		22.16	1400-1800	
Cemsa (Awassa)		24.32	1400-1800	
Koka 18		28.7	1400-1800	
375		24.96	1400-1800	
AJAC-1		23.27	1400-1800	
Tis1499		21.98	1400-1800	
Awassa-83	1997/98	20.7	mid and highland	AwARC/SARI
Tola	2010			BARC
Ma'e	2010			WARC/EIAR
Jari	2008			SARC/ARARI
Birtukanie	2008			SARC/ARARI
BERKUME	2007			HAU
ADU	2007			HAU
Balo	2006			BARC/OARI
Ordollo	2005			AwARC/ SARI

Kero	2005			AwARC/ SARI
Tulla	2005			AwARC/ SARI
Kulfo	2005			AwARC/ SARI
Dimitu	2005			BARC /OARI
Temesgen	2004			AwARC/SARI
Beletech	2004			AwARC/SARI
Belela	2002			AwARC /EIAR & ADARC/ARARI
Dubo	1997			AwARC/SARI
Hawassa-09	2017			HARC/SARI

Source; MoARD, 2016

7.2.4. Production Constraints

- Poor crop managements and use of low yielding cultivars
- Weed competition
- Low or high plant density
- Insect pest
    - Sweet potato weevil (36-78%) yield loss in Uganda
    - In east and south part of Ethiopia 40% yield loss and 25% vine loss resulted from sweet potato weevil
    - Leaf caterpillar accounts for about 55% yield loss around southern parts of Ethiopia
    - Low or high application of fertilizer
    - Lack of improved production packages (Gelmesa ,2006)

7.2.5. Cultivation of sweet potato

Land preparation

Field should be cleared, plowed, disked and harrowed and leveled so as to prepare so as to prepare a desirable bed or ridge. Ridge with recommended spacing should be prepared out after laying out the field. The use of mound or ridges is imperative if the soil is relatively compact or the water table is close to the surface. Because mound or ridges permits easer root penetration and facilitate harvesting.

Planting material and propagation

Sweet potato is often propagated vegetative and rarely through seed. The planting materials are generally obtained from sprouts or draw produced from tubers and from vine cuttings. The most important method is to obtain cutting for direct planting from freshly harvested vines of matured crops. Ethiopian farmers commonly use vine cuttings in all growing seasons. This planting material can be obtained from the top, middle and basal portion of the vine. But the possibilities of establishment under field conditions are variable. Propagating sweet potato by using the tubers is not recommended as a general practice, because it is usually results in very low yield. Propagation of sweet potato by seed is also practice for breeding purpose.

Generally vine cuttings are recommended than sets for several reasons:

- Plant derived from cuttings is free from soil borne diseases
- Propagating with the vines the entire tuber harvest can be saved for consumption or utilization of the family instead of reserving some of the tubers for planting purpose.
- Vine cuttings give more yields and produce tubers of more uniform size and shape.

6.2.6. Planting method

This operation involves the insertion of basal portion of the vine in to the soil. Insertion is nearly such that the vines are nearly horizontal (about 45^0c inclined). If it lies very deep tuber yield may be reduced. Hand planting (manually) or mechanical translators are used.

Plant spacing

The vines are planted a with in row spacing of 40cm between plants and 100cm between rows on the ridge in areas where irrigation water used and 60cm between plants in rained areas. Usually one vine per spot is planted, but 2to 3 vines may be planted to increase survival rate. When the crop is intercropped the space between the plants will depend on the number and density of the other crops.

Planting time

In areas where the crop is cultivated using rainfall it is best to plant early in the rainy season so that the crop can make adequate growth and mature before the onset of the dry season. But in irrigated areas like middle Awash valley the crop is cultivated any time of the year.

6.2.7. Fertilization application

Even though sweet potatoes may give reasonable yields on relatively poor soil, the crop response well to NPK application. A 6:9:15NPK fertilizers applied at 560-1120kg/ha may be generally recommended. But in general the exact type and dosage of fertilizer used will depend on the mature of the soil and cultivars, but excessive N should be avoided since it delays tuber formation and promotes shoot growth at the expense of tuber growth.

6.2.8. Harvesting

The stage of maturity at which sweet potato is harvested depends up on the varieties. In general maturity periods are determined by the following methods:

- ⇒ Time from planting to harvesting depend on cultivars
- ⇒ Change of the leaves and vines to yellow colors
- ⇒ Pres the tuber parts and observing whether the tuber fluid colors are changed or not matured tubers fluid colors does not change and dried immediately
- ⇒ The crop started to develop flower bud
- ⇒ The soils around the tubers started to cracking

Most cultivars mature 5 month after planting. Too early results in low yields while and unduly delayed harvest may cause the tubers to become fibrous. Delaying the harvest for too long encourage the build-up of the sweet potato weevil, which attacks the tubers. Care should be taken to avoid tuber wounding during the harvesting operation. Mechanical harvestings are in use in various parts of the world. Such machines harvests first remove the vines and then dig out the tubers.

6.2.9. Storage and Curing

For storage cool, free of moisture and air ventilated areas are better for long storage. After harvest but before storage the tubers are subjected to cutting, a process, which promotes the healing of wounds, inflicted during harvesting, and toughens the tuber skin. Subjecting the freshly – harvested tubers to a temperature of 27-29.5^{o}c best does curing and a RH of 85-90 for 4-5 days done in well ventilated stored house.

In most cases producers simply store their sweet potatoes under ambient condition in basket in underground pits, or on platforms. Since temperature under such conditions are relatively high (16 ^{o} c), the tubers tends to become pity due to the development of inter cellular air spaces within the tuber fresh. Moreover, tuber respiration is high and sprouting occurs readily. For this reasons tubers tend to deteriorate after only one or two months of storage. For more prolonged storage of sweet potatoes in the tropics the lowing of temperatures with refrigeration sis essential.

7.3. Cassava (*Manihot esculenta*)

7.3.1. Botany

Cassava is a woody shrub of the Euphorbiaceae (spurge family) native to South America and the Caribbean that is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, a major source of carbohydrates.

Cassava is the third largest source of carbohydrates for human food in the world, with Africa its largest centre of production. The flour made of the roots is called tapioca. Cassava is classified as "sweet" or "bitter" depending on the level of toxic cyanogenic glucosides. Improper preparation of bitter cassava leads to a large number of cases of a disease called konzo. Nevertheless, farmers often prefer the bitter varieties because they deter pests, animals, and thieves.

7.3.2. Description

Cassava has a woody cordon runs along the root's axis. The flesh can be chalk-white or yellowish. Cassava roots are very rich in starch, and contain significant amounts of Ca (50 mg/100g), P (40 mg/100g) and vitamin C (25 mg/100g). However, they are poor in protein and other nutrients. In contrast, cassava leaves are a good source of protein if supplemented with the amino acid methionine despite containing cyanide.

7.3.3. Adaptability

Crops such as yam, maize, banana and plantain, cowpea or sorghum and millet are eco-regionally specific; whereas cassava is probably the only crop whose production cuts across all ecological zones.

7.3.4. Economic impact

World production of cassava root was estimated to be 184 million tonnes in 2002, the majority of production is in Africa where 99.1 million tonnes were grown, 51.5 million tonnes were grown in Asia and 33.2 million tonnes in Latin America and the Caribbean. Nigeria is the world's largest producer of cassava. However, based on the statistics Thailand is the largest exporting country of dried cassava with a total of 77% of world export in 2005. The second largest exporting country is Vietnam, followed by Indonesia and Costa Rica.

Cassava, together with yams and sweet potatoes are important sources of food in the tropics. The cassava plant gives the highest yield of food energy per cultivated area per day among crop plants, except possibly for sugarcane. Cassava plays a particularly important role in developing countries' farming - especially in sub-Saharan Africa - because it does well on poor soils and with low rainfall, and because it is a perennial that can be harvested as required. Its wide harvesting window allows it to act as a famine reserve and is invaluable in managing labor schedules. It also offers flexibility to resource-poor farmers because it serves as either subsistence or a cash crop. Cassava is considered as Africa's Food Security Crop.

During the Nigerian civil war, Flora Nwapa, a Nigerian novelist and poet wrote in praise of cassava:

We thank the almighty God
For giving us cassava
We hail thee cassava
The great cassava
You grow in poor soils
You grow in rich soils
You grow in gardens
You grow in farms
You are easy to grow
Children can plant you
Women can plant you
Everybody can plant you
We must sing for you
Great cassava, we must sing
We must not forget
Thee, the great one

7.3.5. Uses

Human food

Cassava-based dishes are widely consumed wherever the plant is cultivated. Some of these dishes have regional, national, or ethnic importance.

Bio-fuel

In many countries, significant research has begun to evaluate the use of cassava as an ethanol bio-fuel. Under the Development Plan for Renewable Energy in the 11th Five-Year Plan in China, the target is to increase the application of ethanol fuel by non-grain feedstock to 2 million tonnes, and that of bio-diesel to 200 thousand tonnes by 2010. This will be equivalent to a substitute of 10 million tonnes of petroleum. As a result, cassava (tapioca) chips have gradually become a major source for ethanol production.

Animal feed

Cassava is used worldwide for animal feed as well. **Cassava hay** is hay which is produced at a young growth stage, 3–4 months and being harvested about 30-45 cm above ground, sun-dried for 1–2 days until having final dry matter of at least 85%. The cassava hay contains high protein content (20-27% Crude Protein) and condensed tannins (1.5-4% CP). It is used as a good roughage source for dairy, beef, buffalo, goats, and sheep by either direct feeding or as a protein source in the concentrate mixtures.

Ethno-medicine

The bitter variety of *Manihot* root is used to treat diarrhea and malaria. The leaves are used to treat hypertension, headache, and pain. Cubans commonly use cassava to treat irritable bowelsyndrome, the paste is eaten in excess during treatment. As cassava is a gluten free natural starch, there have been increasing incidences of its appearance in Western cuisine as a wheat alternative for sufferers of coeliac disease.

Unprocessed cassava root

The cassava root is long and tapered, with a firm homogeneous flesh enclosed in a detachable rind, about 1 mm thick, rough and brown on the outside. Commercial varieties can be 5 - 10 cm.

Environmental conditions for cassava growth

- It does best in warm, moist climate 25-29^{0}C
- It does very poorly under cold climate below 10^{0}C
- Rainfall 1000-1500mm per year
- It is well adapted under conditions of drought 500mm per year

Cassava is a valuable crop

- Low moisture growth will cease and the plant shades some of its old leaves
- When moisture is again available the plant will resume growth and will produce new leaves
- It is only during the first few weeks after planting the cassava plant cannot tolerate drought

Land preparation for cassava

Most common are planting on unploughed land and Planting on mound.

Method of planting

- Inserting the cutting vertically
- Planting horizontally
- Planting at an angle

Planting Material

- Length of cutting
- Age of cutting
- Selection and handling of cutting
- Orientation of the cutting
- Time of planting

Field Operations

• Weed Control
• Fertilization
• Harvesting

Harvesting and Postharvest handling and storage

Cassava is harvested by hand by raising the lower part of stem and pulling the roots out of the ground, then removing them from the base of the plant. The upper parts of the stems with the leaves are plucked off /pick off before harvest. Cassava is propagated by cutting the stem in to sections of approximately 15 cm, these being planted prior to the wet season. Cassava undergoes postharvest physiological deterioration, once the tubers are separated from the main plant. The tubers, when damaged, normally respond with a healing mechanism. However, the same mechanism, which involves coumaric acids, initiates about 15 minutes after damage, and fails to switch off in harvested tubers. It continues until the entire tuber is oxidized and blackened within two to three days after harvest, rendering it unpalatable and useless.

PPD is one of the main obstacles currently preventing farmers from exporting cassavas abroad and generating income. Cassava can be preserved in various ways such as coating in wax or freezing.

The major cause of losses during cassava chip storage is infestation by insects. A wide range of species that feed directly on the dried chips have been reported as the cause of weight loss in the stored produce. Some loss assessment studies and estimations on dried cassava chips have been carried out in different countries.

Cassava pests
In Africa the cassava mealy bug (*Phenacoccus manihoti*) and cassava green mite (*Mononychellus tanajoa*) can cause up to 80% crop loss, which is extremely detrimental to the production of subsistence farmers. These pests were rampant in the 1970s and 1980s but were brought under control following the establishment of the IITA. The Centre investigated biological control for cassava pests; two South American natural enemies *Apoanagyrus lopezi* (a parasitoid wasp) and (a predatory mite) were found to effectively control the cassava mealybug and the cassava green mite respectively.
The cassava mosaic virus causes the leaves of the cassava plant to wither, limiting the growth of the root. The virus is spread by the whitefly and by the transplanting of diseased plants into new fields. Sometime in the late 1980s, a mutation occurred in Uganda that made the virus even more harmful, causing the complete loss of leaves.
Cassava Diseases

- Virus Diseases
  - Bacterial Diseases
  - Fungal Diseases

The Future of Cassava

- Its easy cultivation
- Propagation is by means of none edible stem portion
- High yield per hectare
- Cheaper source of food calories than most crops
- Population increase

7.4. Enset *(Ensete ventricosum* (Welw.) Cheesman)

7.4.1. Introduction

Given the restricted geographic distribution of domesticated enset agronomists and bio-geographers have long considered the Ethiopian highlands to be the primary center of origin for enset agriculture. Anthropologists, archaeologists, historians, and other scholars have also developed theories that argue for the domestication of enset in Ethiopia as early as 10,000 years ago.

Enset [*Ensete ventricosum* (Welw.) Cheesman] is a major multi-purpose crop in Ethiopia, which has been identified as the center of origin and diversity of enset. Enset is a perennial monocarpic crop belonging to the Musaceae family. For thousands of years it has been used as a food crop in Ethiopia where it was once domesticated. Enset is an important co-staple crop for >20% of the Ethiopian population living in the southern and south western parts of the country, including many ethnic groups.

Enset (*Ensete ventricosum*) is the main crop of a sustainable indigenous Ethiopian system that ensures food security in a country that is food deficient. Enset is produced primarily for the large quantity of carbohydrate-rich food found in a pseudostem and an underground corm called"Hamicho"

7.4.2. Environmental adaptation

Domesticated enset is planted at altitudes ranging from 1,200 to 3,100 meters. However, it grows best at elevations between 2,000 and 2,750 meters. Most enset-growing areas receive annual rainfall of about 1,100 to 1,500 millimeters, the average temperature of enset growing areas is between 10 and 21 degrees centigrade, and the relative humidity is 63 to 80 percent.

Does Enset affect the environment?

- Observations in areas that have been planted with enset for many years suggest that native soils have been altered positively by the long-term application of manure.
- Enset's perennial canopy of leaves and the abundant accumulation of litter also reduce soil erosion
- Because enset production improves soils, particularly with adequate manure, many enset fields have been in continuous production for decades, if not centuries. because of the multiple roles that manure plays in improving soils biologically, chemically, and physically
- What does the current situation looks like today.

Enset affects the physical environment around houses where it is most commonly grown. Enset serves the same role as trees, providing people, other plants, and animals with protection from wind and sun. Having a field that partially encompasses the homestead is considered aesthetically desirable by enset-based societies; enset beautifies the Ethiopian landscape by its thick, dark green foliage.

Enset also affect the macro-environment of an area, enset, with deep roots and leaf canopies of long duration; improve the hydrological dynamics of an area, As the proportion of enset increases with respect to annual species, water infiltration increases and surface runoff decreases, resulting in more water in the soil and aquifers. The result is increased water availability and greater volume and duration of discharge to springs, decreasing the effective length of the dry season.

7.4.3. Uses

The food uses of Enset

The major foods obtained from enset are kocho, bulla and amicho. Kocho is the bulk of the fermented starch obtained from the mixture of the decorticated (scraped) leaf sheaths and grated corm. Although many different dishes are prepared from kocho, a pancake-like bread is the most common Bulla is obtained by:

1) Scraping the leaf sheath, peduncle, and grated corm into a pulp;
2) Squeezing liquid containing a starch from the pulp;
3) Allowing the resultant starch to concentrate into a white powder; and
4) Re-hydrating with water. It is considered the best quality enset food and is obtained mainly from fully matured enset plants. Bulla can be prepared as a pancake, porridge, or dumpling.

Amicho is the boiled enset corm, usually of a younger plant. Enset plants may be uprooted for preparing meals quickly if the amount of enset harvested is insufficient, or for special occasions. The corm is boiled and consumed in a manner similar to preparation methods for other root and tuber crops. Certain clones are selected for their amicho production.

Non-food uses of Enset

Enset provides fiber as a by-product of decorticating the leaf sheaths. Enset fiber has excellent structure, and its strength is equivalent to the fiber of abaca, a world-class fiber crop. About 600tons of enset fiber per year are sent to factories. The fiber is used to make sacks, bags, ropes, cordage, mats, construction materials (such as tying materials that can be used in place of nails) and sieves.

Fresh enset leaves are used as bread and food wrappers, serving plates, and pit liners to storekocho for fermentation and future use. During enset harvesting enset leaves are used to line the ground where processing and fermentation take place.

Particular clones (or varieties) and parts of enset plants are used medicinally for both humans and livestock to cure bone fractures, broken bones, childbirth problems (i.e., assisting to discharge the placenta), diarrhea, and birth control (as an abortifacieant).

6.4.4. Enset propagation

Suckers are usually produced from the two- to three year-old corms (10 to 20 centimeters in diameter) and the true stem. These mother corm pieces are obtained by harvesting healthy plants, cutting off the pseudo stems, removing the roots, and removing out the center or apical bud, once the apical bud is removed, these lateral buds form suckers around the periphery of the mother corm piece. 20 to 200 suckers will be obtained per corm piece. These suckers are usually allowed to grow for one year before transplanting

7.4.5. Diseases of enset

Diseases are caused by bacteria, nematodes, fungi, and viruses. Bacterial wilt, caused by thebacteria Xanthomonas campestris pv musacearum, is the most threatening to the enset system. Bacterial wilt attacks plants at any stage, including full maturity. Enset is attacked by numerous diseases in addition to bacterial wilt. These include enset corm rot, enset sheath rot, as well as root-knot, lesions, nematodes, and virus diseases.

7.4.6. Harvesting and processing

The preferred harvesting time is before flowering. The time duration required to flowering time depends upon climatic conditions, clone type, and management. Hence, the flowering time varies from 3 to 15 years but is optimally around 6 or 7 years. Enset processing is carried out by women using traditional tools and the process is laborious, tiresome, and unhygienic.

7.4.7. How do Enset-based farming systems contribute to food security in Ethiopia

Enset-based farming systems play an important role in food security in Ethiopia. The exact role and value relative to other farming systems cannot be addressed without examining enset production and consumption in relation to the concept of food security. Food security can be explained in terms of:

1) Adequate availability of food in line with present population and demographic growth;
2) The nutritional adequacy of food intake;
3) Annual stability of the food supply;
4) Access to food (through production or the market) and
5) The sustainability of the food production capacity over the long term. Each of these five features relating to food security is discussed briefly.

Some of the most dense rural populations of Ethiopia are located in regions practicing enset-based farming in the south western highlands. Rahmato (1996) notes that; among the Wolayta as landholding size declines, there is an increase in the cultivation of enset. These observations indicate that the human carrying capacity (i.e., the number of people per unit of land area that can be adequately fed by the food produced on the same land area) of enset and enset-based farming systems is high and is likely greater than other crops and cropping systems for the same agroecology and inputs.

7.5. Carrot (*Daucus carota* L)

7.5.1. Botany

Carrot is the major vegetable umbellifer cultivated worldwide. Cultivated carrots can be separated into two types: eastern/Asiatic and western. Eastern/Asiatic carrots have reddish purple (anthocyanin-containing) or yellow roots, pubescent leaves which give a grey-green appearance, and a tendency for early flowering. Western carrots have orange, yellow, red or white roots, less pubescent green leaves, and less tendency to bolt without extended exposure to low temperatures. Domestic carrots may have evolved from a wild form similar to its relative known in North America as Queen Anne's Lace. The family name comes from the flower form, which is an umbel. Characteristic of most of the family's plants, an umbel has indivi-dual flower stalks originating from the same point on the stem

7.5.2. Origin

- ✓ Carrots probably originated in Asia around northwest India
- ✓ Cultivation of carrots for medicinal purposes began 2000 to 3000 years ago
- ✓ Yellow types were eventually selected and produced in Syria and Iran in the ninth or tenth century
- ✓ Carrots were introduced to China by the thirteenth century and cultivation spread from the Middle East to Italy, Spain and throughout Europe by the fourteenth century
- ✓ Eventually, white and orange types were selected
- ✓ Orange types, first grown in the Netherlands during the seventeenth century, were brought to North America by early settlers.
- ✓ The root was popular with Native Americans and production currently exists worldwide
- ✓ One of the reasons production is so widespread is that carrots are the major single source of Vitamin A in the diets of many cultures
- ✓ They are also a good source of other vitamins, minerals and fiber.
- ✓ Carrots are produced for a variety of uses
- ✓ Fresh market production for retail sales is still an important market
- ✓ Fresh packed articles include peeled baby carrots, carrot sticks, shredded carrots and salad mixes.

Modern cultivated carrot has been derived from the wild carrot found in Europe, Asia and Africa (George 1985). Carrot is very popular root crop and widely cultivated in Ethiopia.

7.5.3. Economic importance, uses and composition

Health and nutritional purpose

- They were used for a myriad of medicinal purposes including
- Stomach ulcers,
- Abscesses,
- Bladder,
- Liver and kidney problems, to aid in childbirth and even as aphrodisiacs

Food use

- ✓ Carrots are popular as snack foods, for deli trays, in salads, cooked in casseroles,
- ✓ as main vegetable dishes as well as numerous other culinary creations

Economic uses

- Fresh market production for retail sales is still an important market
- Fresh packed articles include peeled baby carrots, carrot sticks, shredded carrots and salad mixes.
- Processing markets include baby food production, frozen and canned products.

Carrot production and trends in Ethiopia

Currently, about 12345.8 t of carrot is produced in Ethiopia on 2215 ha of land (CSA, 2010/11). Although the production trend is not consistent from year to year, the production of carrots has doubled between 2004/5 and 2010/11 (Table 1) mainly due to increasing urbanization and the recognition of carrots as an income and nutrition source. Farmers in Hararghe area also generate foreign currency from exporting carrots to neighbouring Djibouti and Somalia. Moreover, foreign currency income obtained from exporting fresh or chilled carrots and turnips increased from a mere 581 USD in 1997 to 517,172 USD in 2011 (Table 2). In addition, a significant number of individuals get their income from brokering, trading (wholesale or retail), and transporting carrots.

Table 1. Carrot production in Ethiopia from 2004/5 to 2010/11

Year	No of holders	Area (ha)	Production (t)	Productivity (t/ha)
2010/11	117649	2214.9	12345.8	5.6
2009/10	157032	2712.7	18229.3	6.7
2008/9	205637	2100*	13466.6	6.4*
2007/8	149484	1400*	10000*	7.1*
2006/7	137052	946.7	6694.1	7.1
2005/6	134358	1071.2	6881.5	6.4
2004/5	138208	1741.0	17.9	10.3

Source: CSA, 2004/5 to 2010/11

*Source: faostat.fao.org

Table 2. Export of fresh or chilled carrots and turnips from Ethiopia*

Year	Destination	Net weight (tones)	Value (USD)
1997	Djibouti	0.34	581.51
1999	Djibouti	1.76	398.91
2000	Djibouti	0.10	14.80
2001	Djibouti, Somalia, USA	404.19	72,890.27
2002	Djibouti, Sudan	414.77	66,403.84
2003	Djibouti, Sudan	427.96	72,474.71
2004	Djibouti, Svalbard & Jan Mayen Islands , USA	399.13	61,013.67
2005	Djibouti, Jamaica	372.70	55,547.17
2006	Djibouti	500.05	75,445.23
2007	Djibouti	640.62	96,635.21
2008	Djibouti	587.57	87,965.55
2009	Djibouti	798.54	120,023.40
2010	Somalia, Djibouti,	1675.65	316,912.00
2011	Somalia, Djibouti,	2753.52	517,172.70
Total		8980.39	1,543,479.00

7.5.4. Climatic and soil requirements

Elevations

- Carrot is cool season crop, but some cultivars can tolerate quite high temperature
- They grow best above 1000 masl where temperature is between 16 and 21^0C and rainfall is between 700 and 800mm
- In Ethiopia carrots are grown up to 2800 masl in the central highlands

Temperature effect

- Optimum plant growth temperature is (16-24 ºC)
- High temperatures, reduce root length, may produces fibrous, unmarketable carrots
- Low temperatures, long root carrots with poor color

Soils

- Carrots grow well on deep (20-30cm Minimum) friable, well drained soils
- Preferred soil types, are loam and sandy loam
- Optimal soil pH is 5.5 - 6.5

- Sandy soil produces early yield, for higher yields, silt and silt loams are recommended
- Fresh market cultivars are mostly planted in lighter soils (sandy soil)

6.5.5. Cultural practices/agronomy of carrot

Carrots are produced in a wide range of agro-ecologies from the lowlands to the highlands of Ethiopia. They are frost tolerant and have become one of a few alternative crops that can be grown in the frost prone highlands around 3000 masl. They grow in well drained alluvial and sandy loam soils but not in heavy clay and water-logged soils. Carrots are usually grown on small plots in the backyards of town and peri-urban dwellers for family consumption; however, some farmers grow carrots on up to 0.25 to 1 ha as a means of income. Carrots can be grown throughout the year if rain and irrigation water is available (Table 3). In highlands that get bimodal rainfall, two cycles of carrots can be produced based solely on rain. These are the short rainy season (*Belg*, March to May) and the long rainy season (*Meher*, June to September). The third cycle is also possible between October and March with irrigation water.

Varieties:

Nantes and Chantenay are most widely grown carrot verities in Ethiopia. Nantes: -has good yield and quality of roots. Roots are long and cylindrical and orange in color; leaves are few and brittle. Chantenay:- The roots of Chantenay are shorter than that of Nantes. They are thick at the top and dark orange in color. Leaves are large and strong hence they are preferred for long distant transport and storage.

Variety	Year of release	Breeder
Haramaya 1	2014	Haramaya University
SAMSON	2011	Bejo seed B.V.-Crop grow crop production PLC

There are two types of cultivars i.e.

1. European or temperate type and
2. Tropical type or Asiatic type.

Temperate type cultivars require low temperature for some period (10^0c for 6-8 weeks) for flower induction at any time either in storage of root or under field conditions, whereas tropical type cultivars do not require low temperature for flower induction.

Table 4. Yield (t/ha) of eight carrot varieties in variety trial at Alemaya, 1960-61

Variety	Year		Average
	1960	1961	
Royal Chantenay	35.5	32.3	33.9
Imperator	28.5	26.9	27.7
Ox-heart	26.1	20.7	23.4
Nantes	33.2	35.5	34.3
Amsterdam Forcing	-	20.7	20.7
Chantenay	32.9	29.7	31.3
Nantes Improved Red	36.6	34.8	35.7
Touchone	-	29.1	29.1

Source: Kidane-Mariam (1969)

Climate:

Carrot is widely adapted to cool climate exposure of the young carrot plants to prolonged cold weather (4 to 7^0c for 15 or more days) favors seed formation. A dry warm atmosphere is desirable for maturing plants that are tough and woody.

Seed production of European or temperate type of cultivars is suited to temperate regions where climatic conditions remain comparatively drier at seed maturity.

Seed sowing:

- Carrots are sown directly onto the field, a smooth, well prepared seed bed is required
- Raised beds are recommended for carrots production l 1.5 m bed center to bed center and at least 25 cm high.
- Rows should be 25 cm apart
- The soil is cultivated 25cm depth

Root production:

Seed rate: 3.5-4 kg/ha

Spacing

Row to row = 50-70cm

Plant to plant = 10-15cm

All the cultural practices and plant protection measures are followed as per recommendation.

Root yield : 30 tons/ha (average).

Seeding Rate

- **For easer handling seed is mixed with sand**
- **Seed rate: 2 kg/ha**
- **Carrot seeds germinate in 12-18 days (three to four) weeks after sowing, the plants should be thinned to 2-2.5 cm between plants to improve root quality l 2-3 thinning are needed during crop cycle.**
- **Expected carrot yields are 4-6 ton/ha**

Fertilization

- **Carrots should be grown on soils which were heavily manured for the previous crop (cabbage, cauliflower, etc)**

Before sowing,

- **l50 kg of DAP and 25kg urea per ha should be incorporated into the soil.**

After last thinning

- **l25kg of urea/ha should be top dressed in bands when carrots are one cm diameter. If the nitrogen is applied too early, it will promote excessive leaf growth and fanging roots (forked roots). Do not apply the fertilizer too close to the carrots**

Irrigation

- The field should be irrigated immediately after sowing for rapid, uniform seed germination and stand establishment. Carrots have deep roots; they need for continuous irrigation. Carrot furrows need for 6-8 times irrigation during the growing season

7.5.6. Physiological disorder

1. **Carrot splitting or cracking:**

Although splitting or cracking of carrot is a major problem in many carrot growing areas, sufficient attention has not been paid towards this disorder.

A number of factors are responsible for carrot splitting,

i) Genetical factors.

ii) Application of heavy doses of nitrogen and wider spacing also increase splitting.

- Generally, large roots are more likely to split than small roots.

- Split carrots have a larger tops in relation to the size of the roots than the smooth carrots

Control:

i)To prevent carrot splitting, application of nitrogenous fertilizers should be optimised and

ii) Proper spacing should be maintained.

iii) Susceptible varieties to splitting should not be cultivated. Use resistant varieties.

2. Cavity spot:

This disorder of carrot has been reported from widely scattered geographical areas. The disorder appears as a cavity in the cortex, in most cases the subtending epidermis collapses to form a pitted lesion. This lesion may be infected if secondary organisms are present.

Cause: Calcium deficiency.

Control:

i) Calcium deficient soils should be avoided for carrot cultivation.

ii) Apply banced amount of nitrogen.

iii) Avoid moisture stress in the soil.

3. Forking of roots:

Root forking occurs due to rocky, stony or heavy soil. In this disorder many rootlets are formed and thequality of carrot root rduces.

Causes:

i) Hard pan under the soil

ii) Carrot grown in heavy soils.

iii) Excessive nitrogen application

iv) Moisture stress in the soil.

Control:

i) Friable and sandy loam soil is most suitable for carrot production.

ii) Provide proper spacing to plants.

iii) Apply balanced nitrogen fertilizer.

iv) Avoid moistur stress in soil by providing judicious and timely irrigation.

7.5.7. Harvesting and Handling

Carrots harvesting depending on varieties,70-100 days after planting. Most fresh market carrots are harvested partially mature, roots are 1.8 cm or larger in diameter at upper end. For fresh-cut processing, carrots are harvested immature to insure they are tender and sweet.

Harvesting

- Light irrigate the field before harvesting
- Dig on the bed with shovel, remove leaves before

Carrots are transported to the packing-shed in trucks or trailers and unloaded into water to reduce root abrasion. They then pass through a rotary root washer and sizer before moving to the packing line. The storage life of carrots is improved by hydrocooling, preferably before packing. The half-cooling time for loose carrots is 3.2 minutes. Cooling after packing is not as efficient as cooling before packing and thus takes more time. Carrots cannot be vacuum cooled efficiently. Handle carrots as carefully as possible during and after harvest to avoid damaging the roots. Injuries reduce shelf life and increase chances of decay. Fresh market carrots are especially susceptible to injury because they are harvested before maturity (i.e., the epidermis is not fully developed) to obtain the desired market-size roots. Fresh market carrots can be stored for 4 to 6 weeks if held at 32°F and 95% to 99% relative humidity

6.5.8. Diseases and pests

- The first week after emergence is very critical for pest control, and young seedlings should be watched closely for insects and diseases.
- Leaf-hoppers, armyworms, and carrot worms feed on carrots
- Damping-off may occur as seedlings emerge and can be controlled by treating the seed prior to planting
- Leaf spot diseases (Alternaria and Cercospora) may occur later in the season.
- Leaf spots can be controlled with several fungicides applied with a high-pressure sprayer (200 psi).

6.5.9. Carrot (*Daucus carota L) seed production*

Production of carrot seeds is a two-year activity making it much more difficult than seed production of annual crops. Good quality roots must first be produced (first year), these roots must be either harvested and carefully stored in a refrigerator or left in the field (if your cool seasons are not too severe), these cold-treated (vernalized) roots must be grown and supplied with pollinating insects when flowering, and seed harvested. Carrot seed must be produced where no wild carrot is growing.

Procedures

1. Grow vigorous plants

Grow plants at the same time of year and the same way you usually would do. Weak or diseased plants are subject to storage loss during vernalization and they set few seeds. Plants with pencil-sized roots may be large enough, but larger roots are preferable.

2. Vernalize roots

Carrots require 6 to 8 weeks cold treatment (2 to 5°C) for floral induction. Cool growing conditions can reduce the cold storage requirement. Roots can be vernalized in two ways. If carrots are a summer crop in your area, you can simply leave roots in the field over your cool season if your climate provides at least 10 weeks of temperatures below 15°C but where temperatures are not so cold that roots will freeze to death. Early in the growing season plants should be thinned to at least 5 cm apart. Dead or dying leaves must be removed and tops can be cut back at your usual harvest time to 5 cm to reduce transpiration and covered with mulch if necessary. When warm weather resumes, remove mulch if necessary and leaves will regrow and after several weeks a seed stalk will appear. This is the "seed-to-seed" method of carrot seed production. Losses are often very high with this method and off-types of roots cannot be eliminated since roots are not harvested and visually examined. The "root-to-seed" method is more reliable. Harvest roots when you usually would and discard off types. Trim tops back to 2 to 4 cm, air dry until no surface moisture remains, pack in paper bags with an equal volume of wood shavings, and place paper bags in closed polyethylene bags at 2-5°C. Puncture plastic bags after several weeks when water droplets accumulate inside the polyethylene film. Better storage survival is realized if prior to refrigeration, lateral and fibrous roots are removed, soil is removed by washing gently, and senescing leaves are removed. Even with these precautions carrots are often very susceptible to pathogen infection during storage. In commercial production, roots are dipped in fungicide before vernalization but this practice is not advised without extreme caution.

3. Grow vernalized plants.

For the "root-to-seed" method, plant vernalized roots when you would plant seed in the spring, taking care to keep plants well-watered but not in standing water. Seed stalk development will be evident in 4 to 6 weeks. Control of microbial (Alternaria, Cercospora,) and insect pests (aphids, spider mites) is essential to assure seed production. It is very difficult to produce carrot seed where warm humid climates favor microbial growth. Note: Carrot seed can only be produced true to type if wild carrot is not growing nearby since wild carrot will intercross and yield white-rooted plants.

4. Pollination.

Pollination is best performed by introducing bees or flies for pollen transfer during the period of receptivity. Natural populations of bees and other insects will sometimes be adequate. As an alternative, pollen movement is possible by hand or brush but seed set will often be low. Within 4 to 6 weeks after pollination the developing seed turns brown. Harvest (before the seed shatters) into paper bags to dry completely. Late-season rains can reduce seed yield drastically. Remove spines from dry seed by rubbing. Seed is now ready to plant since carrot has no seed dormancy. Store dry seed refrigerated in a moisture-proof container.

7.6. Beet root (*Beta vulgaris* L. subsp. vulgaris var. rubra)

It is indigenous to southern Europe and Asia and now fairly widely distributed in the tropics.

Areas of cultivation

Cultivated to a limited extent in the Caribbean, Malaysia, India, Indonesia, the Philippines, central, west, and east Africa.

Botanical description

A biennial glabrous herb, normally grown as annual.

Roots: including hypocotyl rounded or tapering red, enlarged with food reserves.

Stems: conical, condensed above hypocotyl.

Leaves: in rosette, dark red or green, ovate or cordate

Flowers: perniath of 5 segments; stems 5; stigma 3.

Fruits: aggregate, formed by the cohesion of 2 or more fruits. The calyx continues to grow after fertilization, becoming woody and enclosing the seed .

Seeds: small kidney shaped, brown weight of 1000 seeds = 16g.

Environmental response:

Moist soil conditions are generally essential but the roots are sensitive to excessive soil water. A high soil organic matter is required for optimum growth and sandy loam soils are usually suitable. The root system is fairly tolerant to alkaline soil conditions but sensitive to acidity. A pH of 6.0-6.8 is considered satisfactory, values lower than 5.0 reduce yield significantly. Mulch reduces the rate of water loss.

In addition to the provision an adequate supply of essential minerals in the soil before sowing, young plants usually benefit from additional application of nitrogen during the period of active growth. Boron deficiency causes the formation of internal black spots in the root tissue and may be corrected by applying 10-30kg/ha of borax. Beetroot also responds favorably to applications of sodium chloride in the region of 300-500 kg/ha.

High temperatures over 25^0C adversely affect the growth and roots are likely to show distinct zonal markings as a result of high soil temperatures.

Plants grown in moderate rainfall conditions are unlikely to require additional water but irrigation is required during dry periods to maintain a regular rate of root development.

An elevation of more than 600 m is normally required for successful root development, plants grown at sea level unlikely to produce economic yields.

Cultural requirements

Propagation and planting: Propagation is by seed, preferably monogerm or rubbed (divided). Seeds are sown in drills 25-39 cm apart, at a depth of 1-2 cm, seedlings being subsequently thinned to 10 cm apart in the rows. Transplants are rarely successful. The quantity of seed required per hectare varies from 10-20 kg. On a commercial scale, one million plants per hectare are established.

Irrigation: This may be required during the early stages of growth and during subsequent periods. Excessive soil water may produce deformed roots and irregular irrigation may induce cracking of the roots.

Growth period and harvesting

Plants normally produce roots from 5-8 cm diameter within 70-90 days form sowing. The outer surface of the roots is sensitive to damage during harvesting.

Yield of 15-24 tons/ha may be obtained with good cultural techniques, including effective weed control.

Preparation for marketing and storage

Roots should be firm, deep red in colour and free from cracks, fibrous roots or corky patches; the tops, where left intact, should be turgid and free from diseases and pests.

For fresh market: the roots are sold with or without leaves, when the leaves are attached, the roots can be conveniently tied in bunches. Surplus soil is removed by washing and some form of grading may be carried out, based on size and colour.

Bunched beetroot may be stored at 0^{O}C and a relative humidity of 90% for up to 10 days, whereas topped roots may be stored at 0–1 ^{O}C for 55–90 days at a relative humidity of 90–95%.

Use

The leaves in addition to the roots, are often used as cooked vegetable; the roots are widely used in salads and in the preparation of pickles and chutney.

7.7. Anchote (*Coccinia abyssinica*)

7.7.1. Introduction

- Anchote [(Coccinia abyssinica (Lam.) is one of the indigenous root and tuber crops of Ethiopia
- Which is widely produced in south and southwestern parts of Ethiopia (PGRC/E, 1988)
- The plant is harvested from the wild as a local source of food.
- It is often cultivated for its roots and young shoots within its native range.

7.7.2. Origin

- Anchote (Coccinia abyssinica) tubers are an endemic to the Western parts of Ethiopia
- mainly in the Western region of Ethiopia highlands in Eestern Wollega, Western Wollega, Kelam Wollega, and Mattu (Westphal, 1974).
- The most widely used vernacular name is Anchote, spelt Ancootee in Oromo.
- It is also called: Ushushu (Welayita), Shushe (Dawuro), and Ajjo (Kafigna) (Demel et al., 2010).

6.7. 3. Botany of Anchote

- Anchote (Coccinia abyssinica) is the root crop of the Curcubitacae of the Genus: Coccinia Specific epithet:
- Some of the species are highly resistant to drought
- The most widely used vernacular name of Coccinia abyssinica is Anchote

7.7.4. Economic importance, use and composition

Nutritional and health importance

- ❖ According to local farmers, it helps in fast mending of broken/ fracture bones and displaced joints,
- as it contains high calcium, and proteins than other common and wide spread root and tuber crops.
- Traditionally, it is also believed that, Anchote makes lactating mothers healthier and stronger
- the juice prepared from tubers of Anchote has saponin as an active substance and is used to treat Gonorrhoea, Tuberculosis, and Tumor Cancer

Food use

- ▪ Anchote is a valuable food source and
- Like many other root, and tuber crops, Anchote is rarely eaten raw
- Traditionally, boiled after peeling or boiled before peeling and/ or further cooking are applied prior to consumption

Economic Importance

- ✓ Anchote is not only grown for home consumption,
- ✓ But also, for sale; apart from
- ✓ Tubers as food, anchote seeds and seedlings for propagation are some of the items which are marketed

6.7.5. Climatic and soil requirements

- ✓ The general lack of information on the crop holds true for the lack of information on suitable soils for anchote cultivation.
- ✓ Westpal (1974) based on climate, altitude and soils classified the country into many agro ecological regions between which two regions have special connections with anchote.
- ✓ The south eastern part of the Ethiopian high lands: these areas are situated at altitude of 1800 m a.s.l.
- ✓ They receive 950-1500mm average annual rainfall.
- ✓ The south western part of the Ethiopian high lands including Wollega, Illubabor and Jimma has oxisols, ultisols and vertisols as major soil types.
- ✓ The southwestern part of the Ethiopian/Oromia high lands is situated at 1500-2400 m a.s.l. and receives an annual rainfall about 1500mm to over 2000mm per year
- ✓ According to Amare (1973) anchote is cultivated in areas between 1300-2800m where the annual rainfall is 62-1016mm

7.7. 6. Agronomy of anchote

Variety

- ✓ Based on the underlying (tissue) colours, two anchote accessions are well known among the farmers,
- ✓ locally called (in the Oromo language) as *dimma* (red or deep orange) and *addi* (white) .
- ✓ From the outside, both types look similar, and the only way to discover the tissue colour (red or white) is to remove the corky skin.

Propagation

- ✓ Vegetatively, it is achieved by planting either the whole tuber or by slicing it in two or more pieces, each pieces, having rootlets and an external covering

- ✓ This is usually done to establish "Mother" plants, called "Guboo" to serve as a seed source for further plantings
- ✓ while seeds are extracted from fully mature red-ripe fruits, which are harvested before they start rooting
- ✓ Such fruits are macerated or sliced to separate the seeds from the fleshy juicy part (Ambecha, 2006).
- ✓ The seeds are then mixed with an equal quantity of wood ash and dried in sun.
- ✓ The moisture content of the seeds for storage is based on the desired level.
- ✓ During this storage period the seeds are usually kept in either clay or wooden pots or wrapped in a sheet of cloth (Ambecha, 2006)
- ✓ Sowing Methods
- ✓ The existing practice is to sow the seeds by broadcasting
- ✓ After broadcasting the seeds are covered either by ploughing with oxen or more commonly using a digging hoe (Qofaro) with or without metal (Personal experience)
- ✓ When broadcasting farmers prefer a narrow spacing of about 20 cm than a wider spacing
- ✓ According to (Girma and Hailu, 2009), intra-row spacing highly affect root yield while inter –row spacing affected root yield and average root weight per plant
- ✓ The reduction of intra-row spacing from 30 cm to 10 cm resulted in increase of total tuberous root yield by 37%.
- ✓ Reduction of inter-row spacing from 100 cm to 40cm resulted in high total tuberous root yield by 37.4%.
- ✓ Therefore, 40-60cm inter row and 10cm intra- row spacing are recommended for the western sub-humid zones of Oromia, Ethiopia
- ✓ Fertilization
- ✓ Anchote responds strongly to soil fertility, particularly to wood ash and produces large sized tuber of good shape very rapidly when grown in fertile soils
- ✓ Growers know this from their long practical experience and hence prefer to grow anchote close to the home garden where a cattle pen can be put up and rotated
- ✓ This makes cow dung available as organic manure
- ✓ Other areas within the reach of the family can also be made suitable for anchote through the use of other waste as organic manure in addition to that from cow dung (Amare, 1973)
- ✓ According to Girma and Hailu (2009), 5-8 t ha-1 farm yard manure (FYM) or 46/20 kg ha-1 N/P are recommended for high yield of anchote production and enhancement of soil structure and its nutrient for the western sub-humid zones of Oromia, Ethiopia.

Chapter Eight

Production technology of bulb vegetables

8.1. Onion (*Allium cepa* var. cepa)

8.1.1. Origin and Distribution

Onion is indigenous to the area from Palestine and India. From this area it spread along the trade routes to temperate regions of Europe, North Asia, and North Africa sub-tropical regions. Onion is one of the bulb crops belonging to the family Alliaceae. It is an important bulb crop in Ethiopia. It is considerably important in the daily Ethiopian diet. All the plant parts are edible, but the bulbs and the lower stems sections are the most popular as seasonings or as vegetables in stews. It is a recently introduced crop and rapidly becoming popular among producers and consumers. It is widely produced by small farmers and commercial growers throughout the year for local use and export market. Onion is valued for its distinct pungency and foim essential ingredients for flavoring varieties of dishes, sauces, soup, sandwiches, snacks as onion rings etc. It is popular over the local shallot because of its high yield potential per unit area, availability of desirable cultivars for various uses, ease of propagation by seed, high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms. During 2015/16 cropping season, the total area under production reaches over 29,517.01 hectares and the production is estimated to be over 2,648,493.54 quintals.

8.1.2. Use and composition

One of the oldest vegetable known to man, it is popular vegetable worldwide. Onion contributes substantially to the national economy, apart from overcoming local demands. Products like bulbs and cut flowers are exported to different countries of the world. With the growing irrigated agriculture in the country, there is a great potential for extensive onion seed and dry bulb production in the different production belts of the country. Moreover,

- It is used for its distinctive pungent flavor
- Onion bulb is rich in minerals like P, Ca, Fe and carbohydrate
- It is also contains protein, vitamin C, riboflavin, thiamine and fiber
- The green leaves and mature and immature bulbs are either eaten raw or for the preparation of vegetables.
- Onions are also used in soups, sauces and for seasoning foods
- Dehydrated and onion powder are used
- Medicinal value, ornamental use

Utilization: It is used for seasoning the cooked foods and is extensively consumed as salad. They are consumed for their strong pungent flavor caused by methyl propyl sulphide.

8.1.3. Varieties

Onions are strongly influenced by day length and the varieties can be classified as either long, intermediate short day. Only short day varieties are adapted to Ethiopian conditions, that is to say, a day length of approximately 12 hours. Intermediate or long day varieties will not develop bulbs if grown in a region having a 12-hour day.

The traditional onion of Ethiopia is the red shallot, which is well adapted for growing by small farmers under rain fed conditions but which is not considered suitable for large scale irrigation. For this reason, IAR in 1970 introduced local materials of seeded onions from Sudan and started a program of man selection to adapt it to Ethiopia conditions.

The result has been the release of Adama red, Mermiru Brown, Melkam, Bombay Red, Red creole stakeayer and Mermiru white.

Red creole: - not fully adapted, seed is of variable quality and resistant to leaf diseases.

Bombay red: - Produces high production of split bulbs and of inferior quality to others

The problems of the onion export programme in Ethiopia were: 1) Susceptible to purple blotch and mildew diseases during rainy periods 2) Difficulty in drying the bulb in the field after harvest during wet weather.

8.1.4. Climatic Requirements

Onion prefers well-drained sandy loam with a high content of organic matter. The optimum altitude range for Onion production is between 700 and 2200 m.a.s.l. and the optimum growing temperature lies between 15°C and 23° C.

Soil requirements: The recommended soil for onions is well-drained sandy loam with high content of organic matter.

Altitude: The optimum elevation range for onion production is between 700 and 2200 m.a.s.l. At lower altitudes, production should be restricted to the cooler months of the year. At higher altitudes the crop takes longer to mature. Onion can be grown during the rainy season but the later part of the growing period should be dry. However, incidence of diseases may cause a considerable reduction in yield.

Temperature: The optimum growing temperatures lies between 15^{o}c and 23^{o}c.

8.1.5. Sowing

Percentage and rate of emergence of onions in the tropics seem to be highest between 20 and 27 ^{o}c. Those emerging at lower temperatures seem to be more vigorous than seedlings developed under warmer conditions. Overcrowding in the seedbed may lead to precocious bulbing especially during hot weather.

8.1.6. Land Preparation

Since onions have shallow root system, land preparation involves shallow ploughing to break the soil into friable texture to a depth of 20 to 30 cm. Prior to transplanting; the field should be properly prepared to avoid weed conserve moisture. A fine tilth improves the physical condition of the soils by increasing aeration and infiltration of water. Sticky clay soils must be avoided since they are difficult to work with and become easily waterlogged. The best situations are found in soils rich in humus. Fertile sandy, silt loam or peat soils are excellent for onion production. Heavy clay and coarse sand should be avoided.

8.1.7. Seed rate

Seeds are sown on raised nurseries at a rate of 2.5 to 3.4 kg per hectare. Onion setts (small bulbs about 1 to 3 cm in diameter) can be harvested and stored for planting them in off-season for green onions.

8.1.8. Planting

Direct sowing is most economical in most growing regions. Direct sowing is not applicable on Saline soils because germinating onions are susceptible to salt injury.

Growing onion from seedling transplant

This method is highly labor intensive. The advantage is that the relatively inexpensive furrow irrigation can be used after transplanting. Overhead irrigation is only used during the early nursery period. The nursery area is small compared with the production area. The ratio is 1:18 or 560 square meters nursery area for one hectare production area. The seed rate per hectare is 3 kg. The nursery practice is same as for other transplanted vegetables. A preventive spraying against thrips, downy mildew and Purple blotch is recommended in the nursery.

The fields are moderately moistened just before transplanting. The pre-marked beds have rows of 20 to 30 cm apart, and the seedlings are planted at spacing of 7 to 8 per meter row.

Transplanting should be done when seedlings have reached a height of 12 -15 cm and must be well organized to avoid plant losses. Great care is taken to prevent damage to the leaves during transplanting. After lifting, the roots are carefully spread while planting the seedlings to the same depth as they were in the nursery and early morning dew, helps establishment in the field. Mulching with dry grass and irrigation immediately after transplanting is recommended. Generally the recommended planting system for hand cultivation at Malkassa, during transplanting were flat top ridges with furrows 40 cm, on the flat ridges of 20 cm a part between rows and 10 cm spacing within the row. Transplanting large over-grown seedlings may result in bolting in to flower instead of bulb production.

8.1.9. Fertilizer

Fertilizer containing $NH^{+}4$ ions should not be applied close **to** the plant, as it is toxic to the onions. High N delays bulbing. Therefore, N should be applied in split doses at times of planting and top dressed at the time of bulb formation after weeding and hoeing. According to research results from Malkassa and Upper Awash, 92 kg urea per hectare applied at transplanting and 45 days after transplanting yielded better results. On the other hand the Horticultural state enterprises apply about 200 kg urea per hectare and 400 kg diammonium phosphate per hectare with the expectation of high yield.

8.1.10. Irrigation

Onion roots are shallow (about 30 cm) and therefore surface irrigation is essential for roots and bulb development. Sprinkler irrigation in steep and hilly areas is usually recommended. During the dry season, the onion crop should be irrigated at 5 to 7 days interval. A longer interval may be necessary on heavy soils. Irrigation should be stopped before the bulbs have reached their full size to promote the ripening process. If irrigation is continued too long, the proportion of thick-necked and split bulbs is likely to be higher and the keeping quality of the crop may be impaired.

8.1.11. Cultivation

Onions do not compete well with weeds. Timely shallow cultivation to destroy weeds whilst they are still young is essential for the production of good crops. When cultivating, soil should be drawn away from the plants so that when the crop is mature, the bulbs are sitting on top of the soil and only the roots are below soil level. Earthing up the crops results in bottle-shaped bulbs with very thin outer skin, which do not mature or keep well. The use of herbicides cannot be recommended in Ethiopia at present.

8.1.12. Disease and insect pest

When humidity is high or during rainy period, onion may suffer severely from downy mildew and purple blotch.

Downy mildew (*perenospora desturcto*r) : The fungus coats the outer surface of affected leaves and they soon turn yellow and die. This disease usually appears at a few points in the field and spreads rapidly under favorable conditions. The control measures are long rotation, spraying with fungicide plus sticker and seed treatment with seed dressing.

Purple blotch (*Alternaria porri*): Purple blotch occurs on the leaves, seed stems and bulbs. It first shows on the leaves as small, sunken, white, circular or irregular spots.

These spots have purple centers and increase in size to form elongated purplish blotches which may be bordered with orange bands. Darkened zones, consisting of masses of spores, develop into centers of lesions. Usually the infected leaves turn yellow and die within three to four weeks. Flower stalks are often girdled fall over before the seeds mature. The fungus grows down the leaves into the bulb. Infected bulbs appear somewhat watery at first, later the tissues turn deep yellow, then gradually dark red, and finally dark brown to black. The spores may remain viable in the soil or plant refuses for over a year.

Control measures are the same as for Downy mildew. The variety Red Creole shows some resistance to both diseases. White rot Fusarium and Pink rot have been reported in Ethiopia but are of minor importance at present.

Bacterial soft rot or neck rot: post harvest loses due to these two diseases are often high when onions are properly ripened or dried in the field. This is particularly the case when harvesting takes place during rainy periods. The only solution is artificial drying of the bulbs. The green tops should not be cut off, as infection can be spread in this way. Outer scales rot and become slimy. The rot quickly spreads to the whole bulb. Onions infected with bacterial diseases have a very offensive smell, which is easily recognized.

Pest

Thrips (*Thrips tabaci*)**:**Onion thrips are small, yellowish sucking insects, which attacks the leaves giving them a blanched appearance. The tender center leaves become curled and deformed, and the outer leaves turn brown at the tips. Thrips are most injurious during dry weather and rainy periods. The recommended control measures for thrips is to spray with insecticides plus sticker at intervals of 7 to 10 days.

8.1.13. Harvesting and post-harvest handling

Harvesting can start when 50 to 80% of the tops have fallen over. Take into consideration the following harvest operation: 1) Lift the onions with forks or with tractor-mounted onion lifters; 2) Lay onions in windows and let them dry in the field for about 5 days. Care is necessary to prevent sun scorch by covering the bulbs with the leaves of next row (outer covering); 3)

Transport dried onions to the packing and grading center. Cleaning and grading can be done by hand or mechanized with an onion cleaning and grading machine. Tops should not be removed until necks are dry. Incidence of bacterial soft rot may spread rapidly through trimming with infected knives. Roots should be trimmed as close as possible to the bulb but tops should be trimmed to a length of about 2.5 cm.

8.1.14. Onion (*Allium cepa* L.) seed production

Onion is a major bulbous crop among the cultivated vegetable crops and it is of global importance. It is a biennial crop, cross-pollinated (insects) > 90% cross.

Land requirement: Land to be used for seed production of onion should be free from **volunteer plants.** Although onion can be grown nearly in all types of soil from sandy loam to heavy clay soil, but clays are not satisfactory unless well supplied with humus to lighten them. The soils pH should preferably be 6.0-6.8.

Isolation; Onion seed field shall be isolated from contaminants viz; fields of other varieties and the fields of the same variety not confirming to varietal purity requirement for certification at least 5 m for foundation seed and certified seed during months bulb production and 1000 m and 500 m for foundation and certified seed production respectively during seed production. However, the maximum permissible limit for bulb not confirming to the varietal characteristics is 0.10 percent and 0.20 percent (by numbers) for foundation and certified seed during mother bulb production. The maximum permissible limit of off- types is 0.1% and 0.2% for FS and CS at and after flowering during seed production. Onion seed crop must also is isolated from any flowering multipliers types of onion and shallots.

Method of seed production

There are two methods of seed production. The **seed to seed** and **bulbs to seed** methods and both the methods are in use in onion seed production. But bulb to seed method is most commonly used method of seed production.

a) **Bulb to seed method:**

In this method, the seed is sown in raised bed at 4-5 cm spacing for raising the seedling. The seedlings of 12-15 cm length are transplanted and this height attained 7-8 weeks after the seed sowing. Thus, 6-8 kg seed ha^{-1} is sown. The seedlings are transplanted in previously developed beds in 15x10 cm spacing. The herbicide (Stomp) is sprayed after the transplanting and followed by irrigation to check the growth of the weeds in early crop growth stage. The recommended cultural practices followed to raise healthy bulb crop.

The bulb are lifted when the 75% plant show neck fall/top die down. The bulbs are dried /cured under naturally ventilated place then neck is trimmed leaving 2-3 cm attached with bulb. The bulbs are roughed at this stage based upon the colour, shape and size. The damaged, twin bulbs and long necked bulbs if any are discarded. The medium size bulbs weighing (50-80 g) bulbs are selected and stored. The bulbs are examined again before replanting in the following season. One hectare of bulbs from the first year will plant 3-5 ha for the seed production. The bulbs selected for seed production usually referred to as mothers' bulbs. However, the area coverage is greatly affected by storage method and losses occur during storage.

The storage temperature also influences seed yield. The temperature ranging from 4.5 to14^{0}C with an optimum of about 12^{0}C is the best for the storage of mother bulbs that are to be planted for seed production. The plants from such bulbs produce early and heavy yield than those grown from bulbs that have been stored at higher or lower temperature. The roots of the bulbs should be left intact after harvest.

The 1\3 parts of the bulb are cut before planting to examine the number of glumes, which is related to the compactness, and shape of the bulbs. More the number of glumes flatten the shape and poor the storability. To avoid rotting due to fungal infection of the bulb in field, Bavistin 10 gm in 10 lit of water is used for dipping the bulbs before planting. This should be practice in NS/BS seed production

b) Seed to seed method:

In this method seedlings are transplanted in allowed to over-winter at the same place and allowed to bolt (flowering). The seed are threshed from the mature umbel. This method does not allow to examine the mature bulb characters and field is rogued for off-types. Seed to seed method is not popular, since all the varieties are not suitable for annual seed production due to poor bolting habit and lower seed yield. The seed produced in this method is not suitable for further multiplication.

Field inspection; Field inspection is arranged at mother bulb production and seed production stage.

(a) **Mother bulb production stage**: A minimum of two inspections shall be made as follows;

- The first inspection shall be made after transplanting of seedlings in order to determine isolation, volunteer plants, off type including bolters and others.
- The second inspection shall be made after the bulbs have been lifted to verify the true to type ness.

b) **Seed production stage;** A minimum of four inspection shall be made as follows.

- Before flowering for isolation, volunteer plants, off types including bolters.
- The 2nd and 3rd inspection at flowering to check the off type etc.
- Fourth at maturity to verify the true nature of plant and other relevant factors.

Harvesting: Traditionally onion seed heads are harvested by hand when 5-10% of the capsules on individual heads expose the black seed. The harvesting of seed heads at proper maturity is essential; other-wise the seed heads shatter the seed readily. The harvesting of seed heads should be based upon the experience and the local weather conditions.

The seed heads are cut with 10-15 cm of (seed stalk) attached with head. When heads are cut are supported in the palm of hand and held between the fingers to avoid the loss of seed. The mature heads are harvested in two to three times. The harvested umbels are heaped for a few days drying before threshing the seed. But heap should not exceed 20-30 cm and should be turned each day. The onion seed crop can be harvested directly with harvester. The best time for mechanical harvesting is when the seed dry matter content is of 60-70%.

Threshing and cleaning: The material is ready for threshing as soon as it is dry and the seeds can be separated from their capsules by rubbing in the hand. Over drying may damage the brittle seed. Threshing can be done through rolling, threshing machine or combines. Onion seeds may be damaged during processing and therefore frequent check should be made to ensure that seed coat is not accidentally cracked during any operations. It can be confirmed through the examination of hand lens. The another point which need to be ensured that the threshing does not break too many of the flower pedicels from their stalk as these are difficult to separate from the seed lot in subsequent seed cleaning operation.

Seed cleaning, drying and packaging: The cleaning is achieved with an air screen machine and further upgrades the physical appearance and seed quality than seed lot should pass through the gravity separator or by floatation. In floatation process, it should not be exceed more than 3 minutes. The heavy seeds sink and poor quality seed/pedicels float off. The final seed lot must be dried down to moisture content not exceeding 12% or lower depending on the method of storage and packaging. When seed has to be packed in porous containers (cloth bag/paper bag) than seed moisture should not be >8% whereas packaging in moisture proof containers the seed moisture should be 5-6%.

Seed Storage: Onions possess one of the most rapidly deteriorating seeds among major crops. They quickly lose complete viability in less than a year when stored under hot, humid conditions. If properly stored, however, viability of onion seed can be retained for long periods and low seed moisture content and low storage temperature favor longer storage life. Of these two parameters, seed moisture content is the easiest to adjust. Onion seeds stored at 6.0% moisture content have retained viability up to three years. Small lots of valuable breeding onion seed material are often stored in desiccators over calcium chloride. Under these conditions, their moisture content will equilibrate to about 2.0% and germination can remain high for as long as nine years in storage.

Onion storage

Cured onions are suitable for storage. Rapid development of rot diseases and pre-mature sprouting can be expected in improperly cured crops. Onions are best stored in loose stacks, up to 50cm deep with good ventilation. They should not be bagged until required for market. Size grading and elimination of defective bulbs should be done before storage. Large size bulbs may be expected to have a shorter storage life than smaller once and should therefore stacked separately. The store should be sited where there is good air movement for ventilation. A suitable design under Ethiopian condition consists of an iron roof supported on upright poles and open on all sides. The floor is raised 50 cm above soil level and is constructed of poles. This allow for ventilation beneath and through the stacks of onions. After bagging for market, the bagged onions can also be stacked on the ventilated floor.

8.2. Garlic (*Allium sativum*)

8.2.1. Introduction

Garlic *(Allium sativum* L, 2n=l 6) belongs to the family Alliaceae and is the second most widely used *Allium* next to onion. It is originated on the northwestern side of the Tien-Shan Mountains of Kirgizia in the arid and semi-arid areas of central Asia (Kazakhstan). There is evidence that it has been in use in Egypt before 2000 B.C, in India and China for more than 5000 years. Garlic is one of the most ancient cultivated herbs, and is vegetatively propagated from cloves. This mode of clone propagation allows the production of a uniform crop that preserves quality traits, such as flavor and the nutritive properties of the plant.

During **2015/16** cropping season, the total area under production reaches **11,845.53** ha and the production is estimated to be **1,077434.57** quintals. Increased production of garlic in Ethiopia is due to demand from local market and development of export market. In Ethiopia, subsistence farmers in the high lands grow it traditionally but yields are low.

8.2.2. Origin

Originated in central Asia. Garlic has a distinct odour produced by an organic sulfur compound known as Allicin, which has a potent antibacterials property.

8.2.3. Botany

Monocot, plants resemble onion but the leaves are thin blades and the scale (seed stalk) is solid unlike the tabular form of onion. Garlic also distinguished from onion in that foliage leaves bases never store food. Flowers are invariable sterile. The bulbs are composed of cloves, which are usually ten in number. Each clove consists of two mature leaves and a vegetative bud. The outer most leaf is a dry with and a bored blade. Cloves remain dormant until conditions are favorable for sprouting.

8.2.4 Use and composition

Garlic is used as a seasoning in many foods worldwide, without garlic many of our popular dishes would lack the flavor and character that make them favorites. Garlic's volatile oil has many sulfur containing compounds that are responsible for the strong odor, its distinctive flavor and pungency as well as for its healthful benefits. Medicinal activity seems to be highest in fresh garlic or garlic oil with high allicin content.

- Garlic is used as spice and condiment
- Garlic has high nutritive value than other bulb crops
- It has been considered as a rich source of carbohydrate, proteins and phosphorus, dially disulphide, allicin, alliin
- Medicinal

Varieties

Seven varieties were released **recommended for cultivation**

Variety	**Year of released**	Breeder
Tsedey 92 (G-493)	1999/00	
Kuriftu	2010	DZARC/EIAR
Holeta	2015	DZARC/EIAR
C h e f	2015	DZARC/EIAR
Chelenko I	2014	Haremaya University
Qoricho	2006	SARC/OARI
Bishoftu Netch	1999/00	DZARC/EIAR

8.2.5. Climatic Requirements

In Ethiopia, small growers in the highlands grow garlic traditionally but due to faulty cultural practices, yields are generally low. The yield in large-scale production with irrigation is expected to be about 10 tons per hectare. Garlic is adapted to cool climates and should not generally be planted at an altitude below 2000 m.a.s.l.

Higher temperature is required for optimum bulbing but cooler conditions in early stage favour vegetative growth. Excessive humidity and rainfall are detrimental to vegetative growth and bulbing. Garlic is normally grown in low rainfall areas with irrigation during the early vegetative stage.

Elevation: Elevation from 500-2000 m.a.s.l is suitable for garlic production. Garlic is also photosensitive and is more sensitive to temperature than onion. The cloves cease growth under high temperature above 25^{o}c.

In Ethiopia, garlic is adapted to cool climates and should not generally be planted at altitudes below 2000 m. It is possible to produce a rain fed crop by planting at the start of the rains, but better yields may be expected with supplementary irrigation. Amount of rainfall during the growing period (4.5 to 6 months) should be 600 mm to 700 mm. The optimum temperature for growing garlic lies between 12 and 24^{o}c.Garlic can be successfully grown in warmer climates (Upper Awash at altitude about 1100 m) than was previously thought possible. However, further trials are required in warmer climates to confirm this result.

8.2.6. Soil Requirements

On fertile well-drained sandy or silt-loam are preferred with high organic materials added to improve water-holding capacity. Rain fed crops may be planted on flat beds; but on heavy soils, which are poorly drained during the rains, it is advisable to plant on ridges as for irrigated crops**.**

Amount of rainfall during the growing period (4.5 to 6 months) should be 600 mm to 700 mm. The optimum temperature for growing garlic lies between 12°C and 24°C. Garlic withstands moderate frost. On well-drained soils, rain fed crops may be planted on flat beds; but on heavy soils, which are poorly drained during the rains; it is advisable to plant on ridges as for irrigated crops. It is essential to select land with high fertility or to apply considerable quantities of manure or fertilizers to obtain good yields.

8.2.7. Cultural Requirements

Planting

Garlic does not produce true seed and propagated vegetative through cloves. Freshly harvested garlic bulbs pass through a period of dormancy before they will start growth. Bulbs intended for use as planting material should therefore be stored under dry conditions for two to three months before being planted. Exposure to low temperature (5^{o}c) is essential in some varieties to induce sprouting, particularly if these varieties are to be grown in tropical conditions where the temperatures are above 10^{o}c. Larger clove seeds increase the yield. Also virus free cloves can add up to 50% yields.

Seeding rate

Before sowing cloves are separated and selected for good size. The quantity of planting material required to plant depends on the size of cloves and the plant population. Large sized cloves

increase. Large size cloves give higher yields than smaller sizes. The cloves should be graded and planted separately to ensure even maturity. They are dibbled manually 5 cm deep, in proper position. Planting on two-row ridges, 30cm between rows and 10cm between plants in the row, giving a plant population of 333,000 per hectare (300 to 500 kg) is recommended spacing for rain fed crops.
Significant yield increases could be achieved with irrigated crops or with well distributed rainfall by planting three rows on the flat topped ridge 15 cm apart, with 30 cm furrows between ridges, by reducing spacing in the row to 7.5 cm. This would give a plant population of 666,000 per hectare.

Fertilizer application
Eighty: ninty kg NP per hectare is needed for a good garlic crop. Potash is added if the soil is deficient in potash and N should be applied in two split doses to enhance maximum absorption. Trials are necessary before recommending for fertilizer application. However, trials carried out so far on rather poor red soil s at Holetta showed that increase of yield from 4 to 7 ton per hectare for previously unfertilized soils, to about 11 tons per hectare with application of 80 to 100 tons per hectare of cattle manure or application of the following amounts of nutrients: 120 kg P_2O_5 per hectare before planting; 130 kgK_2O per hectare before planting; 40 kg N per hectare, 50 kg N per hectare four weeks after planting and 50 kg N per hectare eight weeks after planting.

Irrigation
Garlic is planted in cool climate like onion. Similar to onion, garlic also shallow rooted and hence frequent irrigation is necessary. During dry periods the crop should be irrigated at weekly intervals, but a longer interval may be necessary on heavy soils. Irrigation should be stopped as soon as the leaves start to turn yellow.

Cultivation: The crop must be clean-weeded as necessary.

Diseases
Garlic rust (*Puccinia allii*) is the most serious disease of garlic. Reddish brown spots or postules develop on the leaves and stems. Recommended control measures are: 1) selection of resistant local strains; 2) preventive spraying at 14 days intervals with zineb or maneb plus stickers at a rate of 0.3% (the interval has to be narrowed to seven days when the first infection is observed); and 3) cultivation of garlic to be carried out on the same plot after four or five years only.
Insect pests
These are similar with those onion insect pests.

Harvesting and Post-harvest handling
Garlic is ready for harvest when tops are partially dry and bent to the ground. If the harvest is delayed, the bulbs may be attacked by a black mould, which spoils their appearance and considerably reduces the value. Curing and sun drying for one week is done after harvesting. The harvest should be saved from rains or heavy dew at night for an effective curing. Then leaves and roots trimmed off as recommended for onion. The most suitable packaging for marketing is the 25 kg net onion bag.

Storage
Garlic can be stored for several months at room temperature. Longer storage or storage at high temperature leads to shrinkage or loss of moisture. The clean bulb, planting materials should be

stored under cool shades dry with restricted ventilation. Such clean bulbs with leaves are tied in to bunch and are kept hanging on horizontal poles

8.3. Shallot (*Allium cepa* var. ascalonicum)

8.3.1. Introduction

The shallot is believed to have come from Western Asia. It is a perennial and seldom produces seeds, but the bulb when planted divides into a number of cloves, which remain attached at the bottom. It has been in cultivation from a remote period. Bulbs (cloves) are variable in shape, size and color covered with thin red scale leaves. Shallots are important alliaceous crops cultivated in many tropical countries as a substitute for bulb onions (Allium cepa L. var cepa). Although bulb onions can be grown in the tropics, fanners in tropical countries prefer shallots for their ability to propagate vegetatively. Shallots are also preferred for their shorter growth cycle, better tolerance to disease and drought stresses and longer storage life than the common onion and for their distinct flavor that persists after cooking. Shallot plants normally produce clusters of several bulb splits that number from 2 to 2 0 or more pieces, with an ideal marketable size of about 30-40 mm in diameter. In tropical regions, some shallot genotypes rarely flower and even where seed production is possible, the majority of shallot genotypes are clonally propagated.

8.3.2. Use and composition

- Spice and flavoring
- Strong pungency than onion
- High level of fat, sugars, carbohydrate

Shallots in particular are widely cultivated as a source of income by peasant farmers in many parts of the Ethiopia. They have a wide range of climatic and soil adaptation and are cultivated both under rain-fed and irrigated conditions. They are grown primarily for the bulb, although the green tops may also be consumed. In Ethiopia, shallots and onions are used for flavouring the local stew, ‘wot’ and are used in many households almost daily.

8.3.3. Origin and botany

- The Shallot plant is believed to have come from Western Asia.
- It is a perennial and Seldom produces seeds, but the bulb when planted divides in to a number of cloves, which remain attached at the bottom.
- Bulbs (cloves) are variable in shape, size and color covered with thin red scale leaves. Shallot (*Allium cepa* var. ascalonicum) is one of the most widely cultivated and favorite vegetable crops in Ethiopia. Its use as a condiment for many local dishes has significant importance
- Shallots, *Allium cepa*, are closely related to multiplier onions, but smaller, and have unique culinary value. (The term 'multiplier' means that the bulbs multiply freely producing several lateral bulbs). At maturity, shallot bulbs resemble small onions. They are eaten fresh or cooked, chopped or boiled. Shallots have a delicate onion flavor when cooked that adds to but does not overpower other flavours. Raw shallots have a strong pungency, stronger than most onions.

- Shallot is a perennial that produces a cluster of small pointed bulbs from a single planted bulb. The hollow, rounded leaves are up to 24 inches long. Bulbs are ¾ to 1½ inches in diameter and are of varying color — red, pink, white, gray, or russet (Stephens, 2008).

8.3.4. Climatic and soil requirements

It is tolerant to wide range of soils with a pH of 6.0-7.0. Loose, sandy soils with a high level of organic matter are preferable, although silty clay loams are often preferred. Yields range between 50-200qt/ha. Out of this total production, only 85% by weight is a marketable product (MoARD, 2007).

Shallot has a wide soil and climate adaptation and is cultivated both under rain fed and irrigated conditions. It has a very short growing period of only three to four months which allows it to be grown between other crops during the short rains in the dry season. However, planting materials used by farmers are usually heterogeneous in size, shape, color, pungency, storability, and resistance to diseases. They also differ in their time to reach maturity posing problems of harvesting and storing (Getachew and Asfaw, 2000).

Bulbs are tolerating high temperature up to 30^{o}C and high temperature encourages bulb development. Bulbs are not formed at temperature below 20^{o}C.

8.3.5. Varieties

Table. Variety name and year of released

Variety name	Year of release	Method of propagation	Area of adaptation		Maturity days
			Altitude(m)	Rain fall(mm)	
Tropics	2016	Seed	500-2500	800-1500	112
DZSHT-91-2B	2016	Seed	1600-2200		149+22
DZSHT-157-2B	2016	Seed	1600-2200		125+19
Minjar (DZSHT-164-1B)	2009	Bulb			
Dz-sht-193-1A		Seed			
Yeras (Vethalam)	2005	Seed			
Negele	2004	Bulb			
Huruta	1999	Bulb	1800-2200	600-800	95-20
Atlas					
Local					

Source: MoANR (2016)

8.3.6. Agronomy/cultural practices

Recommended field management practices by EARO (2004);

Land preparation: well prepared soil of fertile and leveled. Not used for related crops in the last 2-3 seasons.

Seeding rate: Planted 1200-1500 kg bulbs per hectare.

Planting time: At the beginning of the rainy period, small and big rainy season, i.e.; winter in June/ July; Summer in March/April; for irrigation according to the market situations.

Plant spacing: 30x10cms, planted in rows, plants roots are firmed with the soil.
Fertilizer: 200 kg/ha DAP and 150 Kg/ha Urea. 50% of urea at time of transplanting and the other 50% at and half months after transplanting.
Weeding and cultivations: Every 10-15 days depending on the weed type and population.
Diseases ad pest reaction: Bulb rot, purple blotch and thrips are the major problems, crop rotation, clean planting material and chemical control is applied accordingly.

8.3.7. Harvesting and post-harvest handling

Harvesting stages; when about 50-75% of the leaves fall down. Bulbs are properly dried in the field before stored or distributed.

Shallots may yield approximately 9-12 tons per acre. Harvest shallots when bulbs are fully mature, well colored, and 1-2 inches in diameter. Allow to cure in sacks, or bins, or under cover. Shallots are usually hand cleaned, topped and put into bags or bins for storage after the necks and bulbs are well cured.

Generally shallots are harvested when the leaves and the necks start to senesce. But in Godino, withering of the shoots is accelerated by trampling the plants with foot to catch the early favorable market. Harvesting is done by pulling the plant with hand. In Huruta and Godino, curing is done in the field by piling the plants in an inverted position. However, in Godino, harvested plants are spread in rows in such a way that bulbs of plants in the front row are covered by leaves of plants behind them.
Shallots store well at temperatures of 0–2°C and 60%–70% relative humidity. Because of their small size, shallots tend to pack closely; so they should not be placed into deep piles. Store shallots in slatted crates or trays that allow good air movement in and around the bulbs. This is important to remove excessive moisture and to minimize storage diseases (Bodnar, 2008). Low relative humidity and low temperatures are important to keep shallots sound and dormant and free from sprouting and root growth. At humidities much above 70% and at warmer temperatures of 5–8°C more of the shallots will sprout, develop roots, and decay. With good air flow and humidity control, shallots should store for 8–10 months.

In most part of the country, farmers sale their produce soon after harvest with lower prices to whole sellers on the farm. Some farmers take their products to Addis Abeba. In Ajere and Balchi, however, farmers store shallots until May to get higher prices. The storage structure is a raised wooden bed where alternate piles of bulbs and wheat straw are made at a ratio 2:1 (two piles of shallot bulbs to one layer of wheat straw between piles). Bulbs produced in the rainy season (June to August) cannot be stored until the next planting of the same season but can serve as planting materials for irrigable areas in the lowlands shortly after harvest (Getachew and Asfaw, 2000).

7.3.8. Disease and insect pest

Shallots are susceptible to bacterial diseases, pink root, white rot, downy mildew, purple blotch, onion maggot and thrips. To avoid or minimize these problems, do not plant shallots in the same soil where other

Alliums have been grown in recent years, plant only clean, healthy plants or bulbs, and practice good sanitation.

Basal rot of shallot (*Fusarium oxysporum*) is the major problem in all the areas surveyed. It is distinguished by causing shallot leaves to turn yellow and by causing death of inner leaves resulting in partial or total death of shoots and rotting of bulbs. The incidence was higher in Arsi Negelle than Huruta. It also varied from farm to farm with in a region. In some farms around Arsi Negelle, it was as high as 20% and shallot population in such fields was sparse due to death of the plants.

Downy mildew (*Pernospora destructor*) severely damaged a farm near Arsi Negelle late in the growing period but the bulbs re grow. Downy mildew is usually found associated with purple blotch (*Alternaria porri*) in almost all the areas where surveys were made.

Onion thrips (*Thrips tabaci*) is the most important insect pest of shallot growing in the dry season. In Ajere and Blanchi, a cutworm, locally called 'Mesek', cuts the plants at the base and reduces plant population. It also bores into mature bulbs. A similar insect was recorded at DZARC in 1994. Recently, farmers in Ficke area have reported that cutworms and termites are important pests of shallot. Re-sprouting of plants in the field due to unexpected rainfall at crop maturity, poor storability, and low selling price at pick harvest (about three times lower than during planting time) are also bottlenecks in shallot production.

Chapter Nine

Production Technology of Cole Crops (Cabbage, Cauliflower and Broccoli)

General characteristics

These crops belong to the family cruciferous (*Brassicaceae*). The flower is cruciform with four often brightly colored petals and six stamens. The fruits are pod-shaped, usually long and narrow but with a central cross-wall. The seeds are round and yellow to black. All members do have taproots, which are often fleshy. The lower leaves are often divided and have large terminal lobes.

9.1. Cabbage *(Brassica Oleracea var. Capitata)*

9.1.1. Uses

Cabbages are used raw and in salads chopped. Steamed or boiled alone and in mixture of vegetables and meat.

9.1.2. Origin

The cabbage is a very ancient vegetable derived from wild seakale. It has been in cultivation since 2500 B.C. and evolved from a wild, loose or non-heading type grown in Asia Minor and Eastern Mediterranean.

9.1.3. Botany

Cabbage is a biennial herb with a short, thickened stem surrounded by a series of overlapping expanded leaves, which form a compact head. Head shape may be pointed or round and leaf co lour and shape are variable.

9.1.4. Climatic Requirements

Cabbages are cool season crop and optimum temperature range is 15-20^{o}c; above 25^{o}c growth is arrested. Minimum temperature is 0^{o}c, but cold hardened plants can tolerate as low as 10^{o}c for short period of time.

Cabbages can be successfully grown at elevation of more than 800 m.a.s.l but cultivars, which form heads at low elevations, are available. Head formation is more to occur at temperatures lower than 24^{o}c. A difference of 5^{o}c between day and night temperatures is appearing to be necessary for adequate head formation.

9.1.5. Soil requirements

Cabbages are grown on all types of soils. However, they don’t grow well on highly acid soils. A pH of 6.5 – 6.8 is considered best.

9.1.6. Cultural Requirements

Planting

Seeds can be direct seeded to a field at 1.3 cm depth, 5 to 15 cm apart in single rows 75cm apart or twin rows 35 cm apart on 100 cm beds. Emerging seedlings are thinned as soon as the plants begin to crowd. Plants are spaced 15 cm apart in the rows and final stands may be 30 to 60 cm between plants depending on the cultivars.

Transplanting

Seeds are sown in nursery beds and seedlings are transplanted at spacing of 60-75cm between rows and 45-60cm between plants. Regular watering is required throughout the growing period to avoid check in growth. Cabbages are heavy feeders. So that organic manure and NPK fertilizer should be applied.

Fertilizer requirements

A general fertilizer requirement may be 56 kg N, 112 kg P_2O_5 with another 56 kg N per hectare applied before the plant starts to form the head. The band of fertilizer may be shanked into the bed at or just before seeding or transplanting. The fertilizer is placed 5 cm to the side and 5 cm below the seeds or transplants.

Irrigation

Irrigation is needed to ensure germination and good stand of the crop. It is also beneficial after transplants are placed in the field and may be needed when cabbage is planted at high density. The critical period to provide adequate moisture for the crop is from the time the leaves begin to cup and form a head to the time the crop is ready for harvest. Inadequate water during this time will reduce yields and delayed maturity.

Diseases

Black leg fungus *(Phoma lingam)* and black rot *(Xanthomonas campestris)* spread by diseased seeds or transplants or by insects. Black rot causes yellowing of leaves and blackening of the vines. Black leg causes dark sunken on the young plants. When fusarium wilt occurs lower leaves of cabbage become yellow and turn brown. Others are leaf blight *(Alternaria brassica)*, *c*ercospora leaf spot *(Cercospora brassicola)*, *c*lub root *(Plasmodiophora brassical)*, *d*owny mildew *(Perenospora parasitica)*.

Insect pests

Aphid, cabbage moth, cutworm, flea beetle, cabbage looper, caterpillar and dimond back moth are known to attack cabbage. Aphids ingest young plants causing distorted growth; flea beetle injurious to young seedlings and cater pillar feed on foliage and infest heads.

Physiological disorder

Exposure to prolonged period below 10^{o}c or above 25 ^{o}c will cause deleterious physiological changes. Prolonged exposure (4 to 6 weeks) to cool temperature in the juvenile stage without normal vegetative development trigger flowering. Conversely warm temperatures prolong vegetative character and split head because too much moisture moving in to the mature head. Preventing the plants from receiving excess moisture in the field can minimize it.

Harvesting

The length of growing period varies between 70 and 200 days depending on the climate, variety, and planting season. At lowland conditions heads may be harvested in 70-90 days; at elevations over 1000m it takes longer (80-110days) depending on the cultivars. Individual mature heads should be harvested by severing just below the bottom leaves using sharp knife.

Storage

If stored at 0^{0}c to 2.2^{o}c and at relative humidity of 95 to 98%, cabbage can be stored for 4-6 months.

Marketing and preparation

Cabbage for market is packed in wire bound crates; filler bound carton or mesh bags.

Cabbage (*Brassica oleracea* L var. *capitat*a L.) Seed Production

Cabbage is the most important cole crop grown in Ethiopia. It is a biennial crop for seed production. In the first season heads are produced and in the following season seed production follows.

Climate: The cabbage is a hardy vegetable and is better adapted to the cooler regions. Usually largest and best quality of heads is produced during the cooler months of the year. Cabbage thrives best in cool and humid climate and can tolerate severe frost. It requires a dormant period of cool temperature to bolt and initiate seed stalks and flowers. Headed plants form seed stalks when exposed to mean temperature of about 5^{0}C for 6-8 weeks. However, for immature plants, such temperature is sufficient for two week.

Method of seed production

1. Seed to seed method (In-situ method)

In this method, crop is allowed to continue in the same field where it is first set out in the seedling stage. All off types and undesirable plants are rogued out leaving true to type plants. These plants with curd head are allowed to over winter and produce seeds in the original position.

2. Head to seed method (Transplanted method)

In this method, selected plants with head are uprooted with soil ball and replanted in new field for seed production. This method is not commonly practiced because it is not successful method due to more mortality of replanted plants.

Dichogamy in flowers: Dichogamy is the condition in which the times of maturity of male and female organs differ in hermaphrodite flowers.

Protogynous: The flowers are perfect and tend to be drotogynous (female organ mature first than stamen in hermaphrodite flowers in this condition,

Protendry: Where as in protendry conditions male organ mature first than female organ in hermaphrodite flowers).

9.2. Cauliflower (*Brassica oleracea* L.var.botrytis L.)

Broccoli, Cauliflower and artichoke are also called flower vegetables. Cauliflower is a member of Brassicaceae (Cruciferae) family.

9.2.1. Origin

Derived from wild cabbage, which in turn originated from the Mediterranean region and Asia Minor.

9.2.2. Botany

Cauliflower and broccoli have similar botanical features. They are different in that the curd (flower head) of cauliflower may be **white or purple**, whereas in broccoli it is a **blue green color or grayish** color.

Cauliflower is a biennial plant grown as an annual. The edible portion is the head, which consists of a white mass of abortive flowers on enlarged branches produced at the top of a short, thick stem. Cauliflower leaves are narrower, longer, and lighter colored than those of either cabbage or broccoli.

9.2.3. Climatic requirements

Cauliflower tends to be more exacting in its climatic requirements than other Brassicaceae, which, if ignored, cause failure under field situations. Temperature is major controlling factor rather than photoperiod or water regimes. Cauliflower grows best in cool moist climate tolerating temperatures as low as 4^0C & as high as 38^0C, but the optimum is 27^0C with a range from 7-29^0C. The warmer the mean temperature the more the plant is to remain in the vegetative phase increasing the time needed for maturity. Prolonged cold temperatures (4-14^0C) retard maturity of cauliflower.

Cultivars suitable for growing in the tropics have been developed but cool conditions such as are found at elevation of greater than 1000m.a.s.l. are normally required for optimum growth and development. There are two groups based on curd development: (1) those which form curds and flower in hot weather conditions (tropical adapted groups), and (2) the late maturing types which take a long time to develop curds and require cool conditions for curd development. One of the differences between strains is the period required for the crops to reach maturity. Cauliflowers enjoy more or less the same soil, as do cabbages. Deep, friable soil that is either not be too light or not too heavy with good OM content to enhance water holding capacity and having pH of 6.0-7.5 have been found best.

9.2.4. Cultural Requirements

More than most vegetables high quality cauliflower production requires skillful growing practice. A rich well- drained soil provides better aeration & water penetration.

Planting - Seeds are sown in nursery beds either direct or transplanted. Depending on the cultivar seedlings are transplanted at spacing of 45-60cm between plants and 60-75 between rows.

Blanching - is the activity which involves shading the developing curd by tying the upper leaves over the curd to protect the head from sunburn and to keep it from turning green and developing off-flavors. Any interruption in growth such as extreme heat, cold, drought, or plant damage can abort the development of cauliflower head and curds. The leaves are tied with rubber bands, tape, or twine. Self-blanching cultivars blanch better naturally under cool conditions than under warm conditions.

Self-blanching cultivars - that do not require their leaves to be tied above the developing hard to maintain the whiteness of developing curd. Cauliflower is ready to blanch when it has 5-7.5cm of white curd developed in the head. Self-blanching types are named for their natural tendency to curl their leaves over their head.

Fertilizer application - A general fertilizer recommendation estimated to be 444.5kg reach of N and P_2O_5, and 444.5kg to 555.5kg K_2O_5 plus 83-111kg of borax per ha. The fertilizer is broadcasted or mixed into the row. Side-dressing with 166kg of N for 4 weeks after transplanting is practiced.

Irrigation - About 25.4-38.1mm of water every 5-7 days is generally needed from either rainfall or irrigation to produce large yields of high quality cauliflower heads.

Insects - Major insects include cabbage root fly maggots, cut worms, cabbage worms, cabbage looper worms, flea better and aphids.

Diseases- Powdery mildew, black rot, downy mildew etc.

Weeds - The same as that of cabbage.

9.2.5. Physiological disorders_- Unfavorable conditions (hot weather, drought, or too low temperature) can result in formation of premature heads or curds. These baby Cauliflower heads never develop fully & are called buttons. Blindness is a physiological disorder in which no curds are formed. Blindness may be due to poor fertility, disease, insects and cool temperatures. Molybdenum deficiency results in "Whiptailing" of leaves and prevalent on very acid soils. Deficient levels of boron in the soil results in the plants developing hollow stems with brown discoloration. Riceness or fuziness of the curds of the heads is often the result of high temperatures. Development of bracts or small green leaves between the segments of curds is a result of too high temperatures or drought.

9.2.6. Harvesting - The ideal curd is white or creamy white blemish free head. It is ready for harvest when the head has grown 15-20cm in diameter, typically within 7-12 days after blanching, or 50-55, 70-80, and more than 150 days after transplanting for early, mid-season, and late season, respectively. Mature head should be compact and the curds are firm and white. Over mature cauliflower heads have coarse "ricey" appearance and are not marketable.

Post harvest handling - The harvested heads are trimmed of most of their leaves by cutting squarely across the leaves leaving 1.3-2.5cm stabs projecting above the head. These stubs protect the head from injury caused by rubbing against other heads or the shipping containers. Following trimming, heads are sorted to uniform size and packed into crates. Sometimes heads are trimmed, wrapped in perforated film and packed in cartons. The perforated film prevents off-colors and off-flavors from developing after cooling. Cauliflower is marketed soon after harvest or placed in 0-1.6^{0}C storage. Cauliflower is kept in refrigeration during shipping & ice is generally not used on cauliflower as a post-harvest practice.

Marketing - All cauliflower is marketed without its leaves (except for protective stubs).

Uses - Cauliflower is cooked and served as a vegetable. Raw cauliflower is added to green salads or cut into pieces and dipped into sauces.

9.3. Broccoli (*Brassica oleracea* L.var. italica)

It is a member of Brassicaceae (crucifeae) family

Origin - the name broccoli is an Italian word meaning "cabbage sprouts". Records concerning broccoli are interwoven with those of cauliflower because since Roman times the two variants have been classed as one and the history of broccoli is in essence the history of cauliflower.

Botany - Broccoli has the basic leaf, root, and flower characteristics shared by *B.oleracea*. Broccoli is highly cross-pollinated and self-incompatible, and care must be taken to distance seed fields of other brassicas far enough to prevent accidental crossing.

Among the major differences between broccoli and cauliflower are: 1) flower head of broccoli is a blue-green or grayish while that of cauliflower may be white or purple; (2) in broccoli, secondary floret clusters (lateral side shoots grown into small head) form rapidly after the primary head is removed;(3) The inflorescence of broccoli is attached to elongated fleshy stalks or stems which are equally prized with the florets for their edibility; cauliflowers on the other hand are shortened or ramified and do not extend beyond the base of the head; (4) References with cauliflower head (abortive flowers, peculi inflorescence, or hypertrophied branches at the top of a short thick stem, when it is in its prime and ready for cutting there are judged to be "no traces of floral organs". Not so with broccoli, which is just a few days before floret opening at the time of prime harvestings (5) Broccoli is less sensitive to heat or cold generally than cauliflower and has greater resistance to extremes of temperature.

Climatic Requirements

Broccoli is a cool season plant classed as hardy crop. Preferred temperature ranges for successful production is from 15.5 - 17^{0}C with mean maximum of 24^{0}C. Young plants can withstand light frost down to -4.4^{0}C and may initiate flowering, rendering the plant unmarketable. The marketable plant part is a head composed of immature flower or florets. Temperatures above 26.6^{0}C generally are not suitable to satisfactory growth and production and can cause broccoli heads to become loose and puffy, making them unmarketable. Broccoli buds will turn yellow and flower prematurely (bolting) in hot weather condition.

Soils - since broccoli has a shallow root system, a constant supply of moisture and nutrients are required for good succulent growth. A well-drained, medium heavy soil with a high organic content is optimal for successful broccoli production. Optimum pH ranges 5.5-6.5 and fields are limed if the pH is too low. Adjusting the pH to the preferred range will minimize **tip burn** as a result of ca deficiency, **whiptail** as a result of molybdenum deficiency, and **hollow stems** as a result of boron deficiency.

Cultural requirements

Planting - It can be established by direct seeding or transplanting. If directly seeded to the field, broccoli requires a good seedbed and loose soil to cover the seed. Broccoli seeds are generally planted 2cm deep, 5-15cm apart in rows and 75cm between rows. Irrigation is often necessary for good seed germination and germinates best at 23.8^{0}C.

Transplanting - Broccoli transplants can be grown in hot beds or green houses. Under this, they are seeded 0.6-1.3cm deep, in rows 10-15cm apart with 2-4 seeds per 2.5cm. Plants are usually watered twice a day and fertilized depending up on the weather condition of the area. It may be transplanted 6-8 weeks in hot beds while 4-6 weeks in the green house. Final field plant spacing is 30-60 cm in the row and 75cm between rows.

Fertilization - Broccoli requires 833 - 1111kg/ha of N. Nearly one- third of this often applied prior to planting. The remaining N is applied as a side-dressing at about 2-3 weeks after transplanting and when heading begins.

Irrigation - Irrigation can be provided by furrow, overhead, or drip method. Generally, at least 25.4mm of water per week is required for optimal growth. Lighter sandier soils may require up to 50.8mm of water during hot, dry periods. Moisture stress during plant development can reduce growth and quality of the broccoli head and stalk. Tough, fibrous stalks and **tipburn** of broccoli can result if plants are exposed to inadequate moisture. Adequate moisture is especially necessary during head initiation to produce large quality heads required for successful marketing.

Diseases

Black rot (*Xanthomonas campestris*) - yellow angular spots that progress inward from the leaf margin. Leaf veins become dark brown to black and heads may be deformed. Use crop rotation, clean seeds, clean transplants, and resistant varieties.

Alternaria leaf spot (*Alternaria brassicae*) - yellow concentric spots on foliage. Infected seedlings may be stunted or killed. Use crop rotation and clean seed.

Downy mildew (*Perenospora parasitica*) - Yellow spots on the upper surface with bluish white fungal growth on the lower surface of leaves. Use crop rotation, old crop sanitation, weed management, and recommended planting dates.

Physiological disorder - Extremes of temperature, moisture and fertility are the causative factors or formation of small, button-shaped heads and premature flowering (bolting).

Harvesting - Broccoli is harvested (45-60 days after transplanting) when the head is firm and fully formed with tightly closed florets and no sign of the yellow blossoms within. Approximate commercially marketable mature head size is 7.5 to 17.5 cm in diameter and may weigh 13.5 to 450g each. The upper stem (stalk) and clusters of unopened flower buds (heads) are the marketable parts of the broccoli plant. Broccoli is harvested by hand while the clusters are still compact and before the individual flowers begin to mature and turn yellow. Over mature heads often have a woody outer stem. An average commercial field of broccoli may be harvested 4 to 6 times, at 2 to 3 day intervals (depending on the temperature).

Post-harvest handling - harvested products must be cooled to 0^oC as soon as possible and ice is often placed in the shipping boxes or cartons. The approximate storage life of broccoli under ideal conditions is 10-14 days.

Marketing - Grading, trimming, and bunching are needed for marketing broccoli. Stems are trimmed 15-20cm in length and the leaves are removed
Uses - Broccoli is best steamed (if boiled; only the built end should be placed in the water). Broccoli is used in soups, salad bars, and as a side entree. Other uses include raw broccoli for dipping or adding to salad, soup, macaroni, and cheese or best fit into dishes such as with chicken.

Chapter Ten

Production technology of Leaf/ Stem/petiole and salad vegetables (Swiss chard, Celery and asparagus)

10.1. Celery (*Apium graveolens* Var. dulce (Mill))

It is a member of Apiaceae family. Graveolens means strong scented and dulce means sweet. The characteristic flavor and odor of celery is due to volatile oils in the stems, leaves and seeds.

Origin - Probably originated in Mediterranean basin.
Botany - May be an annual or biennial depending up on temperature during the juvenile period. When the temperature is in the range of 2 to 10^0C for any length of time, the celery plant initiates seed stalk (varying by cultivar) the first year, becoming an annual. Conversely, if young celery plants maintained at 15.5 and 21^oC, there is no bolting. Without temperature triggering bolting, the celery is a normal biennial plant.

Climatic requirements
Celery requires a long, cool growing season with cool nights. The mean minimum, optimum and maximum soil temperature for germination are 4.4, 21, and 29.4^0C, respectively. The optimum air temperature ranges from 15.5 to $18.3\ ^0C$.

Soils - soils having high levels of OM with optimum pH of 6 to 6.5 is best.
Altitude: Elevation above 1800m is required for celery production.

Cultural Requirements
Seeding - Celery seed is very small (about 2,205,000/kg) & germination rates are low (usually 55%). This is partly due to tarnish plant (lygusbug), which is attracted by germinating celery seeds.

In feeding, the lygusbug injects a toxic substance in its saliva that kills the embryo. The other problem is maturity of seed and presence of seed born fungi. The "king" umbel seeds (the first formed) germinate at a higher rate than those from lesser umbels. Seeds stored two or more years do not readily transmit fungi to germinating seed due to an inhospitable environment. Celery seed germinated in the light but not in the dark when temperature alternates from 15-35 ^{0}C. If it held at 30 ^{o}C remains dormant germinates regularly when held between 15 and 30 ^{0}C. In addition, celery requires a moisture regime at near field capacity. To destroy seed born-diseases treat the seeds with hot water.

Planting

It can be done by three methods

1) Growing seedlings in protected conditions (Green house or cold frames) and transplanting to the field. This is used due to erratic germination behavior of celery that makes seeding to stand highly risky and potentially unprofitable; and in the juvenile stage celery is sensitive to cool temperatures - the longer it is exposed to triggering temperatures, the greater will be the number of bolters.
2) Direct seeding **-** To compensate for poorer stands of celery when direct seeded, germination test should be carried out. A deep, open, friable seedbed is essential. Seedbed should be thoroughly irrigated before seeding. Any hardpan must be broken to permit good water percolation. Direct seeding is only feasible when irrigation is available since it is necessary to keep the soil surface moist during germination and early growth.
3) Growing seedlings in outdoor seedbeds and transplanting to the field. The seedbed is prepared after the site has become sufficiently dry to work to control nematode, seed born diseases, insects; to allow clean, healthy transplants to develop for field planting. The transplants are hardened by progressive trimming of the tops 2-8 times beginning when they are 6-8 weeks old and continuing until the plants are pulled. Pulling is done when seedlings are about 15-20cm in height and have 3-6 true leaves. Topping is practiced during the hot periods and dispensed with during the cool cycle. Transplants are spaced 15-20 cm apart in the rows and 60cm between rows. Usually about 56-70 days are required to produce seedlings for transplanting. Varieties of celery, which need blanching, are grown in the trench 40cm wide, 30cm deep and 20cm between two rows and within the rows.

Blanching - Earthing up should begin when the plants are about 30cm tall and be continued every 3 weeks or so, adding about 8cm of soil each time. Before earthing up begins the plants should have their outer leaves removed, and be reduced to a single head. Blanching may also be done on the leaves, by tying heavy brown paper, several layers of newspaper or black polythene around the stems.

Fertilization – celery is heavy feeder and requires large amount of fertilizer, especially during the last 4 to 6 weeks of growth, when the bulk of the crop is formed. An application of a complete fertilizer prior to planting will often improve yield.

Irrigation - Frequent irrigation 25.4 - 38.1 mm of water per week (equivalent to 18-27 liter per m^2) or twice a week (depending upon weather condition) during the growing season is needed. Irrigation during the 6 weeks prior to harvest is especially important due to rapid growth. Drip, overhead or furrow methods can be used depending on the condition. Celery is basically a swampy plant and has high water demand. Therefore, soils that have high water holding capacity like clay loam are preferred.

Disease - Major diseases of the crop include damping-off, root rot, pink rot, basal stalk lesions, early blight, late blight, bacterial blight, cucumber mosaic virus, and nematodes.

Insects - Major insects of the crop include aphids, leafhoppers, carrot weevils, the cabbage looper, armyworms, flea beetles, leaf miner, cutworm and crickets.

Physiological disorders - Black heart occurs when young leaves in the center of the plant do not get adequate water and calcium for proper growth. Apply adequate irrigation with calcium.

Harvesting - It is harvested when the petioles (stalks) from the soil line to the first node are at least 15cm long. It is harvested by cutting the taproot below the ground. The crop is ready to harvest 85 - 120 days after transplanting depending on the cultivar and weather. Over mature crops are not harvested because they often contain cracked and pithy petioles.

Post-harvest handling - celery should be trimmed and packaged then quickly cooled by either vacuum cooling/hydro cooling/ to a temperature of 5 ^{0}C in the heart and 0-2 ^{0}C on the outside. To reduce rotting and discoloration of butt, celery cartons are top iced and the shipping vehicles refrigerated to temperature capable of holding the celery at 0 ^{0}C and 98% RH. When held at 0-1^{o}C and 98% RH, it has a storage life of 4-8 weeks; when held at 5 ^{0}C stores well for only 2 weeks.

Marketing - It is shipped with the butt upward to prevent water accumulation and butt discoloration.

Uses - Grown for the swollen petiole as a soup herb. Used as a medicinal plant (china), a herb eaten to purify the blood. It is a favorite ingredient used raw in salads, or with cheese, or dips. It is an appealing vegetable because it fills a need for food with pleasant tastes (for flavoring). Eating raw celery is also an excellent dental detergent.

10.2. Swiss chard (*Beta vulgaris* L. var cicla (mog.))

It is a member of Chenopodiaceae (goose foot) family.

Origin - Mediterranean basin

Botany - It is an herbaceous biennial, botanically very similar to beet; except that it does not form an enlarged hypocotyl. Swiss chard develops a compressed cluster of petioles (stalks) which may be white, red or pink similar to celery, forming distinctive enlarged petioles with heavy dark green savoyed leaves. The plant features and flowering habit are similar to the table beet but unlike beet, however, it does not respond to high temperatures, which cause bolting in beets, spinach, and lettuce, in the first year as well as subsequent years.

Uses

Chard is used as cooked product: the stems are used like cooked celery and for best flavour should be steamed. The leaves are cooked the same as spinach (with only the water on the leaves left from washing them).

Climatic Requirements

Having the ability to resist high temperatures by not bolting is a distinct merit. In order to induce flower stalk formation, chard roots must be exposed to extended periods of chilling. Soil temperature conditions needed for germination are similar to those for beets as are the mean temperature requirements for growth and quality. Moisture requirements for germination range from intermediate amounts to field capacity. A well-prepared, deep loamy soil high in organic matter will insure vigorous full-grown chard plants. The pH requirements range from 6.5-7.5.

Cultural Requirements - It can be direct seeded in the field and the seeds are planted at spacing of 10-15cm between plants and 50-70cm between rows. If plants seem to be crowded, they can be thinned to 15-30cm apart in the row.

Fertilization - The requirements for soil and fertilizers would approximate those suggested for beets or spinach. Like beets, chard is tolerant of Mg deficiency.

Irrigation - Adequate watering is recommended for successive petiole production and to keep the leaves succulent and tender.

Diseases and Insects: – similar to that of beets. In Ethiopia, Thrips cause serious damage to chard. Use Malathion to control them.

Weeds - The recommendations for beets should be followed as much as possible.

Harvesting - The leaves should be cut regularly after they reach tender maturity usually 50-60 days after planting. After the outer ring of petioles is cut new heart growth occurs and the outer petioles successively mature for continuous harvest. If the outer petioles are not harvested promptly, the expansion of new ones is inhibited.

Post-harvest handling - Petioles that are bright and blemish free are bundled together in bunches and quickly cooled to remove field heat and reduce respiration rate. Chard should be kept at a high RH of 90-95% held at 0 ^{0}C. Under this it can be stored up to 10 days. Constant top icing is necessary to maintain shelf life.

Uses - Used as cooked product - the stems are used like cooked celery and for best flavor should be steamed. The leaves are cooked the same as spinach (with only the water on the leaves left from washing them).

10.3. Spinach (*Spinacia oleracea*)

Family: Chenopodiaceae (goose foot)

Use

Spinach is a very popular fresh salad ingredient though grouped under potherbs. If cooked, it is better to steam it very briefly so as not to destroy the flavour and water-soluble nutrients; spinach is used in many ways in dishes such as soups and pastries.

Origin

Records of the usage of spinach in Europe go back as far as 1351 in china as early as the seventh century. The origin of spinach is believed to be central Asia (persia).

Botany

Spinach is an annual crop grown for its leaves, which may be either smooth or wrinkled depending on the cultivars. The first formed attain large size than subsequent leaves, which become progressively smaller. It is herbaceous annual with a deep taproot and numerous shallow spreading secondary roots. Usually dioecious, seeds are produced on the female plant and the male plant dies after blooming. The pollen is transferred by wind.

Crops are classified according to the following characteristic.

External male - has pronounced flowering habit with the upper leaves more bract like than leaf like.

Vegetative male – similar with the above in having normal flowers but the leaves on the upper part are well developed.

Vegetative female – bears female flowers and plants are larger.

Monoecious – contain mixed male and female flowers.

Vegetative male and female types are preferred as the plants are larger, whereas the extreme males are smaller and flower early.

Climatic Requirements

Spinach is a cool season crop cultivated where the average temperature range is $16\text{-}18^0$c, but it can be thrive in regions where the average temperature is about 10^0c. Young plants can withstand freezing temperatures as low as $–9^o$c without sustaining much injury.

Spinach is a long day plant for flowering. At day lengths greater than the minimum higher temperature cause early bolting. Bolting is more rapid with increase in photoperiods, older plants being more sensitive than younger plants.

Sandy loamy to clay loams is ideal soil type. It is sensitive to acidic soils, preferring a pH range of from 6.0-7.5, and not too sensitive to soil type provided there is high OM content and the soil is well worked with good drainage.

Cultural Requirements

Seeds are either broadcasted or planted in rows 40-60 cm apart, and covered with 1-2cm of soil. Germination is best at soil temperature of 10-15^{o}c. The seed remains dormant if the temperature is above 30^{o}c.

Fertilization at rates of 70-135kgN, 40kg P and 56kg potassium per ha are used for higher yield.

Diseases and Insect Pests

Downy mildew caused by *perenospora effusa*

Spinach blight or yellows: it is virus diseases caused by the cucumber mosaic virus.

Insect pests

Aphids, beetles, mites, and leaf minors are some of the insects, which attack spinach.

Harvesting and storage

Spinaches are harvested when plants have reached good size, usually 35-70dyas after planting depending on the season and climate. Hand harvesting may begin after 5-7 leaves have formed and continue until feed stalk are formed. Harvested spinach stored best near 0^{o}c and under very high humidity. Under these conditions they remain in excellent condition for 10-14 days.

10.4. *Lettuce* (*Lactuca sativa* L.)

Family: Asteraceae (Compositae)

Uses

They are called salad crops. These corps generally is eaten without cooking (raw). Now a day salad crops are appreciated because of their value in the diet. They are especially valuable for the ash constituents and for their vitamin content. All types lettuce is prized as the basic ingredient in fresh salads. Lettuce combines with all kinds of sandwich ingredient as well as dressing up hot or cold dishes.

Origin

The name lettuce derived from Latin and English word meaning the milky juice of the plant. Somewhere east of the Mediterranean Sea, encompassing Asia Minor, Transcaucasia, Iran and Turkistan is considered to be the region where lettuce originated.

Botany

It is an herbaceous annual with a milky juice (latex). In its vegetative phase, it is rosette and short stemmed, whereas the later seed cycle results in a rather tall plant. It is member of Asteraceae (compositae) family. This family include sunflower (*Helianthus)*, Endive (C*ichorium)*, salsify (*Trapogon*), artchoke (*Cynara*), dandelion (*Turaxacum*), and chrysanthemum. Lettuce is self-pollinated and up to 1% crossing may occur due to chance of insect activity. The flowers open for a short period in cool of the morning then close never reopen. There are at least three commonly grown European varieties (A to C) and six morphologically different lettuce types:

A) Cabbage or head lettuce or butter head lettuce (Var. capitata)
The compact rosette of leaves forms a compact (solid) head.

The leaves are broad and the midrib branches into small veins.

B) Cos or romaine lettuce (var. longifolia): forms elongated upright leaves oblong and coarse in texture; give the appearance of toughness due to the heavy midrib formation, the inner leaves are tender and eating quality is high. Most of the leaves are self folding, forming loose heads.

C) Leaf lettuce (var. crispa): The leaves are in a loose rosette similar to cabbage lettuce but the crop is non-heading. Some cultivars do have curled or colored leaves.

D) Stem lettuce: grown in North America and Europe. Unlike other lettuce rarely used raw but rather is preferred peeled and cooked.

E) Crisp heads (iceberg types): have best shipping and holding characteristics. It is large, heavy, tightly folded, brittle or crisp textured, with greenish wrapper leaves and whitish yellow inner leaves. They are predominantly outdoor types.

F) Latin lettuce: forms loose cos like heads. Resistant to lettuce mosaic.

Climatic Requirements

Lettuce is cool season half-hardy crop requiring mean growing temperature of 7.2^{o}c and optimum range 15 to 20 ^{o}c, and maximum 24 ^{o}c. Lettuce is generally grown in areas in which the mean temperatures are 10-20^{o}c.

Heading is prevented and seed stalk form in the temperature ranges of 21-27^{o}c. Cool nights is essential for quality lettuce production; High temperature tends to produce strong flavours (bitterness) and result in stunted growth. However, there are tropical adapted varieties, which tolerate a temperature up to 30^{0}c. At low-elevation high temperature areas some cultivars fail to form soils heads; rather they flower early without forming the normal number of leaves.

A lower temperature inhibits growth; results in pre-mature flowering or seed stalk formation, bitter leaves, internal tip burn of crisp head types, loose leaf structures (do not form compact head), induce shifting from a vegetative an irreversible flowering phase.

Generally, elevation above 1000m.a.s.l. provide optimum growing condition.

Though the crop grows on a wide range of soil types lettuce has weak root system and is concentrates in the upper layer (25 to 30 cm) of soils and thrives on a well-drained fertile soil having high organic matter and adequate moisture with a pH of 6-6.8.

Cultural Requirements

Planting

Propagation is by seed, which germinate 4-5 days after sowing. Optimum germination temperature is 25^{o}c. Above this temperature germination falls rapidly. Viability of seed is reduced under moist condition and high temperature.

Lettuce seed is an achene or dry fruit. The seeds can be sized for uniform growth or pelleted for precision planting. One kg of dry fruit contains 444,444 to 1,000,000 seeds. The small sized, irregular shaped lettuce seeds are difficult to separate and handle during planting. The spacing between rows varies with respect to cultivation, irrigation, fertilization and cultivars. Cabbage lettuce is smaller and can be grown closer than the crisp head types. It is planted 0.6 cm deep, 25 to 35 cm spacing between seedlings and 30 to 35 cm row distance on bed size of 45 to 68 cm wide and 200 to 210 cm length depending on cultivars and location. The seed needed for one ha ranges 0.45 to 0.9 kg bed height depend on soil type, drainage and season.

Seeds may be directly sown in drills 25-30 cm apart rows or frequently sown in container or a nursery bed and transplanted when seedlings are 4 to 6 weeks old. However, direct seeding is laborious and expensive in thinning operation. It is thinned 25 to 40 cm apart when the initial leaves are formed especially the clusters are thinned to one per plant. Late thinning causes root damage prolongs root recovery. At 21^{o}c soil temperature it will germinate within 7 days.

Transplanting

It will take 6 to 8 weeks for the lettuce transplants to develop properly for planting to the field. Transplanting may increase the uniformity of the crop and harvest.

Irrigation

Irrigation is required at frequent intervals otherwise dry soil conditions induce premature flowering. Adequate moisture and cool temperature are necessary at the time of heading. Low moisture associated with high temperature increase incidence of tip burn. Excess rains or irrigation may leach nutrients from the soil and also increase of disease and insects.

Fertilization

About 80% of crop growth occurs during the 3 to 4 weeks before harvest. Fertilization would depend on the nutrients available in the soil and should be applied early, long before the rapid growth, which occurs just before harvest. Although recommendation may be based on soil type (sandy soils may leach nutrients faster than heavier soils and more frequent application of less fertilizer may be needed), many growers apply 1125 kg of 5-10-10 complete fertilizers to sandy silt loam soils. Half of N and P and all K applied at or before seed and the remaining N and P is applied at the time of thinning.

Lettuce may responded favorably to manure application, however, demerits with the use of manures may include the presence of excess amounts of salt introduction of weeds, and poor cost-to-benefit ratio. In temperature areas , it may encourage bolting the of the lettuce.

Other care

Vegetative growth phase characterized by increased root, stem and leaf mass. A rosette of leaves on a short stem form a light intensity and day length increases. Leaf width during this time also increases. Heading varieties produce leaves that cup and curl in ward in an overlapping manner. Non-heading varieties produce a rosette of leaves that curve away from the center of the plant.

Flowering and seed production phase characterize reproductive stage. *Bolting* is the stress-induced transition the plant makes by quickly shifting from a vegetative state to reproductive state. The entire seed to seed cycle requires 6 to 8 months.

10.3.6. Diseases

Mosaic virus which is see-borne, is the most serious lettuce disease. Others include spotted wilt, aster yellows, big vein, downy and powdery mildew, sclerotinia, anthracnose, botrytis and bottom rot *(Thanatephorus cucumeris or Rhizoctonia Solani).*

Insect pests

Aphids, cut worm, armyworm, Cabbage looper, corn earworm, leafhopper and spider mites are some of the more common insect pests that attack lettuce.

Weeding

Successful land preparation is an effective method of weed control in lettuce field. Use early shallow cultivation to reduce weed damage.

Physiological disorder

Include tip burn, rosette spotting and rib discoloration.

Harvesting and Post-harvest handling

Lettuce head (crisp head types) mature within 55 to 70 days from seeding to harvest under normal day length and warm temperature conditions. Generally, head types take up to 140 days to mature when grown under cold temperatures and short day length because of slower growing response. Seed cultivars mature within 60 - 85 days from transplanting but the leaf types may be harvested 35-60 days from planting. Harvesting should be done during the early part of the day.

Two to four harvests of a field may be necessary if maturity in a field is irregular; in uniformily matured fields, up to 90% of the heads may be harvested in a single harvest. It is cut with help of knife at or slightly below ground level. All but 3 to 5 wrapper leaves are removed and the heads placed in boxes. Water is sprayed on the cut ends of the heads prior to placing heads in boxes to remove the latex and soil particles that cling to the cut surface. It is usually packed into 27.5 cm x 31.25 cm x 53.75 cm boxes designed to hold 24 heads. This size box may be packed with 18 large or 30 small heads. Packed boxes weight from 20.25 to 24.75 kg or more. Plastic crates or wooden boxes are used for packing.

Post-harvest handling

Lettuce may be wrapped with porous/perforated clear plastic after harvest in the field. Lettuce grown for processing is bulk packed; then transported to the vacuum cooler or to the processing plant. The estimated loss at the wholesale, retail and consumer levels is 21.3%; in tropical areas can result in 22 to78% of post-harvest wastage. The higher the temperature the faster the metabolic rate and depletion of reserves in the lettuce leaves. Harvesting during cool parts of the day (early in the morning) can reduce high temperature stress of lettuce.

Storage; Lettuce is a highly perishable crop as it has a very high water content. Ideally, lettuce should be pre cooled to about 1^{o}c and held at this temperature at high humidity (95-97%) for storage and transport. Under this condition it can remain in good quality for 10 to 14 days.

Marketing; Point cooling before shipping is desirable and preferred temperature for shipping is 1^{o}c.

Chapter Eleven

Production Technology of Legume and cucurbitaceous Vegetables

11.1. French bean/Green Beans (*Phaseolus vulgaris* L., Haricot beans)

In the past, production of green beans has been of very minor importance because of the very small local demand. Small farmers who planted varieties suitable for harvesting as dry pulse produced the crop. Part of the crop was harvested as green beans but such varieties do not produce green beans of good quality.

Large commercial farmers started production of green beans for export to Europe by air in the early 70s. The varieties grown were adapted for this purpose. Principal demand was during the European winter season and the crops were planted under irrigation during the dry season. More recently the European market has expanded considerably and export is viable over a much longer season. This has created a surplus of non-exportable grades on the local market and has resulted in some expansion of consumption. Green beans are also canned on a small scale.

Soil and Climatic Requirements

A well-drained soil of medium texture and high fertility will produce the best result but production is possible on a wide range of soil types, provided drainage is a good and the pH is between 6.5 and 7.5. A good rotation is necessary to prevent an adverse build-up of soil nematodes and soil-borne root diseases. The most suitable climatic range is between 1,000 - 2, 000m above sea level. Except during the early stage of crop growth, a dry climate with irrigation is most favorable for crop production. Under these conditions, there is little or not incidence of disease. The crop is susceptible to damage by wind causes bent and scarred pods, which are not exportable. Windbreaks must be provided if necessary.

Varieties

Two types of green beans are produced for export, "bobby" beans and "fine" or needle" beans. The varieties of each type, which are being grown at present, are:

1. *Bobby type*: Variety AMBOY, a stringless variety with fleshy pods.
2. *Fine type*: Varieties SUPERMONEL and ROYALNEL; these are not strangles but the pods are harvested before strings develop. They are more firm in texture than AMBOY.

In Europe there is a varying country preference for the two types of bean. However, the fine beans generally fetch a higher price but production is more labour-intensive.

Cultural Practices

Land preparation and layout

Find levelling off the field is essential after ploughing and harrowing. Layout the ridge and furrow irrigation system with flattened ridges 35cm wide. The furrows should be 40 cm wide and 20 cm deep. After ridging, the field should be pre-irrigated and the layout corrected by hand to eliminate any high or low spots. A seedbed made as smooth as possible is required for direct sowing Water should be admitted to the furrows by siphon and should flow smoothly through the length of the furrow, which should not generally 100m in length.

Sowing

The seeds are sown in two rows 15cm apart per ridge and 10 cm from each edge of the ridge. Spacing in the row is 7.5cm and the seed is sown 2-3 cm deep into the soil moistened by pre-irrigation. Calculating seed weight at 300g per 1,000 seeds, the seed rate per hectare at the spacing recommended will be about 100kg. However, some varieties have a higher or lower seed weight and the seed rate per hectare should then be calculated accordingly, to give an optimum plant population about 356,000/ha.The recommendation for ridge and furrow dimensions and plant population are for average conditions and may be varied in accordance with local experience. It is most important to sow the seeds on top of the ridge and not on the sides sloping down into the furrow. Bean seed requires good soil aeration in order to germinate. The soil in the sides of the furrow will have been compacted by irrigation water and will not contain enough oxygen for good germination.

Fertilizer application

The rate and kind of fertilizer applied should depend on the nutrient status of the soil as determined by analysis. However, if this information is not available, the following recommendation is made for average conditions:
DAP - 100/kg/ha, before sowing during field preparation.

Urea - 100 kg/ha, there weeks after sowing together with cultivation, weeding and reshaping of furrows and ridges.

Irrigation

The irrigation intervals have to be adapted to the requirements of the crops and to soil moisture conditions. On no account should irrigation be applied if the soil already contains sufficient available moisture.

Generally, less water is required during early growth and more frequent irrigation is necessary from the time of flowering and onwards.

Water should be admitted to the furrows slowly and flooding of the ridges must be avoided.

Harvesting

The first harvest of fine bean varieties takes place about 55 days after sowing. For bobby beans, it takes place at about 60 days. The harvesting period is two weeks in each case. This necessitates careful planning of sowing dates on a weekly basis in order to ensure that there is no gap in production during the whole of the planned production season.

Once harvesting starts, it is essential to adhere strictly to the recommended harvesting schedule, which is as follows:

Bobby beans: Harvesting of all mature pods from the whole of the production area every two days.

Fine beans: Harvesting of all pods of the specified size grades from the whole of the production area daily.

Deviations from the above schedule will result in reduced yield and too high a ratio of unexportable grades, which must be marketed locally. If unexportable grades exceed 15% of the total yield, it is due to production faults. This must be carefully investigated and rectified. Yields of two tons or more per hectare of exportable grades are possible in large scale production. Great care is necessary to prevent deterioration of the produce after harvest by exposure to sun or drying winds. Fine beans should not be exposed for more than 15 minutes or bobby beans for more than one hour. Shade structures or better still. Evaporative coolers should therefore be constructed in the field for protection of the produce pending transport in covered vehicles to the pack-house. Small growers who do not have pack house facilities may carry out the grading and packing operations inside a field evaporative cooler.

Grading and Packing

The produce should be transported to the pack house in the field boxes or trays in which it has been harvested. The labour of grading is reduced if the harvesters arrange the beans in parallel rows in the harvesting containers. Beans for export to Europe must conform to UN/ECE Standard FFV-06, the principal provisions of which are as follows:

The beans in all class or grades should be:

- Of characteristic shape, size and color of the variety and not bent,

- Young, tender and stringless, without large seeds.
- Free from disease or insect damage and not wilted.

In addition to the above, the following standards apply to fine beans:

- *Fine grade*: The pods shall be not more than 9mm in diameter.
- *Extra fine grade*: The pods shall be not more than 6mm in diameter.

A third grade, not suitable for export to Europe, is defined locally as pods without conspicuous strings but otherwise sound and fit for human consumption.

Export packing

Beans are packed for export in fiberboard cartons which should be of attractive appearance and strong enough to ensure the arrival of produce at the market in good condition. Bobby beans are packed to net weigh of 4-5/kg. Fine and extra fine beans are packed to a net weight of 2.5kg. The pods are arranged in parallel rows in the cartons.

Cool storage

The recommended cool storage temperature for beans not less than 7^0 c at a relative humidity of 90 -95%. It is not advisable to cool-store beans before packing and grading because moisture condenses on the pods after their removal from the cool store to the pack house. If there is a delay between harvesting and grading/packing, beans should be held in an evaporative cooler in field containers. After packing, the cartons should be cooled by forced draught cooling or in an ordinary cool store in ventilated stacks.

Plant Protection

The disease pressure is generally low during the dry season.

Bacterial blights (*pseudomonas phaseolicola*, *Xanthomonas phaseoli*):

The symptoms are almost identical. Brownish small spots appear on the leaves. Stems might also be affected. The pods show water-soaked spots, which later turn brownish with bacterial exudates at the center. The diseases are carried over by soil and seeds. A crop rotation of two years is necessary. The seeds should be grown under dry climate conditions and treated with a copper compound. Rain spreads infections while heave dew also favours the spread of the disease. If necessary, the crop can be sprayed with copper compounds; one spray might be necessary when leaf symptoms appear, as the infection will be carried to the pods. Good coverage of the upper and lower side of the leaves is essential. In case of risk of pods infection, one spray on the young pods after full flower is appropriate. Late sprays will have no effect and only cause copper spots on the pods, which will not be accepted by the market.

11.2. Pumpkin (*Cucurbita moschata*) / *Cucurbita maxima*

The important vegetables of cucurbitaceous vegetables group are;

Common name	Scientific name
Cucumber	*Cucumis sativus*
Bottle gourd	*Lagenaria siceraria*

Bitter gourd	*Memordica charantia*
Ridge gourd	*Luffa acutangula*
Sponge gourd	*Luffa cylindrica*
Snake gourd	*Trichosanthes anguina*
Indian squash or Round melon	*Citrullus verlagaris* var *fistulosus*
Long melon	*Cucumis melo* var *utilissima*
Musk melon	*Cucumis melo*
Water melon	*Citrullus vulgaris*
Pumpkin	*Cucurbita moschata*
Summer squash	*Cucurbita pepo*
Winter squash	*Cucurbita maxima*
Pointed gourd	*Trichosanthes dioca Roxb*
Wax gourd	*Benincasa hispida* Cong.
Ivy gourd	*Coccinia indica* Wight&Arn
Anchote	*Coccinia abyssinica*

All these cucurbitaceous vegetables have similar cultural practices. Among these cucurbitaceous vegetables Pumpkin is more popular in Ethiopia. Commonly grown in the home garden.

PUMPKIN

S.N.	-	*Cucurbita moschata/ Cucurbita maxima*
Family	-	Cucurbitaceae
Growth habit	-	Annual (vine crop)
Origin	-	Arid areas of central America

Cucurbita moshata (pumpkin) is widely grown in Ethiopia mostly for home consumption.

Botany

Pumpkin *(Cucurbita moschata.)* belongs to the family Cucurbit or *Cucurbitaceae*, which contains five most important vegetable crops; pumpkins and squash (*Cucurbita* spp.), watermelons (*Citrullus lanatus*), melons (*Cucumis melo*) and cucumbers (*Cucumis sativus*) (Paris, 2016). About 90% of cucurbit species occur in three tropical regions: Africa (south of the Sahara, including Madagascar), Central and South America, and Southeast Asia and Malaysia. *Cucurbitaceae* family is very diverse group containing about 118 extant genera and 825 species (Lebeda et al., 2007). *Cucurbita* is one of the most diverse genera in the entire plant kingdom with regard to fruit characteristics (colour, size and shape) and has more cultivated forms than any other crop. Different cultivated species of the genus *Cucurbita* were domesticated in different places, ranging from North America to South America (Ferriol and Picó, 2008). Its center of diversity lies in South American temperate zones, where landraces exhibit interesting traits.

Pumpkin plants are hardy creepers or soil surface runners, but able to climb where there are supports. The fruits vary in shape, colour and sizes. They are monoecious and can be bred from pure lines. Pumpkins are cultivated for their ripe fruit with the seeds in the central cavity and the yellow or orange flesh being eaten. Pumpkin contains an important antioxidant, beta-carotene, which is converted to vitamin A in the body. In the conversion to vitamin A, beta-carotene performs many important functions in overall health. Research suggests that pumpkin seeds have unique nutritional and health benefits. The fruits of pumpkin are the largest in the group and usually eaten cooked.

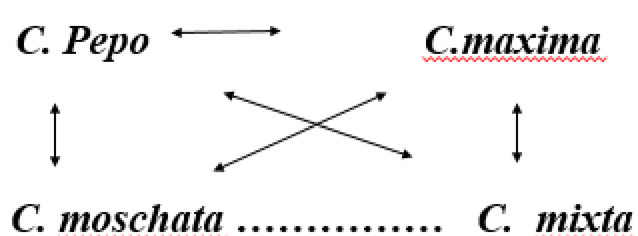
Importance

Pumpkin is the most economically, nutritionally, and medicinally important species distributed worldwide. Its fruits, leaves, seeds and flowers are used for consumption. The crop is rich in nutrients with high value of protein and carbohydrate in leaves and fruits, respectively (Bahru et al., 2018). Pumpkin is an excellent source of vitamin A, with its orange colour indicating high content of β-carotene that is transformed into vitamin A. It is low in calories and a rich source of, vitamin C, potassium and proteins (Tammy, 2008 cited by Ndegwa (2016)). The seeds are consumed roasted as a snack food. The seeds are high-energy source (mainly lipids and proteins) and are also a reasonable good source of K, P, Fe, and *B-carotene*, derived from the inner seed coat. The production of high-quality vegetable oil from seeds is a very traditional practice in different countries (Ferriol and Picó, 2008). Pumpkins seeds and fruits have been used as a treatment for various human diseases such as parasites and applied to burns, scalds, and inflammation (Plants for Future, 2010 cited by Ndegwa (2016)).

In Ethiopia, pumpkin is a traditional crop and commonly regarded as a poor man's food. The production is based mainly in local population for self-consumption (food or feed) and sale on local markets. The crop is produced by small holder farmers on their garden though area coverage and yield data is not available. It is also cultivated as intercrop with other crops such as maize and sorghum. The nutritional value of the crop is not well understood; even it is regarded as an orphaned crop mainly for the low income earners. Emphasis has not given in research activities compared to other vegetables.

Varieties

There is no improved pumpkin variety released yet in Ethiopia except some undergoing researches at research stations. Not only in Ethiopia, the crop is neglected in research; (almost) no breeding for yield, disease resistance and quality in Africa as a whole. The main feature of the crop is its adaptation to a wide variety of agricultural environments and grown in traditional small gardens with minimum external inputs and are adapted to marginal environments. **So** variety development programmes in pumpkin have not yet started in the country. However, a lot of variations are found in fruit shape and size of local materials. The varieties of squashes and pumpkin belong to four botanical species of the genus *cucurbita*, cross may occur among some of them. The diagram indicates the crosses that can or cannot occur.



The species joined by a solid line ( ) do not cross but crossing may occur between species connected by a broken line (-----)

Environmental Requirements

Cultivated cucurbita species are photoperiod neutral, with differing thermal optima. The area where pumpkin is cultivated should receive maximum sunshine to maximize the photosynthetic process, and therefore, produce the largest plant and fruit. The crop grows best with altitude up to 2000m and temperature of 22-25$_o$C, though some are well adapted to high temperatures. Low humidity reduces the incidence of diseases such as mildew. Heavy rain adversely affects flowering and delays development. Pumpkins grow well on soil that is high in organic matter, has good moisture retention capability and is easily drained. Soil pH ranges between 5.5 – 6.8 are ideal for cultivation.

Climate:

Pumpkin is more adapted to warmer areas and temperatures above 25^{0}C are more favourable for growth and development. The *cucurbita* genus is sensitive to frost. The cucurbits require comparatively dry warm and long growing season for seed production.

Soil: Pumpkin grow best on well drained fertile soils with soil PH range 5.5. to 7.5. Pumpkins can be grown on most soil types, providing these are well drained and are of good fertility. Pumpkins are heavy feeders and thrive on large amounts of organic manure. Mix compost or well-rotted manure into the bed to ensure an adequate supply of nutrients.

The soil should be well prepared to provide good tillage to approximately 30 cm deep and to assist in root penetration. If available, well- rotted manure should be incorporated in the soil during ploughing and rotation operations. When there is the risk of water logging, especially in low-lying areas, plants should be planted on raised beds so that excess water can be removed from the root zone.

On soils with a high clay content, there is a greater risk of more problems with root and stem diseases because of the wetter soil surface and higher humidity in the lower canopy especially in the rainy season. In this instance there is often a benefit from planting on raised beds. Managing the crop on heavier soils is often aggravated by excessive moisture. In heavy clays, land preparation operations such as ploughing and rotation help to improve the soil structure and so assist in drainage.

Seed rate: 6-8kg/ha

Spacing :

Row to row= 2.5 -4 .0 m

Plant to plant = 1.0 -1.5m.

Seeds/hill: 3-4

Nutrition

Fertilizer rates should be based on the results of a soil test and the nutrient requirements of the pumpkin crop. Excessive application of fertilizers can be wasteful and expensive and can also make it easier for the plant to give way to pest and diseases. Also excessive use of inorganic fertilizers such as nitrates and fertilizers can find themselves into drains, rivers and ponds through ground water or surface runoff.

Pumpkins need moderate amounts of potassium and phosphorus and high amounts of nitrogen. Pumpkins are large consumers of all the major plant nutrients (nitrogen, phosphorus and potassium), as well as many minor nutrients like calcium and magnesium and other trace elements.

Irrigation
Water management is critical to the development of vigorous vines and the maintenance of the foliage canopy, which support fruit growth and protect developing fruit from sunburn. Frequent irrigation aggravates root and stem rot problems and increases humidity in the lower canopy, which contributes to foliage and fruit diseases. Irrigation management should emphasize infrequent, deep watering to encourage deep root development and allow time for the soil surface to dry between watering. Water deficiency or stress, especially during the blossom-fruit set period, can reduce fruit size or cause blossoms and fruits to drop, resulting in reduced yields. Additionally, sandy soils require close attention to water management (more frequent irrigation) to avoid moisture stress and interruption in foliage or fruit growth. Pumpkins require a good supply of water to produce large thick walled fruits.

Weed Control: Pumpkins are not very competitive with weeds especially in the first few weeks of growth because they are planted in widely spaced rows, are short in stature, and require 8 to 10 weeks to close the canopy. The use of seedling transplants can assist in better control of weeds in the early stages. As the vine senesces later in the crop, this will potentially open the crop canopy, which allows weeds to establish and produce seed. Weed control can be achieved with herbicides and a good crop-rotation system. Several pre-plant and post-emergence herbicides are available for pumpkins, depending on the specific weed problem and pumpkin growth stage. If infestation levels are low, early cultivation (prior to vine running) can help minimize weed problems.

Harvesting and Maturity Indices plants
Pumpkins should be harvested when the fruit are completely mature. Several different indices can be used to determine harvest maturity, including time after planting, external appearance, hardness of the rind, stem texture, die-back of the tendril nearest the fruit, and internal colour. The number of days after planting can be used as a guide to predict the beginning of harvest. Pumpkin fruit are usually fully mature and ready for harvest about 3 months after sowing, or approximately 45 days after flowering.
External appearance of the fruit changes with maturity. Immature fruit typically have a bright surface sheen. As the fruit matures, the amount of shine diminishes. The rind of mature pumpkins has a dull waxy appearance that has lost much of its gloss. The fruit surface should have a good colour, characteristic of the cultivar.
Also, there will usually be a noticeable lighter coloured ground spot on the fruit underside Hardness of the rind is a good indicator of harvest maturity. As pumpkins mature, the rind tissue becomes noticeably tougher and harder. When the rind is sufficiently hard to resist puncture from the thumbnail or from fingernail scratches, the fruit is mature enough for harvest. At this stage of development, the seeds are also mature. Stem texture can be used to determine when to harvest pumpkins.

Internal flesh colour is also an indicator of fruit maturity. Immature fruit have a cream or light orange-coloured flesh. As the fruit matures, the content of carotenoid pigments increases and the flesh becomes a deep orange colour. An orange flesh colour is required for successful domestic and export marketing of pumpkins pair of sharp pruning shears is needed to sever the stem and create an attractive, smooth, clean cut. Do not pick up the pumpkin by the stem, as it may separate from the fruit and provide an easy access for decay organisms. A short length of stem should always remain attached to the fruit. Once removed from the vine, the pumpkins should be put in wooden or strong plastic field crates for transport to the collection site or packinghouse.

During harvesting, handling, and field transport, every effort should be made to avoid bruising or puncturing the rind. Also, harvested pumpkins should not be exposed to direct sunlight or rainfall. Ideally, pumpkins should not be stacked on top of each other. Stacking is a sure way to create bruises. Padding material, such as grain straw, should be used liberally if fruits have to be stacked during harvest. Spread out a layer of dry straw on the ground and set the pumpkins on this. Keep the fruit dry at all times and never store pumpkins on moist bare ground. If the pumpkins must be stacked for transport, the pile should not be more than 1 meter

Sorting/Grading: Pumpkin fruit are quite variable in size, shape, and colour; therefore, it is difficult to obtain consistent uniformity of product from a single harvest. However, grading for uniformity of appearance is important to meet market requirements. There are 3 established size categories (small, medium, and large) for domestic marketing of pumpkins,

Packing: Packages used to market pumpkins vary depending on market destination. Fruit sold in the domestic market and nearby Caribbean export destinations is usually packed in mesh sacks

Cleaning: Any adhering soil in the ground spot area or other surface stains should be removed at the time of harvest with a soft cloth or cotton gloves. Washing is usually not desirable. However, if washing is required to remove excess soil or to enhance the appearance for a particular market, the wash water should be clean and properly sanitized to reduce the potential for spread of disease. Sodium hypochlorite (household bleach) is commonly used since it is an inexpensive and readily available wash water sanitizing agent. It is effective against decay organisms when added to the wash water at a concentration of 150 ppm and the water is maintained at a pH of 6.5.

YIELD:

There is no any information about the yield under Ethiopian conditions. However, individual fruit may weigh up to 15 kg.