Course Title: Root and tuber crops production and management

CHAPTER ONE

1. INTRODUCTION

Definition and characteristics of root and tuber crops

Root and tuber crops includes plants with edible roots and tubers. Root and tuber vegetables are the part of the plant that grows below the soil or on the soil surface. They are widely grown and consumed as subsistence stables in many parts of Africa, Latin America, the pacific Islands and Asia. They are a staple food and main source of calories for an estimated 700 million poor people in Africa, Asia and Latin America.

The potential of these crops is particularly high in humid tropics and sub-humid tropics which are not suitable for cereal production.

In Africa, they provide about 1/3rd of all food. African countries contribute roughly 23% to the world production of root and tuber crops (primary crops). The main root and tubers crops produced in Africa are:

- Cassava (53% of the world production), followed by Asia (29%) and South America (17%);
- Yams (96% of the world production);
- Sweet potatoes (7%), the main producer being Asia (91% of the world production);
- Potatoes (4% of the world production), the main producers being Asia (37%), and the rest of the world (55%);
- Other root crops (70%), followed by Asia (20% of the world production).

Importance of root and tuber crops as a staple food is because of their particular agronomic advantages: They are well adapted to -diverse soil and environmental conditions a wide variety of farming systems. They are highly efficient of edible carbohydrates when compared to other food crops.

Botanically, they belong to a number of different plant families. They all have underground organs, i.e. parts of the plant for storing energy in the form of starch, sometimes sugar. These storage organs may be swellings on the roots (cassava), whole underground stems or stem tubers (cocoyam and xanthosoma where they are called corms and cormels) or a portion of the underground stem as in the case of yams and Irish potatoes.

The edible roots and tubers contain much starch, little protein, hardly any fat, few vitamins, and much water. "Cereals contain a little more protein than most tuber crops, but in every other aspect of food quality tuber crops are superior to cereals." (Westpha, 1978) Yams and Irish potatoes especially produce as much protein as some cereals.

General Characteristics of Root and Tuber Crops

The importance of root and tuber crops as staple foods is because of their particular agronomic advantages:

- They are well adapted to diverse soil and environmental conditions and a wide variety of farming systems;
- They are highly efficient of edible carbohydrates when compared to other food crops.

Their more important limitations are their bulkiness, some tubers weigh over 5 kg, and perishability, moisture contents range from 60% to 90%. These are associated with high transport costs, a short shelf life and limited market margins, which impose serious constraints in the urban markets of developing countries.

Production patterns reflect the agro-climate of the area, traditional farming practices and often the local cultural heritage. With few exceptions roots and tubers are produced by small-scale farmers using traditional tools and without any inputs of fertilizers or chemicals for weed and pest control. Traditionally women have provided most of the labour for production and harvesting. Some form of sequential cropping practice is frequently followed together with intercropping by cereals, legumes and cash crops such as coffee and cocoa.

Table : General characteristics of roots & tubers as compared with cereals

Cereals and oil seeds	**Roots and tubers**
Low moisture content, typically 10% to 15%	High moisture content, typically 70% to 80%
Small unit size, typically less than 1 gram	Large unit size, typically 100 grams to 15 kg
Very low respiration rate with very low generation of heat. Heat production is typically 0.05 megajoule/ton/day for dry grain	High respiration rate. Heat production is typically 0.5 to 10 megajoules/ton/day at 0°C to 5 to 70 megajoules/ton/day at 20ºC
Hard texture	Soft texture, easily bruised
Stable, natural shelf life is several years	Perishable, natural shelf life is a few days to few months
Losses usually caused by moulds, insects and rodents	Losses usually caused by rotting (bacteria and fungi), senescence, sprouting and bruising

Similarities and Dissimilarities b/n Root & Tuber Crops

Root and tuber crops share some common similarities, based on their biology and agricultural production and uses. However, they also have a number of dissimilarities that are not immediately evident to those not directly involved in research or in the development of relevant technologies.

Similarities

The similarities of the root and tuber crops are:

- ✓ Labor demands for production and marketing
- ✓ Perishability of the harvested product
- ✓ both grow underground crops and
- ✓ both are used as anchor the plant, store food and water.

Roots perform two primary functions

- ✓ They absorb minerals and water from the soil to sustain plant growth
- ✓ They also anchor the plant in place by providing a structural foundation root crops and tubers accomplish both this functions
- ✓ Tubers provide plants the same services as normal roots

Differences

Physiological Differences: Tubers and root crops form from different types of plant tissues. Even though a tuber grows underground, it is a type of specialized stem tissue that stores nutrients for the plant. A potato is actually an enlarged stem. Root crops derive from root tissue. Carrots are an enlarged tap root.

Root Structure: Root crops and tubers have a different kind of root structure. Root crops are tap roots. They are a single root that bores down into the soil like a carrot or parsnip. They can be a single rounded modified root like a beet. The key point being, root crops form one vegetable per stem. With tubers, a single plant can produce several tubers. A carrot plant will have one carrot, while a potato plant can produce several potatoes. Unlike root crops, several tubers can grow per plant.

Carbohydrate Composition: Root crops and tubers vary in their carbohydrate composition. Root crops contain more simple carbohydrates such as glucose. Tubers contain long chains of glucose called starch. Potatoes are an important food crop around the world because they contain large amounts of starch, a good source of energy for people's metabolisms.

Propagation: Plants store the energy in tubers for propagation. A cut up radish provides a snack; a cut up potato can grow more plants. Many ornamental plants can be propagated by cutting a portion of stem and sticking it in water. The stem will eventually grow roots. Potatoes are the same way. Slice a potato into several sections containing an eye. A new plant will grow from each section. Root crops cannot do this. Any tuber cut many pieces it grow plant while in root crops cannot grow plant.

Nutrition: Both root crops and tubers offer abundant nutrition. Tubers offer loads of energy and vitamins. Root crops offer vitamins, minerals and micro-nutrients. Carrots contain beta-carotene, a precursor to vitamin A which, according to the Mayo Clinic, is good for the eyes. The Center for Disease Control and Prevention lists the tubers yucca and jicama, as well as root crops horseradish and rutabaga, as high in vitamin C. Rutabagas have 25 percent vitamin C.

Prospects of root and tuber crops production in Ethiopia

- ✓ There is suitable agro-ecological condition and rich water source
- ✓ The crops have a potential to give high yield per unit area and most of the crops are stress tolerant and thus can help as food security crop
- ✓ Current malnutrition problem
- ✓ Requires less exacting condition for cultivation
- ✓ Valued for intercropping with plantation crops e.g. Tannia, Enset and Cassava.
- ✓ Export possibility
- ✓ Relatively easy and cheap to produce as compared to any other known crops

Constraints of root and tuber crops production in Ethiopia

Root and Tuber Crop Production mainly challenging on small-scale farmers because of:

- Insufficient market places,
- Lack of transport,
- Poor market infrastructure,
- Poor infrastructure, e.g. roads in certain regions,
- Lack of market information,
- Lack of credit facilities and e.t.c.

Generally the yield is low per annum b/c of the following constraints

- ❖ Roots and tubers are highly perishable (moisture contents range from 60% to 90%) and as a result, post-harvest losses can be substantial. They therefore require specialized post-harvest handling, storage and preservation techniques in order to minimize losses, extend shelf-life and maintain quality.
- ❖ Root and tuber crops have not been improved much by selection and breeding. Information on the farming of root and tuber crops is scanty.

- Most of them have not been subjected to intensive farming on scientific lines. Production patterns reflect the agro-climate of the area, traditional farming practices and often the local cultural heritage. With few exceptions roots and tubers are produced by small-scale farmers using traditional tools and without any inputs of fertilisers or chemicals for weed and pest control.
- Their bulkiness, some tubers weigh over 5 kg. These are associated with high transport costs, a short shelf life and limited market margins, which impose serious constraints in the urban markets of developing countries.
- Disease and insect pest problem
- Community food habit limitations. Mostly peoples are accustomed to foods such as ceareals, meat and dairy products.
- Shortage of improved technologies like, improved seed, storage and processing facilities.
- Lack of adequate access to foreign market
- Underdeveloped infrastructure
- Weak attention given for the crops related other crops

Importance of root and tuber crops

Roots and tubers were critical components in the diet during the early evolution of mankind (~5 million years ago). The migration of early hominids from the tropical rainforest to the savannah, a move that is thought to have occurred after Ardipithecusramidus, had monumental consequences with regard to food availability. Food acquisition became more critical, and “feast and famine” cycles in food availability were common. Roots and tubers comprised significant components of the diet and had the advantage for hunter-gatherer societies in that they were available over extended periods of time due to their ability to be left in situ until needed. Even today, many indigenous populations display a remarkable knowledge of the general biology of the plant material they gather from the wild.

While the predecessor of modern man is often depicted as a hunter, in reality plant products typically represented substantially more than 50% of the diet. Since plant remains rarely survive, an indication of the importance of vegetable materials in the diet comes from recent hunter-gatherers. Estimates of up to 80% of the diet being of plant origin (e.g., roots, tubers, fruit, and seeds) have been made. With the advent of agriculture, cultivated root and tuber crops became increasingly critical sources of food with the potato, cassava and sweet potato representing the 3rd, 6th and 7th most important sources of food for humans worldwide today.

Nutritional value

- Root and tuber crops are second only in importance to cereals as a global source of carbohydrates. The edible roots and tubers contain much starch, little protein, hardly any fat, few vitamins, minerals and much water.

- The contribution of root and tuber crops to the world supply of calories is 5%(48% for cereal and 46% for other foods).
- In Africa, root and tuber crops contribute 14% to the calorie supply(cereal 51% and 37% for other food)
- In S. America and Asia root and tuber crops contribute 5% and 4% to the calorie supply respectively.

Medicinal value

- ✓ Provide as protective nutrients because of their vitamin and mineral content
- ✓ Act as antioxidant. carotinoids in carrots and flavonoids in radish neutralize free radicals produced during metabolism.
- ✓ Some can be used as a traditional medicine to treat different ailments

Ornamental value

- Some root and tuber crops can be used as ornamental plants by growing them in home gardens.

Economic value

- Can be used as source of income. Because of their high productivity and short life cycle, they can be produced 3 times a year and better return can be earned for the producers.

Social value

- Employment opportunity because any peoples are involved in the farming, processing and marketing root and tuber crops.

Roles of Root and Tuber Crops in Food Security

- The 2nd most important source of carbohydrate next to cereals in the world food.
- To produce the most important staple food for about 20% of the world population and 31% of the African population.
- To supply cheap sources of food and energy to the weaker section of the society.
- Rich in different nutrients (vitamin and mineral).
- Tuber crops (potatoes) achieved important because of their inherent quality of protein and carbohydrates.
- Adapted to wider ecology and marginal growing conditions.

Classification of root and tuber crops

A few crops have similarity while others have dissimilarity in their climate and soil requirements, parts used and method of cultivation etc…Due to these wide variability and voluminous information about these plants a systematic method of grouping or classification is essential preferably having universal applicability. While describing individual root and tuber crops, there is possibility of repetition in many aspects. In order to avoid repetition it is essential to classify or group them in different classes or groups.

There are several systems of classification based on parts used and botanical groups with varying cultural and climatic requirements. But no single method of classification would serve the purpose for different groups like farmers, academic groups like agronomist, breeder, and taxonomist and so on.

Generally root and tuber crops can be classified based on botanical characteristics, life cycle, parts used and methods of culture.

1) **Botanical classification:**

This method of classification is based on botanical relationships among different root and tuber crops mainly on their taxonomy or botanical families. This classification system is best known as the Latin binomial botanical classification. This classification is important for both root and tuber crops breeders and scientists (Horticulturist) to know the botanical relationships of the crops which he/she intends to work upon viz. the morphological and cytological similarities and dissimilarities, their place of origin, crossibility, floral biology and other details which are relevant in crop improvement.

For Horticulturists it allows the identification of some general association with regard to the plant adaptation, cultivation and handling etc.

According to botanical classification all plants are considered as one community (Kingdom) and divided into four Sub-communities (Divisions) given as follows.

Plant Community/Plant Kingdom – Plantea

Sub- Community - Four communities given as follows

i) Thallophyta - Algea and Fungi

ii) Bryophyta - Moses and Liverworts

iii) Pterodophyta - Ferns

iv) Spermatophyta - Seed plants

Spermatophyta is again divided into two classes

a) Gymanosperm- Cone bearing plants

b) Angiosperm-Flowering plants

Angiosperm is divided into two Sub-classes

a) Monocotyledonous

b) Dicotyledonous

Further these classes are divided into: Order, Family, Genus, Species, Variety or Group (Botanical), and Cultivar (Horticultural Variety).

All root and tuber crops come under Angiosperm of the Sub-Community Spermatophyta.

2. **Classification based on Plant Parts used**

In this classification root and tuber crops are grouped according to their edible parts used. Based on this root and tuber crops can be classified in to:

- Tuber Crops (Potato (Solanumtuberosum L, Yam (Dioscoreaspp), Indigenous Potatoes (Coleus spp))
- Taproot Crops(Anchote (Cocciniaabyssinica), Carrot (Daucuscarota), Beet root (Beta vulgaris), Radish (Raphanussativus), Parsnip (Pastinaca sativa), Turnip (Brassica rapa), Rutabaga (Brassica nopus), Parsley root (Petroselinumspp))
- Tuberous root Crops(Sweet Potato (Ipomoea batatas L) and Cassava (Manihotesculenta))
- Corm Crops (Enset(Enseteventricosum), taro (Colocasiaspp), Tania (Xanthomonassagthyfolium) and Celeriac (Apiumgraveolens))

3. Classification based on cultural requirements:

In this classification, crops requiring the same cultural practices (but not same season for growing) are grouped together though they may be divergent botanically. Based on these root and tuber crops can be classified in to potato group, root crops (radish, turnip, carrot, beet root), sweet potato group etc…

4. Classification based on Duration of Crop growth or Life cycle:

According to their life cycle root and tuber crops can be classified into three groups: annual, biennial, and perennial.

CHAPTER -TWO

Major tuber Crops grown in Ethiopia Potato (Solanum tuberosum L.) Yam (Dioscorea spp), Indigenous Potatoes (Coleus spp)

2.1. Potato

Origin

Potatoes are native to South America Peruvian Andes regions Probably originated in the Peru Bolivia area. Now day potato is grown in worldwide especially in temperate climate. Also production increases rapidly in tropics.

History and Importance

The Spaniards introduced the potato to Europe soon after 1580, and the popularity of Potatoes spread all over Europe and the British isles by the end of the 17th century. First introduced into New England by Irish immigrants in 1719. the white Potato is now referred to as the "Irish Potato" because of its association with true potato famine in Ireland in the 19th century.

In Africa, until the end of the 19th century Potato was imported from Europe by missionaries. Introduced to Ethiopia in 1858 by a German Botanist Wilhelm Schimper. adoption by Ethiopian farmers occurred very gradually for several decades. The first available potatoes were a very limited genetic base hence vulnerable to diseases and pests.

Potato production has increased considerably through the twentieth century. Ethiopia's potato area had grown to 160,000 hectares, with average yield around eight tons per hectare.

An upward trend in potato production might be partly due to the continuing increase in population and subsequent hence pressure for agriculture to become more labor intensive.

Potatoes are not roots but specialized underground storage stems called "tubers" .They are ranked with wheat and rice as one of the most important staples in the human diet. It is also a very important food and cash crops in Ethiopia, especially in highlands and mid-altitude areas of the country. As a food crop, it has a great potential supply high quality food within relatively short period and is one of the cheapest sources of energy. It has well balanced protein, and gives more calories from a unit area of land than other major food crops.

Tubers are generally boiled and prepared in many ways; Flour is also produced from processed and dehydrated tubers. Potato provides significant quantities of protein, vitamin C, carbohydrate, iron and to lesser extent vitamins of B complex and Vitamin A.

Table 1: Average constituents of Potato (Solanum tuberosum L.) tubers

Constituents	Percentage (wb)
Moisture	50 – 81
Protein	1.0 - 2.4
Fat	1.8 - 6.4
Starch	8 – 29
Non-starch Carbohydrates	0.5 - 7.5
Reducing Sugar	0.5 - 2.5
Ash	0.9 -1.4
Carotene (average)	4 mg /100 g
Thiamine	0.10 mg /100 g
Riboflavin	0.06 mg /100 g
Ascorbic Acid	12 mg /100 g

General morphology and composition of the potato tuber

The potato is basically a swollen stem mainly composed of water (80%) making it a bulky commodity and one which responds strongly to its prevailing environment. In cross section there are four clearly distinguishable areas (Figure 1):

A. **Skin or Periderm**. A ring of six to ten suberized cell layers, usually thicker at the stem than at the bud end although the total skin thickness can vary substantially depending on variety and growing conditions. The skin can easily be removed in immature tubers but not when the tubers have reached full maturity. If the tuber tissue is wounded, the tuber is able to form a new layer of suberized cells, known as wound periderm. **Lenticels**, which are a circular group of suberized cells, are formed in the periderm and are essential for the respiration of the tuber since the skin is almost impermeable to CO_2 or O_2. **Potato eyes** (effectively buds on the stem), **the bud and stem ends** are also present on the periderm surface.

B. **Parenchyma tissue**. Composed of cells of the cortex and the perimedullary zone. It represents the major part of the tuber and contains starch grains as reserve material.

C. **The ring of vascular bundles**. When the tuber is cut lengthwise part of the vascular tissue is revealed as a ring, known as the xylem.

D. **The medullar rays and medulla**. Also known as the pith.

The chemical composition of potatoes is very variable and is greatly influenced by variety, environment and farming practices. Starch constitutes 65% to 80% of the dry weight of the tuber. Potatoes are also an important source of protein, iron, riboflavin and ascorbic acid.

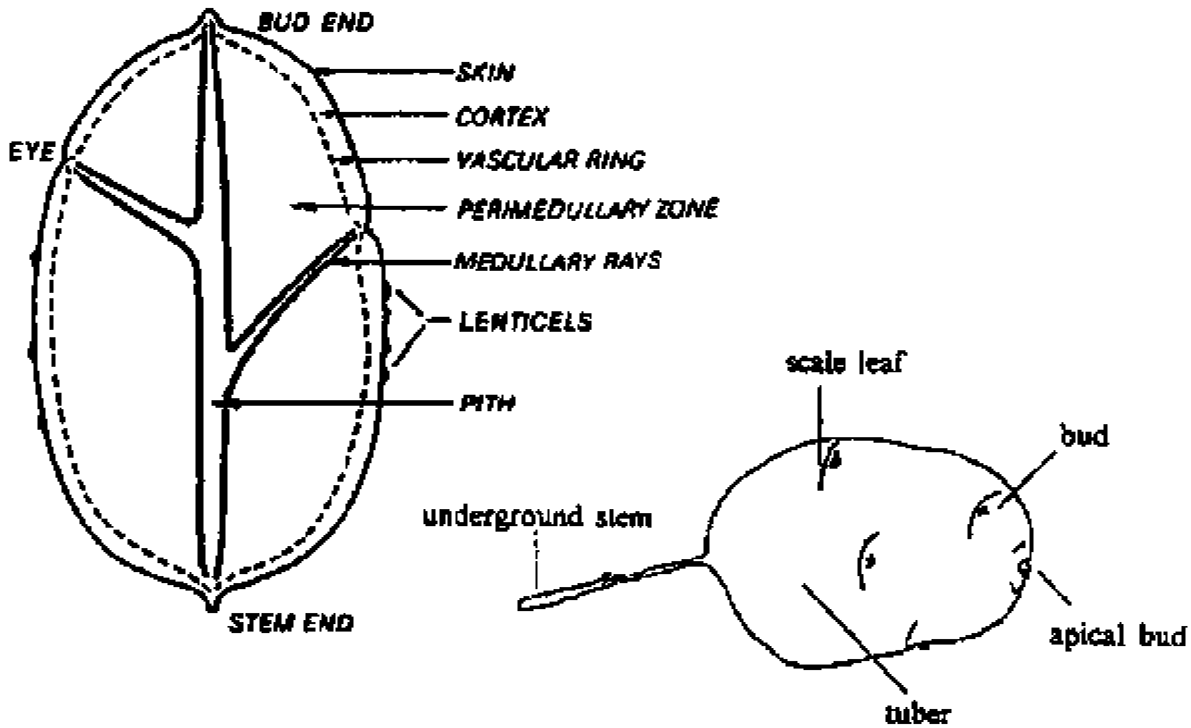
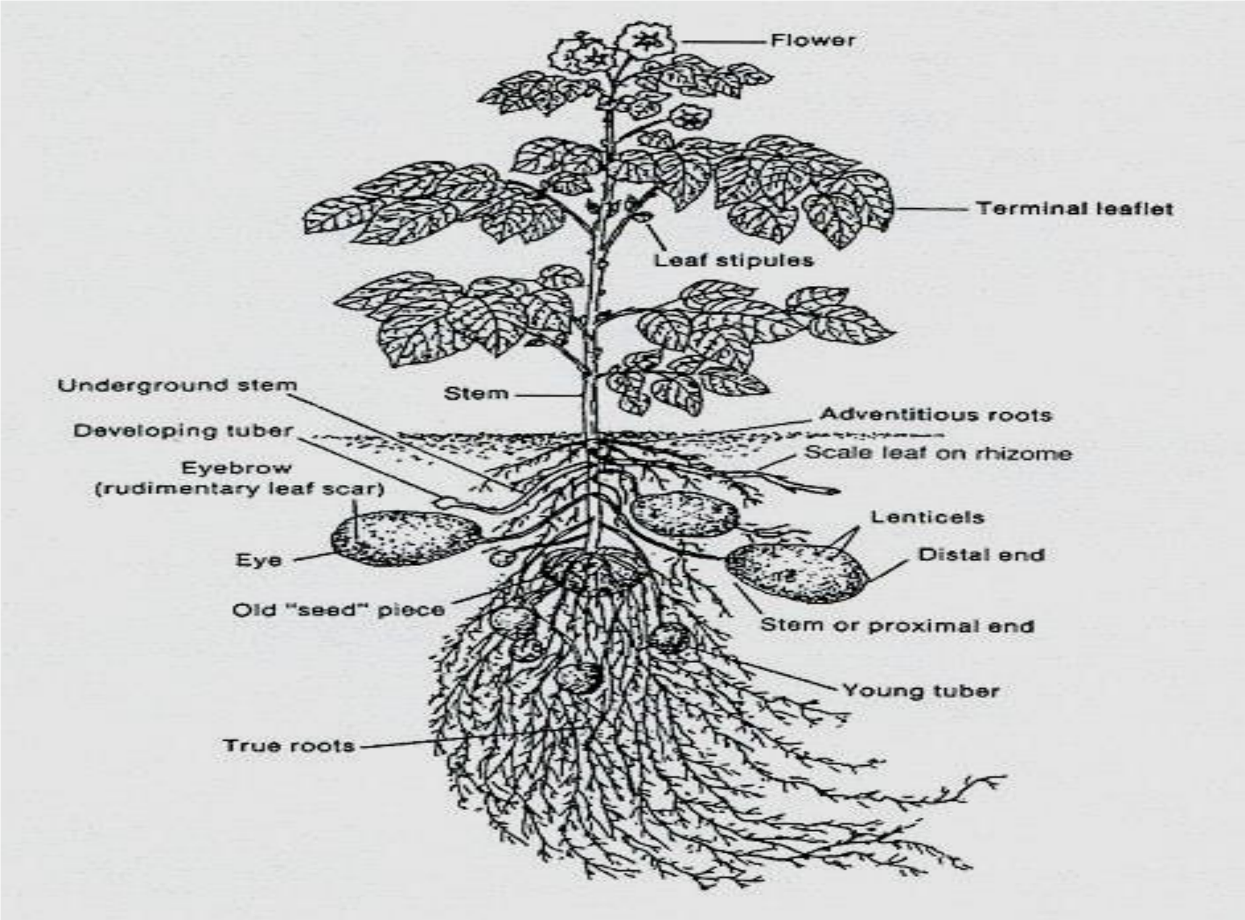


***Figure** 1: Diagram of a longitudinal section of a potato tuber (Rastovski et. al., 1981)*

2.1.1. Description of the Plant

Solanum tuberosum belongs to the family Solanaceaea and genus solanum. Solanum embraces a number of species that have 12 basic chromosomes. Potato belongs to the tetraploid group (2n = 48). It is a short-lived perennial herb, grown as annual, producing swollen underground tubers when mature. It is to the tubers that develop underground on the end of stems (known as stolons) that potato owes its name. Tubers are pieces of stem with short, thick internodes and buds at the nodes. The buds are lodged in hollows, called eyes, and give rise to shoots called sprouts. A sprout can grow into a plant identical to the one the tuber came from.

The aerial parts of the plant composed of several main stems, the number of which depends on how many sprouts developed from the parent tuber. Each leaf is made up of 3 to 5 pairs of leaflets plus a terminal leaflet. Secondary and interjected leaflets are present. The potato's inflorescence has 8 to 10 white blue or purplishlilac flowers. The plant reaches up to 1m in height. Reproduction is usually autogamous and the fruit, a spherical berry 15cm in diameter, may contain 50 to 100 seeds. The fruit contains toxic alkaloids. In some countries (Ecuador, Colombia, China, Egypt, Peru) the seeds are used as a means of propagation but the tuber is used most.



2.1.2. Potato Plant Growth

Growth and quality of potatoes are influenced by environmental factors such as temperature, moisture, light, soil type and nutrients.

- Many factors that influence potato growth are largely uncontrollable:
- length of growing season,
- air and soil temperatures,
- light intensity and duration,
- humidity and wind.

Other factors that influence growth of the crop can be controlled by the growe

- *variety of potato,*
- *size of mother seed tubers,*
- *seed-piece cutting,*
- *seed-piece types,*
- *cut-seed size,*
- *planter operation,*
- *plant stand,*
- *stem population,*
- *moisture,*
- *nutrition,*
- *pest management,*
- *planting date and*
- *harvest date.*

- **Only when all factors are at optimum levels can the most profitable yields of quality potatoes be attained.**

2.1.3. Growth Stages

The development of potatoes can be broken down into five distinct growth stages

Growth Stage I: Sprout Development

This stage begins with sprouts developing from the eyes and ends at emergence from the soil.

The seed piece is the sole energy source for growth during this stage.

Root begins to develop at the base of emerging sprouts.

Growth Stage II: Vegetative Growth

This stage, in which all vegetative parts of the plants (leaves, branches, roots and stolons) are formed, begins at emergence and lasts until tubers start to develop. Growth stages I and II last from 30 to 70 days depending on planting date, soil temperature and other environmental factors, the physiological age of the tubers, and the characteristics of particular cultivars.

Growth Stage III: Tuber Set/Initiation

Tubers are forming at stolon tips, but are not yet enlarging. This stage will last approximately 2 weeks. In most cultivars the end of this stage coincides with early flowering.

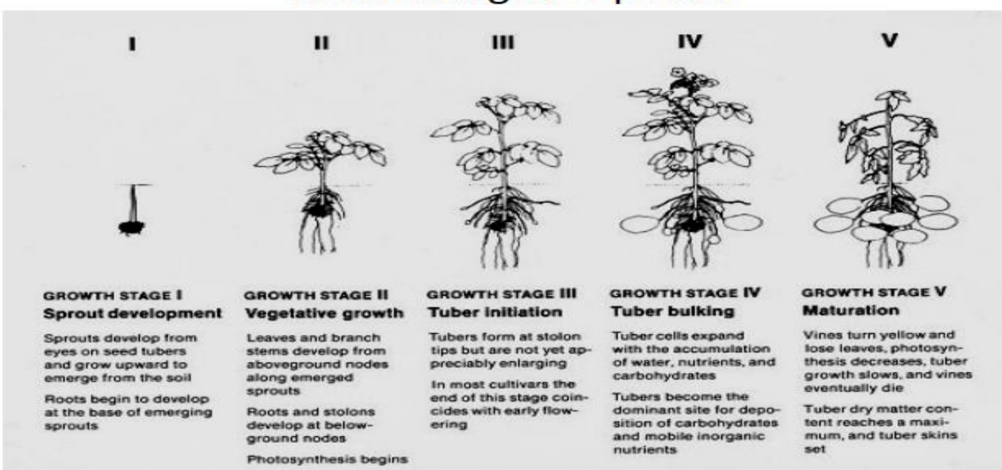
Growth Stage IV: Tuber Bulking

Tuber cells expand with the accumulation of water, nutrients and carbohydrates. Tuber bulking is the growth stage of longest duration. Depending on date of planting and cultivar, bulking can last up to three months. Tubers become the dominant site for deposition of carbohydrates and mobile inorganic nutrients.

Growth Stage V: Maturation

Vines turn yellow and lose leaves, photosynthesis gradually decreases, tuber growth rate slows and the vines die. Tuber dry matter content reaches a maximum, and tuber skins set. This stage may not occur when growing a long season variety.

Growth stages of potato



Improved Cultivars

- Breeding program in Ethiopia developed more than 13 late blight resistances varieties of potatoes.
- The average yield of those varieties ranges from 218 to 467 qt/ha under research station and about 250 qt/ha under farmers condition.
- As a result those varieties have a relative yield advantage of 210% to 750% as compared to the local check.

Table1. Released cultivars of potato in Ethiopia

	Cultivar	Year of release
1	**Kulumsa (KP-90143.5)**	2007
2	**C V R 2007**	2007
3	**Hundee(CIP-90147.8)**	**2006**
4	**Gudanie(CIP-386423.13)**	**2006**
5	**Araarsaa(CIP-90138.12)**	**2006**

Table2. Released cultivars of potato in Ethiopia

Varieties	Year	Breeder/ maintainer
Mara charre (CIP389701-3)	2005	AWARC/ SRARI
Bulle (CIP387224-25)	2005	AWARC/ SARRI
Shonkolla (KP-90134.5)	2005	AWARC/ SRARI
Gabbisa (CIP3870-96-11)	2005	AU
Chala (CIP387412-2)	2005	Alemaya university
(KP-90134.2)	2003	ARARI /SHARC
Gorebala (CIP-382173-12)	2002	ARARI /SHARC
Guasa (CIP-384321.9)	2002	ARARI/ADARC
Jalenie (CIP-37792.5)	2002	EARO/HARC
Degemegn (CIP-384321.19)	2002	EARO/HARC
Zemen (AL- 105)	2001	AU
Bedasa (AL- 114)	2001	AU
Zengena (CIP-380479.6)	2001	AARC
Chirro (AL-11)	1997/98	AUA(NowAU)
Wechecha	1997	EARO/HARC
Tolcha	1993	EARO/HARC
Menagesh	1993	EARO/HARC
Awash	1991	EARO/HARC
Alemaya 624	1987	AUA (NOWAU)

Climate and Soil Requirements

Climate plays an important role in influencing potato yields. The climatic factors that influence potato yields are temperature, light intensity, photoperiod, rainfall and length of the growing season.

Potato is a cool-season vegetable and will withstand light frost in the spring and generally require a growing season of 90 to 120 frost free days.

Temperature

Potato thrives best with moderate temperature during the growing season.

- ✓ Temperature averaging 16-20^{0}C are optimum
- ✓ High temperature reduce tuber formation because it increases the respiration rate in the tuber as result stored food in tuber affected or deplete
- ✓ High temperature can affect initiation of stolon in some cultivars.
- ✓ Tuberization will be ceased above 30^{0}C and maximum photosynthesis obtained at 25^{0}C.
- ✓ Net assimilation maximum at 25oC and above this the rate of respiration increased substantially so that fewer assimilate are retained by plant.

Rainfall

Since the Potato root system is not well developed; it requires a uniform supply of moisture throughout growing season for maximum yield.

The most critical period being at the beginning of tuberization.

Rain fall of 500 – 750mm is generally suitable for potato Production

Excessive amount of rainfall is very detrimental in potato production because it encourages the developmental of leaf diseases.

Inconsistent soil moisture may sometimes lead to

- ❖ development of misshapen tubers
- ❖ bitter taste tuber
- ❖ rough skin textured tubers
- ❖ Tubers which have been subjected to a dry period and high soil temperatures may pass through the dormant period and begin to form shoots.

Altitude

The altitude greater than 1000 m.a.s.l is generally suitable for growth and better economic yield of potato.

In Ethiopia, it is mainly grown at high altitude although cultivars recently produced perform well at relatively lower elevation. Optimum altitude for potato production under Ethiopian condition is between 1,800m and 2,600m.

Light

- Light has effect on tuberization process.
- Tuberization is induced in short day while long day encouraged vegetative growth at expense of tuber formation.
- High light intensity is favorable for tuber formation due to increased photosynthesis.
- Therefore for better tuberization short day and cool season is favorable where as in season with long and hot day tuberization does not at all due to respiration and excessive vegetation growth.
- The extent and duration of tuberization largely depend on the genetic makeup and environment (nutritional)

Soil

- Potatoes are adapted to a wide range of soils but for optimum yield
- well–fertilized sandy loam (light textured fertile) soil with good water drainage and aeration is important and preferred.
- Heavy clay soils produce misshapen (irregular shaped) and rough skinned tubers.
- Compact soils reduce the yield and also produce unmarketable potatoes
- Potatoes have a relatively wide pH tolerance.
- pH of 5.2 to 6 is good for optimum yield and Soil pH's as low as 5.0 to 5.2 can be tolerated
- Such acidic pHs can be beneficial in controlling common scab (Streptomyces scabies) diseases which needs high pH (>6).

However low soil pH

 Reduces availability of P and Increases availability of toxic elements such as Mn and Al. So use of scab resistant varieties at a soil pH of 6.5 is recommended to increase P availability and minimize Mn and Al toxicity.

Cultural Requirement

Field preparation

After site selection the next operation is field preparation.

 Good water penetration and aeration are necessary for proper potato plant growth and tuber formation.

 Land should be cultivated to depth of 25-30cm with organic matter and fertilizers incorporated ahead of planting to ensure efficient growth and development.

 The soil is typically ploughed below any compacted layer within the normal root zone and then disk harrowed before planting.

 Excessive tillage and land preparation can cause compaction and reduce potato growth and yield.

Planting

• Planting material

• Potato is conventionally propagated through:

Tubers

 can be whole tubers or set (cut) tuber

 Each whole tuber has several eyes distributed over its surface with eye having 3-5 buds, which develop into sprouts.

 The cut tuber has minimum of one eye.

 True potato seed (TPS)

Comparison of potato production from TPS and Seed tubers

TPS

 Amount of seeds required is very small (40-45g/ha seed)

 Disease transmitting is negligible

 Require much labor (extra time to raise seedlings)

 Take long time for maturity

 Difference in tuber size, shape (lack uniformity) this because of heterogeneity

 Low cost of transportation and storage

 Better disease resistance due to high heterogeneity in the population

Seed tuber

 Amount required of tuber is large (10 – 20qt/ha)

 Chance of disease transmition is high

 Require less labor

 The tuber are almost uniform

 Mature early

 High cost of transportation and storage

 Suitable for processing due to uniformity

Seed source and preparation

Potatoes are most often propagated from vegetative tissue, either whole tubers or cut pieces of tubers. Tubers used for propagation are typically called seed tubers, seed potatoes, or seed pieces. Potato plants can be produced from botanical/sexual seeds, but these “true” potato seeds (TPS) are seldom used, because they are genotypically variable and give rise to plants with traits that may be completely different from those of the parent plants. Moreover, production from TPS often requires several extra months of initial growth in a greenhouse or seedbed, followed by labor-intensive transplantation into the field.Plant breeders use TPS to develop new potato cultivars.

• Seed tubers should be obtained from reliable source.

• Seed must be:

- ✓ true to type and
- ✓ free from diseases particularly viruses.
- ✓ It is also advised to replace the seed after every 3-4 years because of degeneration problems.
- ✓ For planting potatoes using set tuber,

 Dust cut potatoes in sulfur right after cutting them.

 Cut seed potatoes, whether sulfur treated or not, should be “Curred” or suberize (heal over) before they are planted in order to reduce rot.

To suberize

 Spread in a warm, humid place at 21oC.

 Let them sit for two days so cut surfaces dry.

• **Suberisation:** Formation of Callus layer and wound periderm in the cut tubers before planting.

 Cut tubers are kept at 10-15^{0} C and 85-90% R H.

 Cut tubers are not recommended for planting because it enhances chance of transmitting viral and bacterial diseases.

Planting time

In Ethiopia there are two growing seasons

- Main growing season (kiremt) June-September
- Planting is done in early June. In this season only planting late blight resistance or tolerant varieties or using of frequent fungicide application to control the disease.
- Off – season (by irrigation) October

• However, in areas where frost is a problem

- January - April/May and planting time in early January.

Planting method:

- Plating of potato is done by two methods.

(i) Mechanical (tractor driven potato planter)

(ii) Manual: commonly practiced

Steps in manual method:

- ✓ Ridge and furrow method is followed.

- Lines are marked at given row to row spacing
- Seed tubers are planted at given plant to plant spacing
- Fertilizers are placed on both sides of the lines 4-5 cm away from seed tubers
- Seed tubers are covered by putting the soil from both sides with the help of spade or Ridger
- Automatically ridge and furrow will be formed

Seed rate and spacing:

- Seed tubers: 2 tonns (20 quintals)/ha
- Seed tuber size: 40-60gm.
- Spacing :between rows 75cm:between tubers 30cm for ware

  75cm by 20cm for seed production

Depth of planting: depend on soil types but recommended depth is 10 to 15cm

Fertilizer applications:

• Potato has a high nutrient requirements.

• The following amount of nutrients is recommended to be applied for potato production

 Nitrogen : 50kg/ha before ridging : 50kg/ha at the time of first flowering

 P2o5 :100kg/ha before ridging.

• In Eth, Blanket recommendation

 165 Kg/ha of urea

 195 Kg/ha of DAP

 20- 30t/ha organic manure

 But this varies with the soil status of the area

Earthling up:

• When the plant tops emerge, additional soil ridging (hilling, earthing up) is used

• Earthing up is done:

 To increase soil aeration

 To kill weeds

 To increase tuberization, tuber size and yield

 To prevent tubers from disease like late blight infections.

 To control tuber moths by exposing larva to the sun

 To prevent greening of tubers (protect from sun)

• Sunlight causes a potato to turn green and produce poisonous glycoalkaloids, such as solanine (glycoalkaloid levels of newly released cultivars must be less than 20 mg per 100g fresh weight to be considered non – poisonous

Irrigation:

• Soil moisture is one of the most important factors in determining potato yield and quality.

• The soils used growing potatoes are generally maintained uniformly moist until tubers have reached full size.

• Moisture levels significantly above field capacity also seriously affect yield and quality

• When irrigation is needed to supplement rainfall it is usually applied in frequent small amounts.

• Secondary growth and growth cracks occur when irrigation or rainfall occurs after a period of moisture stress.

 If pre- planting irrigation is not done then light irrigation should be done just after planting.

 Second irrigation is done after one week and subsequent as and when required.

 Stop irrigation 10days before haulm killing.

Haulm killing:

• Haulm destruction is removal of above ground parts and is usually done 7-10 days before harvest.

• It gives chance for the skin to firm in to flesh.

• Removing the haulms (top–killing) three weeks before lifting is good practices to suberize tubers' skin as much as possible.

Haulm destruction can be done either ways:

 Mechanically (by hand, by pulling or cutting off the tops)

 Applying chemical herbicides

 Spray 2.5 liters of paraquate (Gramoxone) dissolved in 750 liters of water per hectare for killing of haulms.

 Applying growth inhibitors 2 weeks before harvest (Diguat is used for chemical haulm destruction.)

• If the crop is grown for seed, top–killing will be necessity to keep the tubers and to prevent any late viral and fungal injections spreading to the tubers.

• To control aphids

 Cut the haulms of seed crop when 3-5 aphids per 100 compound leaves are observed in the insecticide sprayed crop.

 No regrowth is allowed otherwise aphids will attack the regenerated foliage and transmit virus to the crop.

Advantage of haulm destruction

- Helping to easy harvesting
- Reduce disease transmission example late blight
- Hasten maturation
- increase in yield

Harvesting and Postharvest handling

• Potato crop is ready for harvesting in 90-100 days after planting depending on the variety and ecological condition.

• Potato must be harvested when tuber are well matured.

• The crop is harvested 10-15 days stoppage of last irrigation. This allows tuber skin to become firm and tubers do not bruise on harvesting.

• Maturity in potato in indicated by: -

- Change in color of the foliage usually from green to yellow
- The skin of immature tubers easily peels off but for matured ones is firm enough at harvest
- When the vine start dying

•Tubers are harvested 10-15 days after haulm killing when the skin of the tubers has hardened.

- Harvesting is done by digging the ridges and tubers are collected
- Harvesting can also be done with potato digger.

• Care should be taken not to cut the tubers while harvesting.

Grading:

• All cut, damaged and rotten tubers are removed and then tubers are graded according to their size preferably in four grades:

- Small tubers :below 25g
- Medium tubers :25-50g
- Large tubers :50-75g
- Extra large tubers :above 75 g.

Yield:

• Average yield ranges 20-35 tons/ha.

• Whereas, there is lot variation in potato tuber yield at research field (40 tons/ha) and farmer field(20 tones/ha

• In our country very low, the national average is about 80 qt/ha. This is because of:

 Lack of improved technology

 Lack of improved cultural practices

 Lack of good, clean and disease free seed tuber,

 Lack of improved storage facility

 Planting material is very susceptible pests.

Postharvest handling

Immediately after harvesting the tubers should have a period for the skins to harden (suberize), sometimes referred to as 'wound healing', and reduces the possibility of water loss and deterioration during storage.The postharvest handling operations vary with the intended purpose of the tuber.

Storage

• Storage of both seed and ware potatoes is problematic for most farmers, as storage losses can reach fifty percent, sometime higher.

Methods of storage

Cold storage

 Most effective means to maintain tubers in good condition

 Tubers can be stored up to 8 month at temperatures slightly above freezing, but at temperatures below 5^0C, some of the potato starch turns to sugar, reducing cooking quality.

 Before processing potatoes are therefore often moved to a holding area at temperatures high enough to convert the sugars back to starch.

 Chemicals application to stores tuber or growing plants can delay sprouting, because sprouting greatly reduced the food value of potatoes.

 Maleic hydrazid is commonly used as a sprouting inhibitor.

Low cost improved ware potato storage

• This storage has two ventilated windows in opposite side on the top, the other on bottom.

• These windows open at night and closed during day time.

• The potatoes place on ventilated wooden bed. This storage can stored ware potato up to 3 month.

 Potatoes are stored in a cool, dark, well–ventilated area where there is no danger of freezing.

 Tubers exposed to light during storage form chlorophyll and turn green.

Seed potato storage: In Ethiopia, where cold storage is unavailable or too costly, smallholder growers store their potato seeds on the floor, granary or left on farm (unharvested) until next planting season. Seed potato tubers should be stored in diffused light stores with good ventilation, this helps for long term storage and good sprouting.

Light: It is the major element in DLS principle, should be indirect (no direct sunlight), light checks the excessive white, thin sprout growth. Instead, it induces short, green sprouts. Insufficient light intensity is indicated by the development of long, white sprouts which promote quick shrinkage in the tubers. Shrinkage of the tuber means energy loss. Therefore, potatoes must be arranged in the storage area so that each tuber receives sufficient indirect light.

Ventilation: Since the potato tuber is a living organism it requires sufficient air (especially oxygen) to respire. Respiration of the tubers produces heat inside the storage area. Heat speeds up the growth of sprouts which means the tuber is quickly using more energy, thus quickly becoming physiologically old. Good management of ventilation (air flow) helps to remove the heat generated by the respiration and to provide sufficient air for respiration.

Diffused light storage (DLS)

• Mostly for seed tuber

• DLS was developed by CIP,

• It avoids direct light and potato can be stored for about 8 to 9 months in such storage.

• Unlike cold storage it is very economical and hence recommended in most of potato producing region.

Importance of DLS

1. It keeps seed potato tubers in good condition without refrigerate.

2. It late the sprout to develop without growing so long that they are not knocked off during field planting

3. It increases the number of sprouts (3-4 strong green sprouts) per tuber

• Both high temperature and low temperature affect tuber quality in storage.

 High temperature give rise to “black heart” where accelerated respiration produced O2 shortage in which middle parts of the tubers become black in colour.

Disease and Pest Constraints

Disease

1. Late blight (Phytophthora infestans)

• It is the most significant fungal disease of potatoes across the major production areas of Ethiopia, and worldwide.

• In Ethiopia the losses reached 34% and sometimes total failure of the crops is common experience of the farmers

• A potato blight caused the crop to fail during the period 1845 – 1847. About 1 million people died in Ireland and equal number immigrated to North America. Immigrants had already brought the potato to North America.

• **Symptom**

 Appears at first as circular or irregular water soaked spots, usually at the tips or edges of the lower leaves.

 It affects foliage, tuber as well as stem.

2. Early blight (Alternaira solani)

• It is found mainly in hot, humid regions.

• It may occur towards the end of the growth cycle but does not, in such, cases, a great deal of harm.

• Foliage lesion of early blight generally show concentric rings

3. Bacterial wilts (Pseudomonas solanacearum)

• It can be a severe production constraint of potato and other solanaceous crops such as tomato and eggplant, especially in warm weather occurring at lower altitudes in Ethiopia.

Disease control Measure

 Use disease resistance or tolerant cultivars

 Use of certified potato tuber

 Use clean tuber as planting material

 Crop rotation at least 3-4 years

 Planting of Potato in the fields after diseases non – host crops

 Application of chemicals (fungicide), examples Ridomil MZ 3.5 W.P at rate of 2Kg/ha for late blight

 Avoid volunteer plants that develop from diseases tubers left in the field.

 Reduce tuber exposure to the air during crop growing period.

Insect pest management

Insect pests are still the major production limiting factors of potato in the country. The most important insect pests of potato in the country are potato tuber moth, potato beetles and aphids.

1. **Potato tuber moth (Phthorimae operculella)**

Potato tuber moth affects foliage and tubers in the fields and in storage also it affects tubers. Young larvae mine the leaves. Leaves produce silver blotches. Then it bores in to the tubers. From field it is carried to storage. Potato tuber moth survives in the field throughout the year and 5-6 generations are observed in one year under warm weather condition. Major damage is caused by caterpillars burrowing in the tubers. The pest is transferred with the harvested tubers to the potato store, where it can reproduce and infest other tubers. This may lead to total destruction of the stored crop.

Management options

- ❖ Proper hilling-up to cover the tubers with soil at the field
- ❖ Spraying foliage with an insecticide at 7-14 day intervals
- ❖ On time harvest, deep tillage during dry season, destruction of all harvest residues, sorting and discarding infested tubers before storage.
- ❖ Storing only healthy potatoes for seed

- ❖ Dusting the stores using recommended insecticides before storage.
- ❖ Spraying potato at storage with appropriate insecticides, like Diazinon and malathion.

3. Potato aphids (Myzus persicae)

Aphids infest the leaves, flowers, stems and sprouting tubers. Aphids suck the hosts' sap, weaken the plant and subsequently transmits or spreads viral diseases. Usually cause physical damage to the crop serving especially as efficient vectors of viral diseases. Aphids infect a crop with viruses such as potato leaf roll virus and mosaic virus. Virus-infected seed tubers produce poor stands and few tubers. These insects are low in the highland so seed potatoes should be produced in the high elevation areas.

Management options

Deeper planting of tubers, Avoiding host plants from around field and storage areas, Using clean seed and field as well Keep the store clean, Use of resistant varieties, Crop rotation and Use of pesticides

4. Potato beetles

It creates small feeding wholes on the leaves. It can also reduce quality by feeding the periderm of the tuber and exposing it to soil borne diseases. Its damage is common in moist season as the egg and larva couldn't grow in dry conditions.

2.2. Yam (Dioscorea)

Introduction

Yam is the common name for members of the genus Dioscorea (family Dioscoreaceae). There are more than 600 species of yam. Some species are cultivated for the consumption of their starchy tubers in Africa, Asia, Latin America and Oceania. They are used in a similar fashion to potatoes and sweet potatoes. There are hundreds of cultivars (varieties) among the cultivated species. Yam tubers can grow up to seven feet (approx. two meters) in length and weigh up to 150 pounds (68 kg). The yam has a rough skin which is difficult to peel, but which softens after heating. Yam skins vary in color from dark brown to light pink. The majority of the yam is composed of a much softer substance known as the "meat". This substance ranges in color from white to bright orange in ripe yams.

Origin and distribution

The occurrence of Dioscorea spp. in southern Asia, Africa and South America long pre-dates human history. Domestication of the different species in these areas appears to have been by original man. Wild yams and domesticated cultivars occur throughout the tropical and subtropical world.West Africa is the most important cultivation zone, where yam is a major staple, producing about 93 per cent of the world's edible yams.But the crop is also of considerable importance in parts of eastern Africa, the Pacific area (including Japan), the Caribbean and tropical America. A few yams are found in the warms regions of temperate zones.

Botanical description

Yams are climbing plant with glabrous leaves and twining stem, which coiled around a stake they are perennial but are grown as an annual.Yam is dioecious (male and female flowers on the separate plants). Bulbils form frequently in theses leaf axial (Dioscorea bulbifera).Yams have a basic chromosome number n= 10

The parts of a yam plant

The stem

It is the part of the plant above the ground. It consists of a vine-like stem on which leaves and flowers develop. Due to the vine-like nature of yams plant, the stem is weak and requires support. Vines may grow to high heights if provided with rigid support. They may also depend on the plants for support. It is common to find them twined. And the stem produces leaves, flowers and fruits around adjacent plants.

Roots

A yams plant has a shallow fibrous root system concentrated within the top 30 cm of the soil layer. Roots developing from the base of the stem support the plant. They also help the plants to absorb water and mineral salts from the soil.

Tubers

The tuber is part of the stem which happens to be in the ground. Depending on the type of yam the tuber grows, increasing in size. The tuber is the most important part of yam plant, which is grown as a staple food.

There are many varieties of yam species widespread throughout the humid tropics but the edible yams are derived mainly from about ten. The most economically important species are:

a) **White yam (*Dioscorea rotundata* Poir)**. Originated in Africa and is the most widely grown and preferred yam species. The tuber is roughly cylindrical in shape, the skin is smooth and brown and the flesh usually white and firm. A large number of white yam cultivars exist with differences in their production and post-harvest characteristics.

b) **Yellow yam (*Dioscorea cayenensis* Lam.)**. Derives its common name from its yellow flesh, which is caused by the presence of carotenoids. It is also native to West Africa and very similar to the white yam in appearance. Apart from some morphological differences (the tuber skin is firm and less extensively grooved), the yellow yam has a longer period of vegetation and a shorter dormancy than white yam.

c) **Water yam (*Dioscorea alata* L.)** Originates from South East Asia, it is the species most widely spread throughout the world and in Africa is second only to white yam in popularity. The tuber shape is generally cylindrical, but can be extremely variable. Tuber flesh is white and "watery" in texture.

d) **Bitter yam (*Dioscorea dumetorum*)**. Also called trifoliate yam because of its leaves. Originates in Africa where wild cultivars also exist. One marked characteristic of the bitter yam is the bitter flavour of its tubers. Another undesired characteristic is that the flesh hardens if not cooked soon after harvest. Some wild cultivars are highly poisonous.

Depending on the species, yam grows for six to ten months and is dormant for two to four months, these two phases usually corresponding to the wet season and the dry season. For maximum yield the yam requires an annual rainfall of over 1,500 mm distributed uniformly throughout the growing season. White, yellow and water yams normally produce annually a single large tuber, often weighing 5-10 kg.

The major problems presently facing yam production are its high labour requirement, its low yield per hectare compared to crops such as cassava or sweet potato, the relatively large amount of planting material that is required and its long growing season. By far the most critical of these problems is labour requirement, which exceeds that of other comparable crops. For these reasons and problems of storing harvested yam, the costs of yam production are high and yam is slowly losing ground to cassava. It has been estimated that the cost per 1,000 calories of yam is four times greater than those of cassava. But, despite these high costs the nutritional value of yam is sufficiently high to justify further work into its general improvement.

General morphology and composition of the Yam tuber

The tuber shape and size can vary greatly due to genetic and environmental factors. However, cultivated forms of yam generally produce tubers that are more or less cylindrical in shape and 3-5 kg in weight. The yam tuber grows from a corm-like structure located at the base of the vine.

Occasionally this corm remains attached to the tuber after harvest and sprouts will develop from it. When the corm separates from the tuber sprouting occurs from the tuber near to the point at which the corm was attached.

A transverse section of a mature yam tuber shows it to be composed of four concentric layers.

- ⇨ **Corky periderm:** The outer portion of the yam tuber; it is a thick layer of cork cells, often cracked, but which provides an effective barrier against water loss and invasion by pathogens.
- ⇨ **Cortex**: A layer located immediately beneath the cork, comprising thin-walled cells with very little stored starch.
- ⇨ **Meristematic layer**: Elongated thin-walled cells under the cortex. Sprouts are initiated from this layer.
- ⇨ **Ground tissue**: The central portion of the tuber composed of thick-walled starchy cells, with vascular bundles ramifying throughout the mass. Most yams are essentially composed of water, starch, small quantities of protein and other minor constituents

Table1 : Composition of species of yams %

Variety	**Moisture content**	**Carbohydrate**	**Fats**	**Protein**
D. alata	65 – 73	22 - 29	0.1 - 0.3	1.1 -2.8
D.rotunda **D**. cayenensis	58 – 80	15 - 23	0.1 - 0.2	1.1 -2.0
D. esculenta	67 – 81	17 - 25	0.1 - 0.3	1.3 - 1.9
D. bulbifera	63 – 67	27 - 33	0.1	1.1 - 1.5

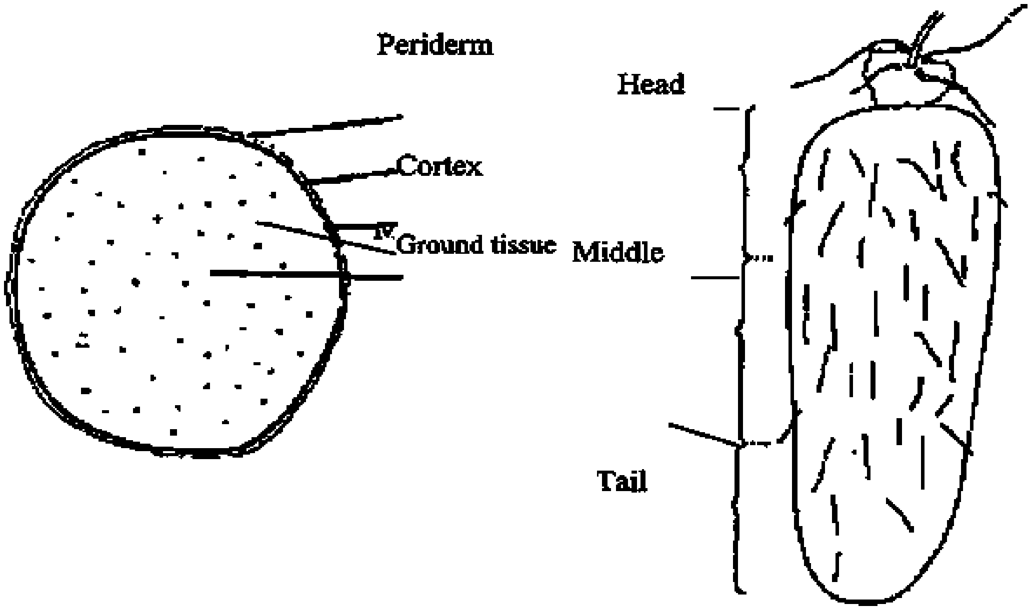


Figure 1. General Morphology and cross section of yam tuber

Economic and Social Impacts of Yams

Yams are second to cassava as the most important tropical root crop. Yams are a staple crop in many parts of Africa and Southeast Asia. In the South Pacific, the yam is a significant food crop, accounting for over 20%, 8.1%, and 4.6% of the total dietary calorie intake in the Kingdom of Tonga, Solomon Islands, and Papua New Guinea, respectively. Besides their importance as food source, yams also play a significant role in the socio-cultural lives of some producing regions like the celebrated New Yam Festival in West Africa, a practice that has also extended to overseas where there is a significant population of the tribes that observe it. In some parts of Southeastern Nigeria, the meals offered to gods and an ancestor consists principally of mashed yam.

Yams store relatively longer in comparison with other tropical fresh produce, and therefore stored yam represents stored wealth which can be sold all-year-round by the farmer or marketer. In parts of Igboland in Southeastern Nigeria, it is customary for the parents of a bride to offer her yams for planting as a resource to assist them in raising a family.

- ❖ About 9 types (spp.) were reported from Ethiopia especially Southeast and Southern part of the country.

Botanical name	**Origin**
Dioscorea rotundata	West Africa
Dioscorea alata	Southeast Asia
Dioscorea Cayenensis	West Africa
Dioscorea esculaenta	Indo-china
Dioscorea joponicia	Japan
Dioscorea abyssinica	Ethiopia
Dioscorea shimperiana	Ethiopia
Dioscorea bulbifera	Ethiopia
Dioscorea hispida	India/ SE Asia
Dioscorea opposita	China

Importance

Source of food- Yams is a staple food in many Africa, Caribbean and Pacific countries.

As a carbohydrate, the crop is an excellent source of energy.

It is also a source of vitamins, minerals and proteins. commonly eaten as a vegetable, either boiled, baked or fried.

Economic status- The number of yam stands a famer plants is a measure of his or her economic status in the locality. Moreover, eating yams thrice in a day is a sign of affluence in some African communities. Income generation- a source of income for many farmers in the tropics.

Social-cultural significance- In some African communities yams play a significant role during ceremonies and festivals. In Nigeria, for example, yam is a totem of masculinity. It is the centre for annual harvest celebrations. It is also an important token in the negotiation of bride price in traditional marriage contracts; the bigger the yam tuber, the more sincere the bridegroom.

Subsidiary uses: Yams are sometimes dried and made into flour; this is often the case with damaged yams or with yams that are surplus to requirements, essentially as a method of storage. In recent years there have been attempts at more sophisticated processing for exporeg fufu from Nigeria, canned yams and yam soup from Puerto Rico, and yam flakes from Barbados. In general these attempts have not been commercial successes, largely owing to the high cost of the raw material.

Health Benefits of yam

Protection against Cardiovascular Disease and reduce heart attack and stroke.Yams are good sources of potassium (K) K deficiency is common b/c of consumption of NaCl=> hypertension Yams contain Dioscorin - is a storage protein, reduce hypertension . Preliminary research suggests that dioscorin can inhibit angiotensin converting enzyme, which would therefore lead to increased kidney blood flow and reduced blood pressure.

Secondary and waste products

Peelings and waste from yams are often used for feeding poultry and livestock.The possibility of using yams for the production of starch or of alcohol has been considered, but not developed, as there are many cheaper sources of both these products in the countries where yams are grown.

Production and trade

Despite the increasing consumption of introduced foods such as cassava and rice in the main yam-consuming area of the world (West Africa), it appears that yam production is remaining constant at about 20 million tonnes per year. Some 97 percent of the world's production is from Africa (over 90 per cent from West African countries).

Environmental requirement

Temperature

Optimum growth occurs at about 30°C; temperatures much above this have an adverse effect, especially if associated with drought. most edible yams cannot withstand frost and make poor growth below 20°C.

Rainfall

Although generally considered drought resistant, yams require adequate moisture throughout their growing period. There is a positive correlation between high and regular rainfall, vine growth and tuber yield. For optimum yields adequate moisture between the 14th and 20th weeks of growth is of great importance.

Light

Light is an essential growth factor for all crops. Yams require sunshine hours during the active growth period of the crop. For example, to achieve high tuber yield from yam the crops require 4-5 sunshine hours per day during the active growth period which can be achieved by planting the crop during the months of March/April and the active growth period falls between the month of May and September.

Soil

Yam require deep well-drained soils (sandy loam) soil that is loose in texture, and rich in organic matter content. these soil qualities allow easy penetration and swelling of tubers. On heavy, waterlogged soils the tubers are liable to rot.

On poor/shallow soils

the weak root system is unable to obtain sufficient water or nutrients to produce reasonable sized tubers develop deformed tuber that are unattractive, a factor that reduces the market value of the crop.The presence of rocks and roots in the soil affect the shape of yams deforming. Marginal soils that support cassava are not suitable to yam. Yams are susceptible to Al toxicity so lower pH level less than 5.5 isnot suitable.

Propagation

Edible yams are normally propagated by the use of small tubers (seed yams), cuttings of the tubers, sets (pre-sprouted tubers or pieces of tuber), or bulbils. It is possible to use vine cuttings, but tuber production by this method is generally uneconomic. The best planting material is the small whole tuber. Species such as D. esculenta and D. trifida, which produce a fairly large number of tubers, can be propagated very easily by reserving a few of the tubers and planting these at the beginning of the next season. Other species such as D. bulbifera and some forms of D. alata and D.rotundata produce aerial bulbils, which can be used majority of the more important food yams only produce 1-3 tubers a season and in this case sets cut from the tuber are often used and are referred to as tops or 'heads' (proximal), middles, and bottoms or 'tails' (distal). In general, tops are preferred and the larger the sets, the earlier and greater is the rate of germination.

A recent development tissue culture has been the production of virus-free planting material yams grown from virus-free meristem tip cultures are being multiplied in the field and, after inspection, distributed for planting. This material has been tested in a number of countries and has given approximately double the yield obtained when conventional seed yams are planted, and the operation is now commercial.

Time of planting: Yams are not normally grown under irrigation and in areas where the rains last 8-10 months, planting normally takes place just before or at the beginning of the rains. Where the rainy season is less than 8 months it has been found that early planting, up to 3 months before the rains, can give a 30 per cent increase in yield.

Seed rate: The number of sets used obviously varies according to the species and the cultivar

but for most large-tubered yams 10,000-15,000/ha are used, requiring at least 2.5 t/ha of setts.

Land preparation: Usually the farm is prepared between December and March in readiness for the rains. This should be done well. Once the farm is cleared then the digging or ploughing should be fairly deep, 20-40cm. Humus and manure can be applied as the digging or ploughing progresses in order to mix well with the soil.

- ❖ On the basis of the type of land tillage, four general methods of yam planting exist.
  - ✓ Planting of yam on mound
  - ✓ Yam planting in holes
  - ✓ Ridging
  - ✓ Flat planting

The former two methods are peculiar to the traditional peasant yam production, while the later two are characteristics of improved, partially mechanized agriculture.

Mounding- heap of soil in conical shape. We can plant two or more setts per hole

Advantages of mounding: Since the soil is loose there is no blocking for tuber bulking. The heap of soil or mound is rich in top fertile soil It facilitate harvesting

Important in water management in the field

Flat land (Flat planting): Using holes 20cm by 30cm or 30cm by 30cm**.** Plant only one sett per hole**.** Some people recommended subsoiling/deep ploughing improving flat soil**.**Yield lower and are more difficult to harvest.

Ridges: As in cassava and sweet potato made ridges. Most of the mechanized agriculture. Put the sett on top of the ridge

Advantage of ridges: The same as the advantages of mounding. On sloply area erosion control (if the ridges is made along the contour line to control erosion). Mechanized farming can be applicable.

Planting Material:

Sett type

Yam is commercially propagated by means of the tuber.The tuber pieces used for planting could be small whole tuber or tuber piece obtained from the large tuber by dividing. The setts derived from the head, middle and tail region are referred to as heads, middle and tails, respectively.

Sett size

The greater the weight of the setts used to establish a yam plant the greater the weight of the yam to be produced by the plant. The following reasons will support the above relation ship.

Large setts sprout more rapidly than the small setts and as a result establish and grow more quickly

2. Large setts produce more sprouts per sett than small setts

3. The large setts give rise to more vigorous plant than small setts

4. The large setts have more food material which can be translocated directly to the newly established plant.

Growth period

Most edible yams normally reach maturity 8-11 months after planting, though in certain species a first harvest may be obtained after 5 months. The growth period usually comes to an end at, or shortly after, the end of the rainy season: neither late planting nor subsequent irrigation will prolong growth beyond the normal annual periodicity for the particular species.

Crop management in the field

Mulching

Once the setts have been planted they have to be mulched within two days in order to reduce chances of setts drying up due to the sun's rays. Mulching also prevents weeds from germinating in the farm. Usually grass is used as much. Either lay the mulch on the top of the ridges, in the rows where the setts have been planted, or simply lay the mulch around each of the setts. Mulching increases the yields.

Staking, using supporters

Staking an important practice, without staking not yams production possible because yams are climber plant. Staking is supporting the yams vines so that they can grow upright. Either stakes say 4m, or strings can be used to support the yam stem so that they can get sunlight, which is essential for photosynthesis. This is done when the vines are about 1-1.5m. Preferably, each yam should have its own support. Once this is done the young vines are trained or assisted to climb. In the end the vines entangle, twine and climb on their own.

Weeding

Farm preparation is indeed, a primary method of controlling weeds. Two methods are used to control weeds in the farm. Traditionally, pulling the weeds by hand, or hoeing is used to control weeds. The hoeing should be done in the third, eighth, twelfth and sixteen weeks. Chemicals or herbicides can also be applied as soon as the weeds begin to germinate.

Intercropping: Yams can also be intercropping with pepper, beans, maize or even millet since such crops mature fast.

Use of fertilizers: Having prepared the setts for planting, apply and mixed the humus or manure with the soil. Yields can be increased with the application of artificial fertilizers in the sixth and twelfth week after planting. Such fertilizers should largely have the nitrogen element, along with calcium and phosphate.

Harvesting and handling

Two general practises exist in yam production;   Each plant in the field can be harvested twice. This practice is called double harvesting. Plant in field is harvested only once. This practice is called single harvesting. At the start of the dry season yam plants normally die back

The tubers are ready for harvesting, though in most cases they may be left in the ground for several weeks as deterioration is usually not rapid.

In some species, eg D. rotundata and D. alata, an early crop may be taken as well as the main harvest in this case the tuber is carefully cut below the head and removed, leaving the top to grow again and produce another tuber, or tubers.

Yield

Under optimal conditions yams are among the most efficient producers of human food

yields of 70 t/ha (D. esculenta) have been recorded from West Africa.Under normal farming conditions, however, yields are considerably lower. The normal range for yams in pure stands being: West Africa 7.5-18 t/ha; South-East Asia 12.5-25 t/ha; the Caribbean 20-30 t/ha. These yields are gross, and because a substantial quantity is used for propagation, net yields are generally about 2.5 t/ha less.

Yam Production in Ethiopia

Ethiopia is the 7th largest yam producing country in africa with about 62,000 ha of land.

The subsistence farmers in Ethiopia particularly in many areas in south, southwest, and western regions such as Kaffa, Sheka, Benchmaji, Welaita, Sidamo, Amaro, North Omo, south Omo, Benishanguel, Jimma, West and East Wollega, lliubabour cultivate yams.

Different vernacular names of yam in Ethiopia:

- **Boye:- By Yemi people**
- **Wocheno:- By Oromya**
- **Bohe:- welayita**
- **Kuso:- yem**
- **Boina;- Sidama**

Cultivated Yam species in Ethiopia

D. bulbifera

D. abyssinica and are native to Ethiopia

About nine types of yam have been reported to grow in Ethiopia indicating the diversity of the species in the country (EIAR, 2008).

Disease and insect pests of Yam

Yams are susceptible to a variety of pest and diseases during growth as well as postharvest. Attack by the yam beetle, and microorganisms such as nematodes and yam virus are the most devastating. The major postharvest disease is tuber rots caused mostly by fungi. Fumigation is generally carried out using methyl bromide, the application must be checked with appropriate regulatory authority and with the importer if produce is destined overseas. Fencing, poisoning, and trap setting are common methods for controlling rodents.

Insects

- weevils in the store, termites in the field, Yam beetle, Chrysomelid beetle, Mealybugs
- Nematodes
- Yam nematode
- The root-knot nematode
- The root-lesion nematode
- Fungi-Tuber rots, leaf spot, anthracnose
- Bacteria- Tuber rots
- Mammals- Rodents

Common insects of yam and their control in Ethiopia

Yam beetle (Heteroligus meles) can be controlled by using Aldrin, endosulfan or grammalin dusting of holes or soil surface.

Chrysomelid beetle (Lilioceris livida). Can be controlled by removing larva by hand or by spraying with carbaryl

Mealybugs (Planococcus citri). Can be control by using a clean planting stock.

Other common problems of yam and their control in Ethiopia. Tuber rots is a common yam disease which can be controlled by careful selection of tubers for planting and crop rotation. Yam nematode it can be controlled by rotation and fallowing.

- **Indigenous Potatoes (Coleus spp) your assignment!!!**

CHAPTER -THREE

Common Root Crops grown in Ethiopia

Several root crops are grown especially for their edible storage roots and tuber portions. They belong to different botanical families. **Only one enlarged (fleshy) underground root is produced per plant for carrot (Apiaceae), table beet (Chenopodiaceae), radish, turnip, and rutabaga (Brassicaceae). But Several fleshy roots are produced from one plant for sweet potato (Convolvulaceae) and cassava**.They are consumed either fresh or in processed forms. Most root crops have long storage life and extend the market supply over a long period. There are other minor root crops produced more on a regional basis, such as salsify (Tragopogon porrifolius) and black salsify (Scorzonera hispanica) of the Compositae, parsnip (Pastinaca sativa) and celeriac (A. graveolens var. rapaceurm) of the Apiaceae, yam bean (Pachyrrhizus erosus) of the Fabaceae,and horseradish (Armoracia rusticana) of the Brassicaceae. The carrots, beet root, radish, turnip, and rutabaga are all direct-seeded to well-prepared seedbeds. After emergence, plants are thinned to desired population density. The crops are established more easily under cool and moist conditions.

The major tap root crops in Ethiopia are:

- Carrot (Daucus carota)
- Beet root (Beta vulgaris)
- Anchote (Coccinia abyssinica)
- Radish (Raphanus sativus)
- Parsnip (Pastinaca sativa)
- Turnip (Brassica rapa)
- Rutabaga (Brassica nopus)
- Parsley root (Petroselinum spp)

3.1. **Carrot (Daucus carota)**

Introduction

Carrot (Daucus carota L., var. sativus Hoffm.) is one of the important root crops cultivated throughout the world for its fleshy edible roots. They are cooked alone or with other vegetables in the preparation of soups, stews, curries and are used in salads. Carrots possess many medicinal properties and are used in ayurvedic medicine. Carrots are a rich source of b-carotene and contain appreciable amounts of thiamine and riboflavin.

It is grown in spring, summer, and autumn in temperate countries and during winter in tropical and subtropical regions.

Origin: Carrot (Daucus carotavar. Sativa) is a native of Europe, Asia, and Northern Africa, and possibly North and South America. Carrot is a biennial vegetable and belongs to family Umbelliferae. The genus Daucus contains about 60 species, of which very few are cultivated. Carrots are a dicotyledonous herbaceous crop grown for the enlarged taproot. The color of cultivated carrot roots varies from white to yellow, orange, light purple, deep red, or deep violet,

Many varieties of carrot are grown throughout the world. They may be grouped into two types, namely,

(1) **The temperate or European cultivars**, which are biennial, orange in color, and uniform in thickness with a small core, and

(2) **The tropical or Asiatic cultivars**, which are annual, red in color, more juicy, have a bigger core, and a heavier top.

Some important commonly grown varieties of carrot are Amsterdam, Barlikuner, Chantenay, Royal Chantenay, Delattya, Danvers, Emperador, Flakker, Goldpack-28, Gonsen Lemer, Gross Karotel, Honey Sweet, Karotina, Pusa Kessar, Pusa Meghalli, Rubica, Berlicum, Rote Rusen, Selection-23, Nantes, No. 29, Nantesca, Saint Valery, Sperton Fancy, Tip-top, UH-AC, and Pusa Yamadagni

and the shape varies from short stumps to tapering cones. The root diameter and length can vary from 2 to 6 cm and 6 to 30 cm, respectively.

Botanical description

The carrot (Daucus carota var. Sativa) is a native of Europe, Asia, and Northern Africa.

Carrot is a biennial vegetable and belongs to family Umbelliferae. Carrots are a dicotyledonous herbaceous crop grown for the enlarged taproot. The color of cultivated carrot roots varies from white to yellow, orange, light purple, deep red, or deep violet, and the shape varies from short stumps to tapering cones. The root diameter and length can vary from 2-6cm and 6 to 30 cm, respectively. Anatomically, most of the storage root is comprised of parenchymatous phloem and xylem permeated by vascular tissues with cambium sections joining together in a cylinder. High-quality carrots are those having a large content of phloem relative to that of the xylem (‘core’) portion. Many varieties of carrot are grown throughout the world. They may be grouped into two types, temperate and subtropical.the temperate or European cultivars, which are biennial, orange in color, and uniform in thickness with a small core, Eg. ‘Nantes’, ‘Imperator’, ‘Danvers’ and ‘Chantenay’ the subtropical or Asiatic cultivars, which are annual, red in color, more juicy, have a bigger core, and a heavier top. Eg. ‘Kuroda’, ‘Brasilia’, and ‘Tropical Nantes’.

The storage root shape of many carrot cultivars is conical, but the extent of taper varies between cultivar types. Some cultivar types are cylindrical, round or various intermediates of these shapes.

Carrot cultivars are classified by root shape and date of maturity:

- ⇨ **Danvers**: roots medium to long with broad shoulders, tapering toward the tip (tapered tips).
- ⇨ **Imperator**: roots slender, slightly longer and smoothly tapered, late maturing, good for storing, grown for winter market consumption.
- ⇨ **Nantes**: roots nearly cylindrical shaped medium to long, early maturing, and eaten fresh in summer.
- ⇨ **Chatenay**: medium to short and tapered with blunt end, maturing by midsummer.

Carrots are usually mechanically harvested 90–120 days after planting. Large-scale carrots are eaten raw, cooked, or processed into juice. The harvest stage is judged by suitability, before the carrots achieve their full potential size or weight. Fresh carrots are marketed either topped or bunched with attached tops. Fresh cut-and-peel baby carrots are also available; they may also be cut into short pieces from mature carrots. Carrots are good plant sources of pro-vitamin A, containing about 5–8 mg/100 g of b-carotene.

Importance:

1. **Used for human consumption**

They are cooked alone or with other vegetables in the preparation of soups, stews, curries, and pies; fresh grated roots are used in salads; tender roots are pickled. Carrot root is valued as a food component mainly because it is a rich source of b-carotene, the precursor of vitamin A. Carrots are also good sources of carbohydrates. The edible portion of carrots contains about 10% carbohydrates. The soluble carbohydrates ranged from 6.6 to 7.7 g/100 g in four carrot cultivars.

The free sugars identified are sucrose, glucose, xylose, and fructose. The crude fiber in carrot roots consists of 71.7, 13.0, and 15.2% cellulose, hemicellulose, and lignin, respectively. The cellulose content varied from 35 to 48% in four carrot varieties. Vitamins (Thiamine, riboflavin, niacin, folic acid, and vitamin C) and minerals like calcium, phosphorus, iron, and magnesium are also present in appreciable amounts in carrot roots. The moisture content varies between 86 and 89% .

The edible portion of carrots contain 0.81.1 g protein/100 g (26). The presence of nitrate and nitrite has also been reported in carrots. The average nitrate content in fresh carrot was reported to be 40 mg/100 g and the nitrite content was 0.41 mg/100 g. Carrot roots are a rich source of carotenoids. The total carotenoid content in the edible portion of carrot roots ranges from 6,000 to 54,800 µg/100 g. The carotenoid content in carrots is associated with the color of the root. Numerous reports have appeared on the volatile constituents in carrots.

Chemical Composition of Carrot Roots

	Gopalan *et al* ., 1991	Gill, et al., 1974
• Moisture (%)	86.0	88.8
• Protein (%)	0.9	0.7
• Fat (%)	0.2	0.5
• Carbohydrates (%)	10.6	6.0
• Total sugars (%)		5.6
• Crude fiber (%)	1.2	2.4
• Total ash (%)	1.1	
• Calcium (mg/100 g)	80	34
• Iron (mg/100 g)	2.2	0.4
• Phosphorus (mg/100 g)	53	25
• Sodium (mg/100 g)		40
• Potassium (mg/100 g)		240
• Magnesium (mg/100 g)		9.0
• Copper (mg/100 g)		0.02
• Zinc (mg/100 g)		0.2
• Carotenes (mg/100 g)		5.33
• Thiamine (mg/100 g)		0.04
• Riboflavin (mg/100 g)		0.02
• Niacin (mg/100 g)		0.2
• Vitamin C (mg/100 g)		4

- Energy value (kJ/100 g) 125

2. As animal feed: The white varieties of carrots are valued as feed for horses and dairy cattle.

(3) Carrots possess many medicinal properties

The use of carrots in herbal medicine has been documented. It is considered a popular remedy for jaundice; the roots and seeds are used as an aphrodisiac and nerve tonic as well as poultice for ulcers, burns, and scalds. Carrots have also been reported to have diuretic, nitrogen-balancing properties and are effective in the elimination of uric acid.

b-Carotene functions as a free radical-trapping agent and a singlet oxygen quencher in biological systems. b-Carotene has been reported to reduce the risk of cancers of lung, cervix, esophagus, and stomach. It has been found to be helpful in the treatment of patients suffering from photodamaging skin conditions. b-Carotene has also been reported to reduce the risk of cataract formation.

Worldwide production

Worldwide production of carrots increased from 10.09 to 13.37 million metric tons (MT) during 1980-1990 (Table 1). The major carrot-producing countries are the former USSR, China, Japan, France, the United States, and the United Kingdom (2).

TABLE 1 World Production of Carrots Continent/Country Production (1000 MT)

- Algeria 160
- South Africa 175
- North Central America 1,777
- United States 1,312
- Dominican 378
- South America 667
- Argentina 185
- Colombia 178

- Asia 3,993
- China 2,749
- Japan 700
- Turkey 174
- Europe 3,930
- France 490
- Germany 445
- Netherlands 330
- Poland 740
- United Kingdom 470
- USSR 2,200
- Developed, all 8,700
- Developing, all 4,599
- World 13,369

Ecological requirement

Temperature: Carrot is a cold weather crop. However, it thrives well in warm climates

The best temperatures for getting excellent growth of the top portion ranges between 16 and 18°C Temperatures between 15 and 20°C result in attractive roots with very good red color and quality. while temperatures above 28°C drastically reduce top growth.Temperatures lower than 16°C affect the development of color and result in long slender roots, while higher temperatures produce shorter and thicker roots

Soil: Carrots can be grown in a wide variety of soils. However, the ideal soil should be deep, loose, friable, well drained, and rich in humus Loamy or sandy loam soils with ample quantities of humus are well suited to the cultivation of carrots.The ideal pH range for obtaining good yield is 5.5-6.5 **.** Soils with pH up to 7.0 can also be used, but too alkaline or acidic soils are unsuitable for this crop

Propagation: The carrot crop uses seeds that are drilled or broadcast in the field.The seeds are small approximately 800 pergram. They remain viable for nearly 3 years, and up to 85% germination is very common. However, germination of some local vars may be poor. Therefore, it is necessary to ascertain the germination %age when calculating the seed requirement. For best results, it is also necessary to procure clean, healthy, and viable seeds from reliable sources. The seeds take approx 7-21 days for complete germination.The best seed germination occurs at 20-30°C.

Cultural Practices

1. Sowing

Carrots can be grown practically throughout the year if the temperature does not go below 3.9°C. The best time for planting depends primarily on the climatic conditions prevailing in the given area. However, some of the varieties have a tendency to bolt at low temperatures. In contrast, some of the European types are more tolerant of low temperatures and do not bolt unless the temperature is very low. The soil for carrot cultivation should be properly prepared to get the desired tilth. It is necessary that the field provides a loose, friable, deep, and well-drained for seeds to germinate. This can be achieved by repeated deep ploughing at least 20-30 cm deep followed by harrowing, leve ling, and cleaning.

All old debris or remains of previous crops should be removed completely to obtain the desired seed bed condition.Since the seeds are very small and delicate, the seed bed should be very finely prepared. Beds of convenient size should be prepared before sowing.The seeds are either broadcast, drilled, or dibbled by hand and are mixed with sand, ash, or fine soil to facilitate sowing The seeds are sown either in ridges or in a flat bed. In any case, a shallow furrow is made 30-45cm in length. When the seeds are dibbled, they are sown with 7.5-10 cm spacing.

With such conditions about 46 kg of seeds are needed per hectare. The seeds are then lightly covered with soil or sand. Some growers irrigate the field about 24 hours before sowing to ensure that adequate moisture is present at the time of sowing. Many varieties germinate in about 10-15 days.

Manuring and Fertilization

According to Thompson and Kelley, carrot crops yielding 28-30 tons of roots require 32 kg nitrogen, 18 kg phosphorus, and 100 kg potash per hectare. Carrot is a heavy potassium feeder. Potassium deficiency can affect the quality of the roots in addition to disturbing the overall metabolism of the plant. Potassium-deficient roots are less sweet and the flesh does not have the desired luster. The fertilizer recommendation for carrots should be based on the soil type, variety, and the season. Most of the recommendations stress potassium fertilization.

Kumar and Mathur recommended the application of 23 tons of farmyard manure along with 50 kg nitrogen, 40 kg phosphorus, and 50 kg potash per hectare. In case farmyard manure is not available, the doses of inorganic fertilizers should be increased to 80 kg nitrogen, 60 kg phosphorus, and 60 kg potash per hectare. Choudhury et al.suggested the application of 54 kg nitrogen and 54 kg phosphate per hectare for alluvial soils.

Abo-Sedera and Eid (19) reported the best results in terms of vegetative growth, yields, and quality with 60 kg N 2+ 72 kg K2O with the Red Colored Chantenay cultivar.The entire quantity of farmyard manure should be mixed thoroughly with the soil, preferably to a depth of 20-25 cm, applying it at the time of land preparation. Half the dose of nitrogen and the full dose of phosphorus and potassium should be applied before sowing. The remaining nitrogen should be given 56 weeks after germination.

Irrigation and Intercultural Operations

The first irrigation should be light and carried out immediately after sowing. Subsequent irrigations are given as needed. When the seeds are broadcast or drilled, they should be thinned to maintain proper spacing or plant density. The frequency of irrigation depends upon soil type, season, and variety. In general, one irrigation every 45 days in summer and 10-15 days in winter provides adequate moisture for the crop. During the rainy season only occasional irrigations are needed. Water stress should be avoided during root development to avoid cracking of the roots, which also become hard. Earthing-up may also be necessary, particularly in the long rooted types.

Splitting or cracking of carrot root is a major problem in many carrot-growing areasAlthough cracking is controlled by genetic factors, a number of other factors such as high nitrogen and chloride levels in the soil may be involved. Diseases are not a serious problem in carrots. However, some microbial infections have been reported to occur in different parts of the world. These include leaf blight (Alternaria radicina, Alternaria dauci),leaf spot or Cercospora carotae),powdery mildew (Erysiphe sp.), and several viral diseases such as yellows, carrot leaf virus, carrot motely dwarf, and carrot mosaic, which may cause extensive damage to the crop.

Some of the common insect pests that cause damage to carrot crop are carrot rust fly, lygus bug, vegetable weevil, carrot beetle, parsley caterpillar, wingless May beetle, and cut and army worms. Besides insect pests, nematodes cause galls and distorted roots. The most important nematode damaging carrots is a species of Pratylenchus, but Heterodera carotae and Meliodogyn esp. are also of common occurrence. Control of nematodes can be obtained with ASC 66824 900EC.

Maturity, Harvesting, and Handling

Carrots are harvested when the roots are about 1.8 cm or larger in diameter at the upper end. The soil may be loosened with a special plough (carrot lifter) or an ordinary plough. The field is irrigated once the day before harvesting to facilitate harvest. Carrots to be sold in bunches are hauled to a packing house, where they are washed, iced, and packed for market. Most of the carrots go to the market with the tops cut off and the roots packaged in transparent film bags.

Topping and bagging greatly reduce the loss of moisture during transportation to the market in addition to enhancing the shelf life of carrots. The packaging films are perforated to prevent the development of off-flavors. Prepackaging operations such as topping and washing are done mechanically, and the roots are sorted by size before packaging.

Storage: Several chemical changes occur in carrots during storage. Polysaccharides are converted into simple sugars sucrose into reducing sugars**.** The addition of as little as 2.5% $CO_2$to the storage atmosphere retarded the latter conversion**.** Ethylene stimulates development of isocoumarin synthesis nd then bitter flavor.A short anaerobic treatment before storage prevents isocoumarin formation. By storing washed carrots in sealed polyethylene bags, CO_2concentration rises and O_2 concentration drops to retard ethylene synthesis.

Precooling and Preconditioning

Prompt cooling to 5°C or below after harvest is essential for extended storage of carrots Poorly precooled roots decay more rapidly. Mature carrots can be stored for 7-9 months at 01°C with a very high relative humidity of 95-100%. However, even under these conditions, 10-20% may show some decay after 7 months. The highest freezing point for carrots is -1.2°C. Severe tissue injury after freezing results in lengthwise cracking and blistering caused by the formation of ice crystals beneath the surface. Toivonen et al. suggested that low-temperature preconditioning improved the shelf life of fresh carrots stored at 13°C and 90% relative humidity.

Preconditioned carrots showed significantly less weight loss and maintained a brighter orange color than unconditined carrots. Due to enhanced deposition of suberin on the surface of the periderm and lignification of the subsurface cell layers.

Low-Temperature Storage

Carrots can be stored for about 6 months in good condition at a temperature of 0°C and a relative humidity of 93-98%.They deteriorate in quality during storage owing to a slow loss of sugar in respiration. The loss of sugar can be slowed down under good storage conditions and the carrots will retain high quality for at least 5 months. The bunched carrots need slightly higher relative humidity than the topped carrots. The storage life of the latter is considerably longer (about 20-24 weeks) as compared to the bunched carrots (4 weeks).

Controlled Atmosphere Storage

The controlled atmospheres (CA) used for other commodities are not useful for carrots Ryall and Lipton suggested 24% $CO_2$to prevent the development of bitterness.CA storage (mixtures of 4% CO_2+ 2% O_2) reduced respiration to 50%.

Low-pressure storage (LPS)

LPS provides a simple means of reducing theeffect of ethylene-producing vegetables upon carrots when they are stored together. A reduction in the air pressure to 10 kilopascals (0.1 atmosphere) is equivalent to reducing O 2 concentration to about 2% at normal atmospheric pressure. LPS is also expensive to construct because of the low internal pressures required, and the application costs are high, which limits its utilization in the storage of carrots.

Modified Atmosphere Storage

Packaging of fresh ready-to-use grated carrots with films of high permeability (about 22000 cc/m2/day/atm at 25°C) allows better preservation and improved retention. In packs with high-permeability films stored at 10°C, the atmosphere at equilibrium contained about 20% CO2and 5% O2 With these films, however, a reduction in sugar content was observed, especially in sucrose, which is the main component contributing to the taste of carrots. Packaging films had a slight influence on the carotene content, an important aspect of the nutritive value of carrots.

Irradiation

Salunkhe (72) investigated the usefulness of g-irradiation to minimize sprouting losses of several bulb, tuber, and root crops, including carrots. Canned carrots irradiated at > 14.9 × 103rad and the cans stored for 5 months at 10°C and 85% relative humidity, either retarded or inhibited sprouting of carrots.

The level of irradiation did not change the sensory quality of carrots during the first month of storage. However, in subsequent storage for 4 months at 10°C and 85% relative humidity, the quality scores increased as the dose of irradiation increased, which may be due to a reduction in sprouting losses.

Postharvest Diseases and Their Control

Carrots are susceptible to bacterial soft rot (Erwinia carotovora), black rot (Stemphylium radicinum),gray mold rot (B. cinerea), Rhizopussoft rot (R. tritici, R. stolonifer,and R. oryzae),and watery soft rot (S. sclerotiorum).

Rhizopus sp. and Monilinia sp. have been reported to cause heavy losses. Treatment of carrots immediately before storage with TBZ-20 (thiabendazole) at 1.10%, quintozene at 60 g/100 g, or formaldehyde at 0.05 liter/m3 significantly reduced storage rots caused by A. radicina and S. sclerotiorum. Dichloran, an aromatic amine, was very effective in controlling Rhizopus and Monilinia infections. Certain preharvest disease control treatments may have an effect on the chemical composition and shelf life of carrots. the effects of the nematicides Telone (1,3-dichloropropene and other chlorinated hydrocarbons) at the rate of 10, 20, and 30 gal/acre and Nemagon (1, 2-dichloro-3-chloropropane) at the rate of 1, 2, and 3 gal/acre applied as soil fumigants one week before planting of carrots are recommended.The chemicals significantly enhanced the total carotene, bcarotene, and sugar levels, and decreased the rate of respiration.

The chemicals, however, did not change the reducing sugar and total nitrogen contents the reduction in respiratory rate may prolong the shelf life of carrots.

Cultivars: Red Cored Chantenay is exclusively used for the canning of whole carrots. Red Cored Chantenay, Danvers Half Long, Imperator, and Autumn King used for canning of slices and dices. Imperator and Red Cored Chantenay can also be dehydrated, and Chantenay, Long Imperator, and Nantes are used for freezing. Carrots with longer lengths, medium diameter, orange or yellow color, smooth surface, good core, and less bitterness are preferred for processing.

2. Beet root (Beta vulgaris)

Introduction

The table beet, red beet or beet root (Beta vulgaris L.) is an indigenous species to Europe and is important home garden and market root crop. Beet is a good source of sugar. It is usually cooked and can be served cold or warm, either alone or in conjugation with leafy salads.

Origin and distribution

Originating in Europe and Western Asia, the garden beet or table beet is one of the various forms of Beta vulgaris of Chenopodiaceae family. It is closely related to Swiss chard, sugar beet, and fodder beet. The leaf beets were developed before the root beets. Red root beets were cultivated by the Romans. The root beet is grown throughout Europe and America. The red pigment, betanin (a nitrogen-containing anthocyanin) can be used for food coloring. The table beet, being introduced in 1800, is one of the most popular home garden crops in the U.S. Table beets prefer a cool climate and sunny days. Temperatures for optimum growth range between 16 and 190C. During hot weather, the roots may become tough. They are very sensitive to soil acidity and require a pH of 6.2 to 6.8. Beet roots may vary in color and shape. The oblate- or globe-shaped red-rooted types are most popular, and most of the commercial production is for processing.

Botanical description

Beet is a biennial crop but is grown as an annual for its root. It behaves as a biennial, producing a thickened root and a rosette of leaves in the first year, flowers and seed in the second year. Under prolonged cold conditions, the plant may produce flowers and seeds in the first year. Beetroot is mainly grown for its swollen roots but the leaves can also be eaten as spinach.

Importance

Table beets contain only about 30 calories per 1/2 cup sliced beets, and are a good source of folic acid. Beet tops, high in vitamin C, may be used as food and are prepared in the same manner as spinach. Beet tops and spinach also contain oxalic acid. Consuming large amounts of either with a low calcium diet can cause a calcium deficiency and diarrhea. It is best to eat a balanced diet to avoid this problem. Use tender young beet leaves as the oxalic acid content increases in older plants in late summer and fall.

Climatic & soil requirements

Soil and Temperature:

Temperature: Beetroot is a cool-weather crop that is hardy and tolerates some freezing.It grows best in cool weather to produce good quality beets with high sugar content and dark internal color throughout the root.The sugar content of the root increases at low temperatures. Beets require low-temperature treatment (vernalization 2 weeks at 4-10°C) for flower bud initiation. This crop can tolerate frost much better than other vegetables but cannot withstand hot dry weather. The ideal temperature for producing excellent quality roots is 16-18°C.

Soil: Beet can be grown in a wide range of soils but does best on deep and well-drained, loose, loamy to sandy soils. Light soils produce better crops than heavier ones. A heavy clay soil hinders the development of roots. The pH range most suitable for production is around 6.0-7.0, but beet can be grown even in more alkaline (pH 9-10) soils. Acid soils are likely to create nutrient deficiency problems and should be avoided or limed to raise the pH. Mature beets are fairly tolerant to salinity, whereas seedlings are relatively sensitive.

Propagation: Beetroot is propagated by seed. Beet seed is produced in cold climates. Seeds are dark brown or black in color and contain up to 5000-6000 seeds per 100 g. The best temperature for germination of beet root seed is 20-30°C.Under ideal conditions they take about 5-10 days for germination.

Cultural Practices

Sowing: As seed is sown directly, fields need to be prepared correctly and thoroughly. The soil must be well tilled, free of old plant material and have a good crumb structure. Good soil preparation can be achieved by ploughing, harrowing and leveling prior to sowing. Beet can be planted all year round, but as a rule of thumb areas where there could be frost conditions around planting time or the possibility of scorching from excessive heat should be avoided.

The seeds are sown by broadcasting or drilling. Seeds are sown in rows that are 30-45 cm apart. A plant-to-plant distance of 5-20 cm is maintained, depending upon the variety and soil type. When the seeds are broadcasted, thinning of seedlings may be necessary. In general, about 12-15 kg of seed may be needed per hectare. Soaking of seeds in water for about 12 hrs before sowing improves seed germination.

Manuring and Fertilization: Beet root needs higher levels of phosphorous and potassium. However, it does not need too much nitrogenous fertilizer if the land is rich in organic matter.

For better yields of excellent quality roots application of fully decomposed farmyard manure is also recommended.The entire dose of farmyard manure should be given at the time of land preparation, while the inorganic fertilizers are applied at the time of sowing. Adequate soil moisture is necessary to obtain the best results from fertilizer application.

Weed Control

Good seedbed preparation is one of the best ways to prevent weed problems in table beets. Developing weeds are most easily controlled and less damage is done to the crop when weeds are destroyed when small. Remove any weeds in the rows when plants are thinned. Young beet plants are easily injured and should be hoed or cultivated with care.Beets planted early may germinate slowly. A few faster germinating radish seeds mixed with the beet seeds help mark the row should cultivation be necessary before beets are easily seen. Hoe or cultivate shallowly and do not mound or throw soil around the plants. Cultivating or hand-weeding are the recommended methods of controlling weeds in small gardens.There are a few herbicides available to home gardeners with large plantings.

Irrigation and Intercultural operations:

As with most vegetable crops it is very important to keep the soil moist until the plants emerge. In the case of very hot weather, a layer of mulch can be used to prevent the soil drying out too rapidly. Beetroot has shallow roots, with an effective depth of 300mm, and it is important to water the plants regularly and frequently.The first irrigation is carried out immediately after sowing. Subsequent irrigations are performed depending upon the soil type, weather conditions, and variety. Large fluctuations in soil moisture content will result in poor quality roots that are malformed and have many small hairs or side roots. Beet crop is most sensitive to water stress at the time of root development and during early stages. However, waterlogging should be avoided at all times. Intercultural operations like shallow hoeing and weeding are necessary to check weed growth.

Diseases , Insect pests and Disorders

Cercospora leaf spot (Cercospora beticola): This is a common disease in beetroots caused by a fungus which enters the leaves and causes small round spots.The spots are at first brown with a dark purple border and later turn grey in the center.These spots are also found on the flowers and seed on plants grown for seed production.

Control

• Crop rotation

• Seed treatment with registered chemicals

• Avoiding over watering

Downy mildew (Peronospora schachtii): The disease is seed-borne and it can affect the crop early in the season. Leaves of infected plants partly or completely turn yellow and curl downwards. The diseased patches later turn brown. A grey fungal growth can be seen on the underside of the leaves.Flowers and the crown can also be infected.

Root rot, damping-off (Phoma betae)

The disease is common on compact soil.

Germination of infected plants is weak.

Young seedlings grow poorly, turn yellow, wilt, topple over and die and the roots turn black.

Seedlings that are not severely affected produce small, malformed beetroots.

Control

Seed should be sown in soils with a good structure

Practice crop rotation

Planting at the right time and not too deep

Treating seeds with chemicals (thiram)

Pests:

- ✓ **Aphids and red spiders**

Disorders : Internal black spot of beets. Caused by boron deficiency and can be controlled by adequate fertilization with borax. Hard or corky black spots develop on the roots, especially in the light-colored zones of the young cells and tissues.

Maturity, Harvesting and Handling

Beet maturity is generally indicated when the leaves fall away from the plant in the upright position. Beetroot is usually harvested when the roots reach 3 to 5 cm in diameter, but most roots are lifted when they are 5 to 7.5 cm in diameter. However, larger beets having a diameter of more than 5 cm are not in great demand.

The crop is lifted by hand or mechanically when grown on a large scale, by using a machine which lifts the crop from the soil and cuts off the leaves. Care should be taken in pulling roots from the soil and in their handling so that damage from bruising can be minimized.The best storage temperature for beets is near the freezing point, but beets should not be allowed to freeze. Enough humidity is needed to avoid wilting and withering of roots. Beets keep well at 0°C with a relative humidity of about 90%, which is common practice where beets are stored for processing. Under most storage conditions, relatively large roots keep better than small ones because they shrivel more slowly. Beets can be preserved by freezing, drying, or canning. Uniform dark red color without zones or rings and tender flesh free of fiber are desirable processing qualities. Beets destined for processing must be harvested before they develop woodiness.

3. Anchote (Coccinia abyssinica)

Introduction

Anchote (Coccinia abyssinica (Lam.) Cogn.) is an annual trailing vine belonging to the cucurbitaceous family best known and grown principally for its tuberous root even though its tender leaves are also widely used as food.

Among the major root and tuber crops Anchote is a potential crop produced on nearly 3000ha of land in West Wollega zone with a yield about 25,000 tons and it is used as food, cultural, social and economical crop for the farming communities. The genus Coccinia is made up of 30 spp. of which eight are reported to occur in Ethiopia. The species recorded in flora of Ethiopia since 1995 include C. abyssinica (Lam.) Cogn., C. adoensis (Hochst. Ex. A. Rich.) Cogn.), C. grandis (L.) Voigh (Syn. C. indica wight and Arn.), C. megarhiza, C. Jeffrey and C. schliebenii Harms. The remaining three species have not yet been described.

Anchote is cultivated in areas between 1300-2800 m above sea level where the annual rainfall ranged between 762-1016mm. Ethiopia has 18 agro-ecological zones which are endowed with suitable climatic and edaphically conditions for quality and quantity production of various kinds of root and tuber crops. The majority of the Ethiopian population depends mainly on cereal crops as food source. The food potential of root and tuber crops has not yet been fully exploited and utilized despite their significant contributions towards food security, income generation, provision of food energy and resource base conservation.

The low agricultural productivity, recurrent drought and socio-political factors have greatly contributed to critical food shortages in Ethiopia coupled with over-dependence on few cereal crops; thus, integration of root and tuber crops into the food system of the people should be given a serious attention. Due to the lower attention given to the research and development of Anchote, there is no variety so far developed and released. There are traditional selection practices being followed by farmers to have Anchote types of desirable qualities, such as larger tuber size. Women usually do the selection and maintenance of good quality Anchote root and discard of the undesirable ones. Farmers have their own experience by which they maintain seeds for the next planting. Among the quality attributes the farmers take in to account are cooking quality, durable quality and time taken for tuber formation. Beyond the traditional experience, there is no scientific research done on the selection of more yielder and better adaptive varieties of this crop.

Origin and distribution

Anchote is indigenous root crop of Ethiopia and domesticated in Western, Southwestern and Southern parts of the country. Anchote is thought to have the longer duration in Wollega and to have spread to western and south West of Ethiopia.

It is now cultivated usually as a vegetable garden crop and also as field crop in all parts of Wollega, south and southwestern parts of Ethiopia, especially, in Sidama, Wallayita, Gurage, Sheka, Kefa, Jimma and Illu abba bore zone, South- Western Gojam (especially Agewu Zone)

Botanical description

Anchote belongs to the Cucurbitaceae family. The Cucurbitaceae are mostly prostrate or climbing herbaceous annuals comprising about 90 genera and 700 species that are further characterized by commonly having five angled stems and coiled tendrils. The leaves are alternate and usually palmate five lobed or divided; stipules are absent.The genus Coccinia is made up of 30 species of which eight are reported to be occurring in Ethiopia. Anchote (Coccinia abyssinica) is among these species.

Anchote is producing new growth annually from shallow, persistent roots, but for optimum results the newly growth plant is treated as an annual. A single root may weigh up to 5 kg and have a diameter of up to 20-30 cm. The vine is moderately thick, slightly ridged and grooved, and can reach three to 5 meter in height, if given support. The leaves are trifoliate, oblong, stiff petioles; the leaflets are ovate, 7.5-15 cm long with the terminal one usually longer than the laterals and attached to the petiole by a marked pulpiness.

The inflorescence is borne on an auxiliary raceme, up to 3 cm in length, with 2 to 10 flowers, which may be yellow or white. It has been reported that anchote is highly self pollinated crops.

The fruits are oval in shape they contain 20-50 seeds which can vary in color from white, through varying shades of yellow and brown to black

Importance

- Anchote has diversified advantages such
- as human nutrition
- animal feed
- medicine
- social value
- industrial raw material for starch production makes it the most important crop to be further researched for enhanced utilization.

Anchote is endemic root crop of Ethiopia and it is a unique root crop in its uses and the parts consumed. All parts of anchote: root, leaves and the immature fruit are consumed even though the root is the most economic concern in most growing areas of Ethiopia. A farmer in Western parts of Wollega usually plants 400 to 600 square meters of anchote, mainly for home consumption.The consumable parts: root, leaf, and fruit are rich in protein, calcium, iron, and potassium and it can be used as a useful crop to fight malnutrition.

The calcium, phosphorous, iron and potassium content of anchote is higher. The concentration of vitamin A and riboflavin are higher in the peeled root anchote while the vitamin C content is higher in whole anchote. Anchote contains 3.9 g proteins in 100 g of peeled one and it contains 3.0 g /100 g in the whole one.The protein content of whole anchote is 2 times higher than the values reported for potato and sweet potato. vitamin A and riboflavin content of anchote are much higher than those in white fleshed sweet potato, potato and cassava.

Due to its good vitamin A content, consumption of anchote may help to reduce the problem of vitamin A deficiency. Vitamin C content of whole anchote is 10 mg in 100 g serving and thus anchote may help to make dietary iron soluble and more bioavailability. Anchote is consumed after boiling; roots and vines are also fed to livestock. Industrially starch and calcium can be extracted from roots. Like many other roots, anchote is rarely eaten raw.

Ethno-medicine

In addition to its nutritional importance, anchote is a cultural and medicinal crop widely used in growing areas. juice of anchote root is used to treat cancer, tuberculosis, skin eruptions and gonorrhea by traditional medicine practitioners of Ethiopia. Other Coccinia groups such as grandis and indica are also widely used to treat gonorrhea, asthma, skin eruptions, diabetes and eye diseases and they are rich in calcium, potassium, iron and protein. Traditionally, it is believed that anchote heals broken or fractured bones, helps sick people to recuperate and makes lactating mothers healthier and stronger.

Adaptation: Anchote is cultivated in areas between 1300 to 2800 meters above sea level with 762 to 1016 mm rainfall. Anchote is a potential dry land crop and suitable to be produced in arid areas.

Planting:

For both sole and intercropping, the land is prepared immediately after the first rains. Anchote is well yielder when it intercropped with sorghums and maize but it is more and more yielder in sole cropping. By using “gaso or doma” to loosen the soil to at least 15 cm deep and removes all the weeds for normal growth of the crop. Avoid stony soils because they limit tuber expansion. In drier areas, planting can be done when the top 15 cm of soil is wet. In high rainfall areas planting can be done when the top 7.5 cm is wet. Seed is the most commonly used planting materials and the vine is used in some cases. Correct spacing for anchote planting is 40cm between rows and 20cm between plants. Problems handicapping the future development of this crop are the lack of adequate supplies of seeds due to the long time requirement of the crop for seed production.

In certain areas of Wollega and the growing areas the crop is treated as a perennial and the tubers are left in the ground to produce fresh plants immediately, for seed production. But the plant is treated as annual crop for good root production.

Method of planting -Anchote is mostly planted lonely for more root production and it can be intercropped with maize and sorghums and the like for seed production, thus inter cropping serve this crop as the vine supports or it hold up the vines for more fruit formation. For root and seed production planting is possible on the flat or steep land. The seeds are put in holes about 2-3 cm deep, at the beginning of the rainy season. The effect of staking on the yield of root is not significant but it has significant effect on the production of seed. Seedlings make slow growth for the first 3-5 weeks and efficient weed control is usually necessary until they are well established.

Fertilizers requirement

Very few farmers apply fertilizers on anchote. However, farmers used organic fertilizers for good yield. If the soil is very poor, apply about 5-8 ha- 1 FYM or 46/20 kg ha-1 N/P ' depending on the condition of the land.

Growth period: Production of anchote roots starts within three months and continues for several weeks. However, for adequate yield it is grown more and more, harvesting is normally four-eight months after sowing.

Pests and diseases: In general anchote is free from diseases and other problems.

The most common pest of anchote fruit is caterpillars. In addition some animals like porcupine or “jart”, seriously consume the root.To some extent powdery mildew can affect anchote leaf but it is not common problem because the disease occurs after full physiological maturity of the plant.

Weeding: Usually the land is kept free from weeds until the crop covers the ground. The first weeding should be done two-three weeks after planting and it continuous until the vines cover the ground or suppers the weeds.

Harvesting and handling: Locally the farmers can harvest anchote after three and half months in the dry and hot areas and after four months in the cooler and wet land areas. You can harvest the root at once or you can leave some in the ground for up to until you need them. Locate the large roots by cracks in the ground. Loosen the soil around the tuber with a sharp tool like a fork and lift the root from the ground. Use a ‘gaso’ if you want to harvest the whole plot at once.

The annual root tubers are normally harvested when they reach 2.5-5 cm in diameter and 7.5-12 cm in length. Lifting is usually by fork, care being taken to avoid damage; the practice of growing the plants on rows facilitates this operation. Where grown on the flat, the ground is sometimes flooded to make digging easier and to reduce the possibility of injury.

There is little information on storage of the root tubers as they are normally eaten immediately after harvest, but it has been found that under normal tropical conditions deterioration is rapid (loss of moisture, loss of vitamin C and long cooking time), but at lower temperatures and higher humidity storage for a few weeks was possible, provided that fungal growth was prevented

Yield: Yields of roots and tubers greatly influenced by; conditions of growth, altitude and variety. Similarly, yield of anchote varies widely with varieties, altitude and location due to environmental differences. In most cases, fresh tuber yields can reach 40-60 tons per ha.

Radish (Raphanus sativus), Parsnip (Pastinaca sativa), Turnip (Brassica rapa) Rutabaga (Brassica nopus), Parsley root (Petroselinum spp) your assignment!

CHAPTER-Four

Major Tuberous root Crops grown in Ethiopia,

- ✓ Sweet Potato (Ipomoea batatas L) and
- ✓ Cassava (Manihot esculenta)

4.1. Sweet Potato (Ipomoea batatas L.)

Introduction

HISTORY AND ORIGIN

Scientists believe that sweet potato was domesticated more than 5000 years ago. There is still much debate as to just where in the Americas this took place South America or Central America, although recent evidence suggests that it was the latter. The exact time of introduction of sweet potato into the Ethiopian traditional farming system is not clearly known. However, the crop has become popular for centuries particularly in the densely populated areas of the south, south western, and eastern part of the country where it has remained an important co-staple food among the communities.

Sweet potato is the second most important, root crop next to enset in the country. Sweet potato gives high yield in a relatively short time and require very little labour and care compared to other crops.

CLASSIFICATION

A very large number of sweet potato cultivars exist; the number is larger than for yam, cassava and cocoyams. On the basis of tuber texture after cooking sweet potato can be divided in to three:

- firm dry mealy flesh
- soft, moist gelatinous flesh
- very coarse flesh

On the basis of their tuber skin color they are usually: white, brown, yellow, Reddish purple On the basis of their tuber flesh color they are usually: White, Yellow, Cream, Sweet potato cultivars also differ from one another in the shape of the tuber, shape of leaves, depth of rooting, time of maturity and several other vegetative characteristics.

Taxonomy and Botanical description

Despite its name, the sweet potato is not related to the potato. Potatoes are members of the Solanaceae family, which also includes tomatoes, red peppers, and eggplant, while sweet potatoes belong to the morning-glory family (Convolvulaceae). And unlike the potato—which is a tuber, or thickened stem—the sweet potato is a storage root.

The sweet potato (Ipomoea batatas) is a dicotyledonous plant which belongs to the family Convolvulaceae. Amongst the approximately 50 genera and more than 1000 species of this family, only I. batatas is a crop plant whose large, starchy, sweet tasting tuberous roots are an important root vegetable. The young leaves and shoots are sometimes eaten as greens

The genus Ipomoea that contains the sweet potato also includes several garden flowers called morning glories, though that term is not usually extended to Ipomoea batatas. Some cultivars of Ipomoea batatas are grown as ornamental plants. The edible tuberous root is long and tapered, with a smooth skin whose color ranges between red, purple, brown and white. Its flesh ranges from white through yellow, orange, and purple.

The root system

When sweet potato is planted from the stem cuttings, adventitious roots arise from the cutting in a day or two. These roots grow fast and form the root system of the plant. Research results has confirmed that sweet potato roots can penetrate the soil to a depth of over 2 meter, the exact depth depends on soil type.

Based on its origin, the root system of sweet potato is divided into the:-

- ✓ Adventitious roots arising from the subterranean nodes of a vine cutting and
- ✓ Lateral roots arising from the existing roots.

The adventitious roots can be subdivided into:

- ⇨ storage roots
- ⇨ fibrous roots and
- ⇨ pencil roots.

The lateral roots are also subdivided into;

- o Primary roots,
- o Secondary roots and
- o Tertiary roots.

Above ground plant organs of sweet potato

Vines: Sweet potato has long thin stems that trail along the soil surface and can produce roots at the nodes. Sweet potato genotypes are classified as either erect, bushy, intermediate, or spreading, based on the length of their vine. Branching is cultivar dependant and vary in number and length. Normally sweet potato produce three types of branches; primary, secondary and tertiary at different stage of growth. Spacing, photoperiod, soil moisture and nutrient , supply influence the branching intensity of sweet potato plant.

Leaf and Petiole: The leaves of sweet potato occur spirally on the stem. The total number of leaves per plant varies from 60-300. The number of leaves per plant increases with decreasing plant density, increasing irrigation, and nutrient application. The petiole retains the ability to grow in a curved or twisted manner so as to expose the lamina to maximum light.

Flower and seed: Sweet potato has a funnel shaped flower and the seeds are black and about 3 mm long.

Global production

Because of its versatility and adaptability, sweet potato ranks as the world's seventh most important food crop after wheat, rice, maize, potato, barley, and cassava. More than 133 million tons are produced globally per year. Asia is the world's largest sweet potato-producing region, with 125 million tons of annual production. China at 117 million tons accounts for 90 percent of worldwide sweet potato production.

Nearly half of the sweet potato produced in Asia is used for animal feed, with the remainder primarily used for human consumption, either as fresh or processed products. In contrast, although African farmers produce only about 7 million tons of sweet potato annually, most of the crop is cultivated for human consumption. African yields are quite low—about a third of Asian yields—indicating huge potential for future growth.

Latin America, the original home of the sweet potato, produces 1.9 million tons of sweet potato annually. Production in North America is about 600,000 tons. The only European country that produces sizeable quantities of sweet potato is Portugal, at 23,000 tons. Over 95 percent of the global sweet potato crop is produced in developing countries, where it is the fifth most important food crop. Sweet potato is currently grown in more than 100 tropical countries. In the densely populated, semiarid plains of eastern Africa, sweet potato is called cilera abana, "protector of the children." This title alludes to the vital role it fulfills in thousands of villages, where people depend on the crop to combat hunger.

Importance

Nutrition and health benefits

Sweet potato is high in carbohydrates and vitamin A and can produce more edible energy per hectare per day than wheat, rice or cassava. It has an abundance of uses ranging from consumption of fresh roots or leaves to processing into animal feed, starch, flour, candy, and alcohol.

Besides simple starches, sweet potatoes are rich in complex carbohydrates, dietary fiber, beta carotene (a vitamin A equivalent nutrient), vitamin C, and vitamin B6. Sweet potato varieties with dark orange flesh have more beta carotene than those with light colored flesh and their increased cultivation is being encouraged in Africa where Vitamin A deficiency is a serious health problem.

Despite the name "sweet", it may be a beneficial food for diabetics, as preliminary studies on animals have revealed that it helps to stabilize blood sugar levels and to lower insulin resistance

Other use

The roots are most frequently boiled, fried, or baked. They can also be processed to make starch and a partial flour substitute. Industrial uses include the production of starch and industrial alcohol.

Non-culinary uses: In South America, the juice of red sweet potatoes is combined with lime juice to make a dye for cloth. By varying the proportions of the juices, every shade from pink to purple to black can be obtained. All parts of the plant are used for animal fodder.Several selections are cultivated in gardens as ornamental plants for their attractive foliage, Taiwanese companies are making alcohol fuel from sweet potato.

Disaster relief: Sweetpotato has a long history as a lifesaver. The Japanese used it when typhoons demolished their rice fields. Sweet potato kept millions from starvation in famine-plagued China in the early 1960s, and in Uganda, where a virus ravaged cassava crops in the 1990s, rural communities depended on the sweet potato to keep hunger at bay.

Climatic & soil requirements

Temperature: In its native environment, sweet potato is a tropical plant. Like other warm climate crops, it thrives better in warm humid weather, requires ample sunshine, and is vulnerable to frost injury. It can withstand drought conditions very well and can yield fairly well even in a semi-arid climate without supplemental irrigation. The optimum temperature for obtaining excellent vine growth as well as tuber yield is 24°C.

Temperatures lower than 10°C generally cause chilling injury. The optimum temperature range was found to be 2030°C. Higher soil temperatures (>30°C) affect tuberization and tend to encourage vegetative growth of aerial plant parts at the cost of tuber formation and growth.

Lower soil temperatures (<10°C) also affect tuber development. Fleshy root development in the sweet potato is governed by photoperiod: short days promote it, whereas long days favor vine growth and inhibit fleshy root development.

Rainfall: For the best growth of sweet potato crops, rainfall should be moderate and should occur during the early stages of growth. The optimum rainfall is considered to be around 500-675 mm, but sweet potato can thrive with up to 1000 mm rainfall. The growing season is usually determined by the amount of rainfall received at a particular place and the availability of supplemental irrigation. For example, in heavy rainfall areas, sweet potato is grown mainly as a rabi (OctoberMarch) crop, while in places where rainfall is moderate, but abundant during the early part of the growing season, crops can be grown throughout the year. In general high rainfall, fewer hours of sun, and high humidity results in maximum tuber weight and maximum yield of sweet potatoes.

Soil: Soil texture, drainage, and aeration have tremendous influence on the growth and productivity of sweet potato vines. The ideal soil for sweet potato must be light, well drained, and aerated. Sandy or loamy sand soil with a clay subsoil are ideal for its growth. Sandy loam soils favor maintenance of proper balance between vegetative (aerial) growth and fleshy root development.

In contrast, clayey soils or soils that are rich in organic matter produce a great deal of vegetative growth at the cost of fleshy root development, the result being that productivity is adversely affected. In heavy soils, roots become rough, small, irregular in shape and stringy.These soils, due to their sticky nature, cause harvesting difficulties leading to fleshy root injury. In contrast, very light soils without relatively compact subsoil and deep soils produce long slender roots, which are not commercially desirable

Sweet potato Propagation

Sweet potato will grow adequately if propagated by means of: Seeds, tubers and vine cuttings. The most common method of propagation in sweet potato is from cuttings taken from vines of the previous crop. In some countries like India where the growing season is relatively short, the tubers are planted in nursery beds spaced at 45 × 30 cm and 56 cm deep. After sprouting, the shoots are cut and planted in another nursery bed spaced at 60 × 30 cm in order to encourage rapid vegetative growth. When these vines are of the desired length, cuttings are made for further planting in the main field.

The cuttings, about 30 cm long, are taken from healthy vines. When tubers are used, it is necessary to recognize the effect of apical dominance only one terminal shoot emerges from one shoot. To break apical dominance, the tubers must be dipped in warm water (4042°C) for 10 minutes or in 10 ppm 2,4-D. The soil for planting of cuttings is brought to a fine tilth by repeated shallow ploughing, harrowing, and leveling. The recommended method of propagating sweet potato is by means of the vine cutting for several reasons:

1. Plants drived from cuttings are free from soil born diseases

2. The entire tuber harvest can be saved to be consumed or utilized by the farm family instead of resorving some of the tubers for planting purposes

3. Vine cuttings give more yields and produce tubers of more uniform in shape and size.

Type of Planting Material

- ✓ Top cutting
- ✓ middle cutting and
- ✓ Basal portion cutting

Cultural practices

Planting: The cuttings, taken either from the vines of the old crop or newly planted crop, are planted in flat beds or ridges and furrows. The recommended spacing for rooting of cuttings is 15 × 30 cm for flat beds or 60 × 22 cm for ridges and furrows. Sweet potato is normally planted in ridges, with space between rows of 60 cm and plant-to-plant spacing of 20 cm, thus accommodating 83,000 plants/ha. The land must thoroughly be irrigated to have the cuttings planted in muddy soils. Planting posion could be vertical, horizontal, at an angle, or U-shape.

When planted in ridges, the cuttings are planted at about one third the height of the ridges in such a way that both ends of the cuttings are free and the central portions are buried in the soil, which yield roots in about a month's time.

One hectare of land accommodates about 1,25,000 such cuttings, and the grower must have additional cuttings to make up for plant mortality, which can be as high as 10-25%.

Time of planting: The optimum time of planting for sweet potato production is the beginning of the rainy season when the rain ensures good establishment and the crop has the entire rainy season to grow.Under irrigation planting is possible throughout the year.

Manuring and Fertilization: Sweet potato requires smaller amounts of nutrients than potato. Choudhury (16) reported that a sweet potato crop yielding 6.6 tons of tubers per hectare removes from the soil 30 kg of nitrogen, 9 kg of phosphorus, and 60 kg of potash. Other reports in this regard indicated that a crop yielding 5.5 tons of tubers required an uptake of 15 kg of nitrogen from the soil, while a crop producing 15 tons of tubers per hectare removed 70 kg of nitrogen, 20 kg of phosphorus, and 170 kg of potash.

However, an excess of nitrogenous fertilizers must be avoided, as it results in stimulation of vegetative growth at the cost of tuberization and tuber development.Fleshy root development is promoted by higher levels of potassium. Therefore, the fertilizer schedule for sweet potato must involve less nitrogen and higher doses of potassium. Choudhury recommended the application of 60 kg of nitrogen, 60 kg of phosphorus and 120 kg of potash per hectare for optimum growth. In addition, 25 tons of farmyard manure should be added at the time of soil preparation.

The amount of individual fertilizers to be applied depends largely on the type of soil and existing fertility status of the soil . Analysis of soil and plant parts indicated that approximately 41 kg P, 68 kg K, 22 kg of Ca, and 8 kg of Mg are needed to produce 18 tons fleshy roots/per hectare of sweet potato.

Irrigation: A total of 500-700 mm of water is required during the growing season for this crop. Whenever the rainfall is inadequate, supplementary irrigation should be performed. irrigation should be done at intervals of 10 days or whenever required during hot season. Supplementing rainfall with irrigation and proper drainage in low-lying areas are the most important aspects of water management in sweet potato. For proper sprouting and establishment of vine cuttings, planting should immediately be followed by irrigation so as to have moist soil for 45 days after planting. For dry-season crops, 810 irrigations are required

Pruning of Vines: Pruning of vines has been shown to increase root yields in sweet potato. The retardation of vegetative growth of vines has also been shown to reduce rotting of new vigorous shoots capable of photosynthesis and also reducing wastage of photosynthesis, which are in turn translocated to roots. The vines are pruned back to 20-30 cm to increase root yields. Some growers prune the vines after one month to improve their productivity.

Turning of Vines: The vines, due to their ability to grow rapidly, can create a favorable microclimate for insect pests to hibernate or conditions conducive to bacterial or fungal growth. The vines produce roots at nodes when they come in contact with the soil, thereby affecting the growth of the main root system. Therefore, vines should be turned at least once or twice before they are fully grown. Some workers have suggested turning the vines every week, while others think this unsafe as it may cause injury to the vines.

Intercultural Operation: Regular hoeing and weeding are necessary to check weed growth and to maintain soil aeration. First weeding should coincide with the onset of rapid growth of vines, which takes place 3 weeks after planting.

Diseases: Bacterial diseases Bacterial stem and root rot (Erwinia chrysanthemi), Bacterial wilt (Ralstonia solanacearum).

Fungal diseases: Alternaria leaf spot and stem blight Alternaria spp. Alternaria storage rot Alternaria spp.

Nematodes: Burrowing Nematode Radopholus similis

Insect Pests of Sweet potato in Ethiopia

Insect pests can be mentioned as one of the important factors in limiting the production of this crop. Research work conducted on sweetpotato can be categorized under survey, biology and control methods. The result of the survey made in southern Ethiopia between 1986-1990 showed that sweetpotato weevel (Cylas puncticollis) and sweetpotato butterfly (Acrea acerata) are the major insect pests of sweetpotato.

Insect pests of sweet potato recorded in the southern Ethiopia:

Cylas pancticollis Sweetpotato weevil

Acraea acerata Sweetpotato butterfly

Agrius convolvuli Sweetpotato moth

Bedellia somnulentella Sp leaf miner

Control measures

The biology of sweetpotato weevil was studied in both Awasa and Nazareth Research cementers. Agronomic practices such as time of harvesting, earthing up of the crop and crop rotation are the most important agronomic practices in preventing sweetpotato from sweetpotato weevil damage.

Harvesting, Handling, and Maturity

The roots are separated after digging and left on the row to dry. Excessive handling of roots should be avoided by collecting and depositing sweet potatoes directly into storage crates. The harvesting operation is usually performed early in the morning to avoid heat injury (sunscald). According to Thompson et al. (22), in steep areas after the roots are pulled, the soil is commonly returned to allow smaller roots to develop.

According to Thompson et al., in steep areas after the roots are pulled, the soil is commonly returned to allow smaller roots to develop. There are no definite maturity indices for sweet potatoes. A random sampling or trial digging of the area indicates the fleshy root maturity. The maximum concentration of carotene and total carotenoid pigments occurred at the time of usual harvest for storage. In general, the carotene and total carotenoid pigments of sweet potatoes increased during the first part of the harvest period and then decreased. The ascorbic acid content decreased later in the harvest period.

The harvested sweet potatoes are prepared for market by careful grading, cleaning, and packaging. Uniform, medium-sized sweet potatoes, free from cuts, bruises, and rot, are in great demand. In some countries, sweet potatoes are usually washed before they are packed for market, machine-washing sometimes being adopted. Sweet potatoes are packed in various types of containers, such as hampers, round staved baskets, crates, and boxes.

4.2. Cassava (Manihot esculenta)

Introduction

Cassava, (Manihot esculenta Crantz) is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. It is also called yucca, manioc, and mandioca. Cassava has the ability to grow on marginal lands where cereals and other crops do not grow well; it can tolerate drought and can grow in low-nutrient soils. Because cassava roots can be stored in the ground for up to 24 months, and some varieties for up to 36 months, harvest may be delayed until market, processing, or other conditions are favorable (IITA, 2007).

Cassava is the basis of many products, including food. In Africa and Latin America, cassava is mostly used for human consumption, while in Asia and parts of Latin America it is also used commercially for the production of animal feed and starch-based products. In Africa, cassava provides a basic daily source of dietary energy. Roots are processed into a wide variety of granules, pastes, flours, etc., or consumed freshly boiled or raw. In most of the cassava-growing countries in Africa, the leaves are also consumed as a green vegetable, which provides protein and vitamins A and B (IITA, 2007).

In Southeast Asia and Latin America, cassava has taken on an economic role. Cassava starch is used as a binding agent, in the production of paper and textiles, and as monosodium glutamate, an important flavoring agent in Asian cooking. In Africa, cassava is beginning to be used in partial substitution for wheat flour (IITA, 2007).

History

Wild populations of M. esculenta subspecies flabellifolia, shown to be the progenitor of domesticated cassava, are centered in west-central Brazil where it was likely first domesticated no more than 10,000 years BP. By 6,600 BC, manioc pollen appears in the Gulf of Mexico lowlands, at the San Andres archaeological site. The oldest direct evidence of cassava cultivation comes from a 1,400 year old Maya site, Joya de Ceren, in El Salvador. Although the species Manihot esculenta likely originated further south in Brazil and Paraguay. With its high food potential, it had become a staple food of the native populations of northern South America, southern Mesoamerica, and the West Indies by the time of the Spanish conquest, and its cultivation was continued by the colonial Portuguese and Spanish. Forms of the modern domesticated species can be found growing in the wild in the south of Brazil. While there are several wild Manihot species, all varieties of M. esculenta are cultigens. Cassava is almost entirely produced and consumed in developing countries. It is highly productive, tolerant of poor soils, periods of drought and is relatively disease free and pest resistant. It provides a major source of energy for over 500 million people; the energy content of cassava in diets in the tropical areas of Africa, America and Asia has been estimated as 37%, 12% and 7% respectively. In recent years a substantial trade has developed in dehydrated cassava chips and pellets which are exported to Europe as a low-cost animal feed ingredient. The European Economic

Community in 1975 is reported to have imported 2.3 million tons of dried cassava chips, mostly from Thailand.

Origin and distribution

The cassava plant originated in north east Brazil, with the likelihood of an additional centre of origin in central America. It probably entered into cultivation at these two centres of origin, and today Manihot esculenta does not exist in the wild state. From its place of origin, the plant has spread to various part of the world, and it is today cultivated in all tropical regions of the world 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 center of production.

Numerous cassava cultivars exist in each locality where the crop is grown. The cultivars have been distinguished on the basis of; morphology (that is leaf shape and size, plant height, petiole colour etc.), tuber shape, earliness of maturity, the content of cyanogenic glucoside of the root. This last named characteristic has been used to place cassava cultivars into two major groups:

1. The bitter varieties, in which the cyanogenic glucoside is distributed throughout the tuber and is at high level, and

2. The sweet varieties, in which the cyanogenic glucoside is confined mainly on the peel and is at low level. The flesh of the sweet varieties is therefore relatively free from the glucoside, although it still contains some.

In general the sweet varieties tend to have a short growing season; their tubers mature 6-9 months, and deteriorate rapidly if not harvested soon after maturity. The bitter cassava , on the other hand, require 12-18 months to mature, and will not deteriorate if left unharvested for several months. Some caution should be exercised in using the level of glucoside as a distinguishing characteristic for cassava cultivars.

This is because the exact level of glucoside in a particular cultivar will vary according to the environmental conditions under which the plant is grown. The glucoside content of the cultivar may be high under some conditions and low under others. Botany of Cassava

Cassava unlike yam, a single species, Manihot esculenta Crantz (Synonymous with Manihot utilissima pohl.).

It is a dicotyledonous plant belonging to the botanical family Euphorbiaceae, and like most other members of that family, the cassava plant contains laticifers and produce latex.

Family:	**Euphorbiaceae**
Genus:	***Manihot***
Species:	***M. esculenta***

Botany

The cassava root is long and tapered, with a firm homogeneous flesh encased in a detachable rind, about 1 mm thick, rough and brown on the outside. Commercial varieties can be 5 to 10 cm in diameter at the top, and 50 to 80 cm long. 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 calcium (50 mg/100g), phosphorus (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.

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Malpighiales

Family: Euphorbiaceae

Subfamily: Crotonoideae

Tribe: Manihoteae

Genus: *Manihot*

Species: ***M. esculenta***

Taxonomy:- Early literature on cassava described the genus with two edible species, M. ultissima Phol or sweet and M. aipi Phol, delineating species which have high and low cyanogenic glucoside concentrations respectively. More recently cassava was classified as all being the same species M. esculenta. It is the only one of 98 species in its family that is widely cultivated for food production. Cassava uniformly is 2n = 36. Other ploidy levels are not utilized, but have been produced experimentally. There are several closely related species found in the tropical and subtropical Americas that can be crossed with M. esculenta. (O'Hair, 1995)

General morphology and composition of the cassava root

The edible portion of cassava is a starchy root, which matures to harvest within 8 to 24 months of planting, depending on cultivar and climate. A mature cassava root may be anything from 15 to 100 cm in length and from 0.5 to 2.0 kg in weight, subject to variety and growing conditions. The root is circular in cross-section. It is generally fattest at the proximal end and tapers gently towards the distal end. Transversely a cassava root consists of three principal areas.

- The periderm. Comprises the outermost layer of the root. It is composed mostly of dead cork cells, which seal the surface of the root. The periderm is only a few layers of cells thick and as the root continues to increase in diameter, the outermost portions of it are sloughed off and replaced by new cork formations from the inside layers of the periderm.

□ The cortex. A layer 1 to 2 mm thick located immediately beneath the periderm.

□ The starchy flesh. The central portion of the root, consisting mainly of parenchyma cells packed with starch grains.

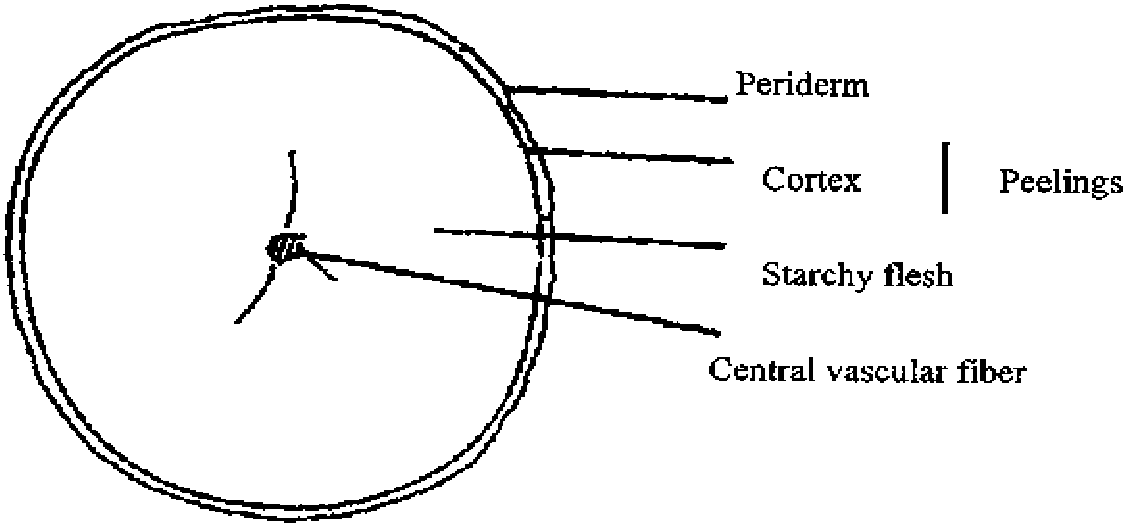


Figure 1. *General view of a cassava root (Onwueme, 1983)*

Cassava contains about 1% protein and some 30-35% of amyloses and amylopectins on a dry weight basis; it is thus a predominantly starchy food. As a human food it has been criticized for its low and poor quality protein content, but the plant produces more weight of carbohydrate per unit area than other staple food crop under comparable agro-climatic conditions. The edible starchy flesh comprises some 80% to 90% of the root and includes:

Water	62%	Fiber	1-2%
Carbohydrate	35%	Minerals	1%
Protein	1-2%	Fat	3%

2.4.5. The problems of cyanogenic glycosides in cassava

Cassava roots and leaves contain cyanides in two different forms: the glycosides; linamarin and lotaustraline which are considered "bound" and the non-glycosides; hydrogen cyanide (HCN) and cyanohydride which are considered "free". Free cyanide comprises 8%-12% of the total tuber cyanide. This cyanide can, under some circumstances, lead to human toxicity problems and cassava for food use has to be processed to remove cyanide-containing substances.

There is remarkably little quantitative information on the effects of processing on cassava toxicity and its significance for humans. There is a great variation in toxicity between cultivars. A distinction is usually made between "sweet" cultivars with relatively low contents of cyanogenic glycosides (below 10mg/100g of fresh weight), and "bitter" cultivars with high cyanogenic glycoside content (above 20mg/100g fresh weight), although many intermediate forms exist. Traditionally the sweet cultivars were considered non-toxic while the bitter ones were considered toxic. Although the sweet cultivars are generally less toxic there is no direct correlation between toxicity and taste (Coursey and Haynes, 1970). Cyanide levels in the range 6 to 370 mg/kg have been found depending on the particular cultivar, growing conditions, (i.e. soil type, humidity, temperature) and the age of the plant.

The highest proportion of HCN is found in the peels and the cortex layer immediately beneath the peels (Hahn, 1984; Onwueme, 1978). It is for this reason the cassava root is always peeled before being processed or consumed. Peeling removes the cortex and the outer periderm layer adhering to it. Peels can represent 10% to 20% of the fresh root weight, of which the periderm accounts for 0.5% to 2.0%. The lethal dose of free HCN for an adult is 50-60 mg but the toxicity of bound HCN is less clearly understood. The glycosides are hydrolysed to HCN by the endogenous enzyme linamarase, which is present in the human digestive tract. All the traditional cassava processing methods reduce or remove the toxicity by releasing HCN from the glycosides. Since HCN is soluble in water and has a boiling point of 25°C it can be removed by soaking. Boiling fresh cassava has little effect on its toxicity as the glycoside limamatine is heat resistant and the enzyme linamarase is inactivated at 75°C.

While most processes rely on enzymatic hydrolysis to reduce the glycoside concentration, in practice the extent of glycoside breakdown is mainly controlled by fermentation time (Bruinsma et al. 1983). The so-called "sweet" types may be eaten raw or lightly boiled without harm. The "bitter" forms are traditionally processed by one or a combination of operations of peeling, grating, fermenting, dehydrating, sun drying, frying or boiling. Hence, for example, fermentation before processing into products such as ***chikwangue*** or ***fufu*** eliminates almost all total and free HCN. The amount of total HCN is reduced by 83% to 96% in such products as ***gari*** and ***attieke*** for which the cassava roots are peeled and grated before processing.

Table 1 : HCN contents of some traditional African Cassava Products (IITA, 1982)

Product	Total HCN mg/100 g of fresh weight		Free HCN mg/100 g of fresh weight	
	Mean	**% Reduction**	**Mean**	**% Reduction**
Peeled fresh roots	15.9	--	0.65	--
Attieke	0.65	95.9	0.07	89.2
Boiled tuberous roots	4.79	69.9	0.70	+7.69
Chikwangue	nil	n/a	Nil	n/a
Eba	0.02	99.9	0.01	98.5
Fufu (Ghana)	3.10	80.5	0.28	56.9
Fufu (Nigeria)	0.72	95.5	0.35	46.2
Fufu (Zaire)	0.02	99.8	Nil	100
Gari (freshly fried)	2.66	83.3	1.22	+87.7
Gari (after 4 months	0.29	98.2	0.26	60.0
Konkonde	0.72	95.5	0.09	86.2
Oyoko	1.46	90.8	0.68	+4.62
Fresh leaves	201	N/A	4.85	N/A
Pondu (cooked leaves)	8.53	95.8	Nil	100

Description

Unprocessed cassava root

The cassava root is long and tapered, with a firm homogeneous flesh encased in a detachable rind, about 1 mm thick, rough and brown on the outside. Commercial varieties can be 5 to 10 cm in diameter at the top, and 50 to 80 cm long. A woody cordon runs along the root's axis. The flesh can be chalk-white or yellowish. Cassava roots are very rich in starch, contain significant amounts of calcium (50 mg/100g), phosphorus (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.

Adaptability: Crops such as yam, maize, banana and plantain, cowpea or sorghum and millet are ecoregionally specific cassava is probably the only crop whose production cuts across all ecological zones.

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 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 (Dioscorea sp.) and sweet potatoes (Ipomea batatas) 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. As a result Cassava is considered as Africa's Food Security Crop

2.4.6. Composition and Uses/Importance

Cassava is grown for its enlarged starch-filled roots, which contains nearly the maximum theoretical concentration of starch on a dry weight basis among food crops. Fresh roots contain about 30% starch and very little protein. Roots are prepared much like potato. They can be peeled and boiled, baked, or fried. It is not recommended to eat cassava uncooked, because of potentially toxic concentrations of cyanogenic glucosides that are reduced to innocuous levels through cooking. In traditional settings of the Americas, roots are grated and the sap is extracted through squeezing or pressing. The cassava is then further dried over a fire to make a meal or fermented and cooked. The meal can then be rehydrated with water or added to soups or stews. In Africa, roots are processed in several different ways. They may be first fermented in water. Then they are either sun-dried for storage or grated and made into dough that is cooked. Alcoholic beverages can be made from the roots Young tender leaves can be used as a potherb, containing high levels of protein (8-10% F.W.). Prepared in a similar manner as spinach, care should be taken to eliminate toxic compounds during the cooking process. One clone with variegated leaves is planted as an ornamental (Hair, 1995).

a. Human food

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

Cassava can be cooked in various ways. The soft-boiled root has a delicate flavor and can replace boiled potatoes in many uses: as an accompaniment for meat dishes, or made into purées, dumplings, soups, stews, gravies, etc.. Deep fried (after boiling or steaming), it can replace fried potatoes, with a distinctive flavor. Tapioca and fou-fou are made from the starchy cassava root flour. Tapioca is an essentially flavorless starchy ingredient, or fecula, produced from treated and dried cassava (manioc) root and used in cooking. It is similar to sago and is commonly used to make a milky pudding similar to rice pudding. Cassava flour, also called tapioca flour or tapioca starch, can also replace wheat flour, and is so-used by some people with wheat allergies or coeliac disease. Boba tapioca pearls are made from cassava root. It is also used in cereals for which several tribes in South America have used it extensively. It is also used in making cassava cake, a popular pastry.

The juice of the bitter cassava, boiled to the consistence of thick syrup and flavored with spices, is called **cassareep**. It is used as a basis for various sauces and as a culinary flavoring, principally in tropical countries. It is exported chiefly from Guyana. Cassava is used in bubble drinks in East Asia.

The leaves can be pounded to fine chaff and cooked as a palaver sauce in Sierra Leone, usually with palm oil but vegetable oil can also be used. Palaver sauces contain meat and fish as well. It is necessary to wash the leaf chaff several times to remove the bitterness.

b. 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 tons, and that of bio-diesel to 200 thousand tons by 2010. This will be equivalent to a substitute of 10 million tons of petroleum. As a result, cassava (tapioca) chips have gradually become a major source for ethanol production. On December 22, 2007, the largest cassava ethanol fuel production facility was completed in Beihai with annual output of two hundred thousand tons, which would need an average of one and half million tons of cassava. In November 2008, China-based Hainan Yedao Group reportedly invested $51.5m (£31.8m) in a new bio-fuel facility that is expected to produce 33 million gallons a year of bio-ethanol from cassava plants.

c. 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.

d. 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 bowel syndrome, 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.

e. Fermented products

i. Cassava Alcohol

Cassava is one of the richest fermentable substances for the production of alcohol. The fresh roots contain about 30 percent starch and 5 percent sugars, and the dried roots contain about 80 percent fermentable substances which are equivalent to rice as a source of alcohol **(FAO, 1977).**

Ethyl alcohol is produced from many carbohydrate materials. In Malaysia and some other countries, many factories are equipped to use cassava roots, starch or molasses (by-product of the sugar industry), the type of product depending on the costs of the raw materials. When cassava is used, the roots are washed, crushed into a thin pulp and then screened. Saccharification is carried out by adding sulfuric acid to the pulp in pressure cookers until total sugars reach 15-17 percent of the contents. The pH value is adjusted by using sodium carbonate, and then yeast fermentation is allowed for three to four days at a suitable temperature for the production of alcohol, carbon dioxide and small amounts of other substances from sugar. Alcohol is then separated by heat distillation. The yield of conversion is about 70-110 liters of absolute alcohol per ton of cassava roots depending on the variety and method of manufacture. The crude alcohol of cassava is described as average in quality. It has a disagreeable odour, but can be improved if the first and last fractions in the distillation process are discarded. It is usually utilized for industrial purposes, as in cosmetics, solvents and pharmaceutical products. If the production is required for human consumption, special care should be taken in handling the roots to rid them of hydrocyanic acid**.**

ii. Dried Yeast

Microbial protein is attracting growing interest owing to the enormous protein requirements of the world. Among the microorganisms which are considered possible food sources, yeast has perhaps stirred the greatest interest. Candida and saccharomyces yeasts have had a well-established place for many years as feed, and the technology of production, the composition and the nutritive value of yeast are well known.

Most of the production of yeast is based on such low-cost raw materials as waste liquids, wood hydrolyzates and molasses. Starch-rich plant materials from wastes or surplus production are also utilized as substrata for yeast production. Cassava starch and cassava roots are being used in Malaysia and some other countries for the production of yeasts for animal feed' the human diet and for bakery yeast. The starch is hydrolyzed into simple sugars (predominantly glucose) by means of mineral acid or by enzymes. Certain yeasts are then propagated which assimilate the simple sugars and produce microbial cellular substances. The dry, inactive yeast contains about 7 percent moisture and the raw protein content can vary between 40 and 50 percent depending on the raw material.

The yield of yeast production also depends on the raw material. In some applications of cassava starch conversion into substances obtained from yeasts, a 38-42 percent yield of yeast product containing 50 percent raw protein has been obtained (FAO, 1977).

iii. ***Non-food uses***

Starch makes a good natural adhesive. There are two types of adhesives made of starches, modified starches and dextrins: roll-dried adhesives and liquid adhesives. The application of cassava in adhesives continues to be one of the most important end uses of the product. In the manufacture of glue the starch is simply gelatinized in hot water or with the help of chemicals.

For conversion into dextrin it is subjected separately or simultaneously to the disintegrative action of chemicals, heat and enzymes.

In gelatinized starch adhesives, quality requirements are such that the medium-quality

In gelatinized starch adhesives, quality requirements are such that the medium-quality flours can be used. In dextrin manufacture, the demands are much more exacting: only the purest flours with a low acid factor are acceptable. Cassava dextrin is preferred in remoistening gums for stamps, envelope flaps and so on because of its adhesive properties and its agreeable taste and odour.

Dextrins were accidentally discovered in 1821 when during a fire in a Dublin (Ireland) textile mill one of the workmen noticed that some of the starch had turned brown with the heat and dissolved easily in water to form a thick adhesive paste.

Main Constituents and Nutritional Value

A comparison of the chemical composition of cassava tubers and some products derived from it (gaplek and tapioca flour) with that of potatoes and rice, as presented in Table 9, may convey an impression of the relative nutritional value of cassava. (It should be borne in mind that only the peeled root is edible.). As cassava is inferior in protein and fat content to both rice and potatoes, animal protein or products such as soybeans are often used to balance the diet in cassava-consuming lands.

Table 2: Nutrients in Cassava Roots Compared With Other Food Products

	Calories \100g	**Protein**	**Fat**	**Carbohydrate**	**Ash**	**Moisture**	**Fiber**
	Percent						
Cassava tubers	127	0.8-1.0	0.2-0.5	32	0.3-0.5	65	0.8
Gaplek	355	1.5	1.0	85	0.8	15	
Tapioca flour	307	0.5-0.7	0.2	85	0.3	15	0.5
Potatoes	89	2.1	0.1	20	1.0	77	0.7

Potato flour	331		0.3	82	0.3	15	0.4
Husked rice	347	8.0	2.5	73	1.5	15	0.7- 1.0

2.4.8. Problem of Cassava Production

According to IITA (2007), the major pests of cassava in Africa are the cassava green mite, the cassava mealy-bug, and the variegated grasshopper. The main diseases affecting cassava are cassava mosaic disease, cassava bacterial blight, cassava anthracnose disease, and root rot. Pests and diseases, together with poor cultural practices, combine to cause yield losses that may be as high as 50% in Africa.

The production of cassava is dependent on a supply of quality stem cuttings. The multiplication rate of these vegetative planting materials is very low compared to grain crops, which are propagated by true seeds. In addition, cassava stem cuttings are bulky and highly perishable as they dry up within a few days (IITA, 2007). As a root crop, cassava requires considerable labor to harvest. Because they are highly perishable, roots must be processed into a storable form soon after harvest. (IITA, 2007).

Many cassava varieties contain cyanogenic glucosides, and inadequate processing can lead to chronic toxicity. Various processing methods, such as grating, sun drying, and fermenting, are used to reduce the cyanide content (IITA, 2007).

Status of the crop production

Cassava is a major source of low cost carbohydrates for populations in the humid tropics. The largest producer of cassava is Brazil, followed by Thailand, Nigeria, Zaire and Indonesia. Production in Africa and Asia continues to increase, while that in Latin America has remained relatively level over the past 30 years. Thailand is the main exporter of cassava with most of it going to Europe. It was carried to Africa by Portuguese traders from the Americas. It is a staple food in many parts for western and central Africa and is found throughout the humid tropics. The world market for cassava starch and meal is limited, due to the abundance of substitutes (O'Hair, 1995).

According to FAO estimates, 172 million tons of cassava was produced worldwide in 2000. Africa accounted for 54%, Asia for 28%, and Latin America and the Caribbean for 19% of the total world production. In 1999, Nigeria produced 33 million tons making it the world’s largest producer. In terms of area harvested, a total of 16.8 million hectares was planted with cassava throughout the world in 2000; about 64% of this was in sub-Saharan Africa. The average yield in 2000 was 10.2 tons per hectare, but this varied from 1.8 tons per hectare in Sudan to 27.3 tons per hectare in Barbados. In Nigeria, the average yield was 10.6 tons per hectare (IITA, 2007).

Production Requirement

Ecological Requirement

a) Climate

Cassava is a typical tropical plant. The approximate boundaries for its culture may be accepted as from 30ºN to 30ºS latitudes; however, most cassava growing is located between 20ºN and 20°S. In general, the crop requires a warm humid climate. Temperature is important, as all growth stops at about 10ºC. Typically' the crop is grown in areas that are frost free the year round. The highest root production can be expected in the tropical lowlands, below 150 m altitude, where temperatures average 25-27°C, but some varieties grow at altitudes of up to 1 500 m.

The plant produces best when rainfall is fairly abundant, but it can be grown where annual rainfall is as low as 500 mm or where it is as high as 5 000 mm. The plant can stand prolonged periods of drought in which most other food crops would perish. This makes it valuable in regions where annual rainfall is low or where seasonal distribution is irregular. In tropical climates the dry season has about the same effect on Cassava as low temperature has on deciduous perennials in other parts of the world. The period of dormancy lasts two to three months and growth resumes when the rains begin again.

As a tropical crop, cassava is a short-day plant. Experiments conducted in hothouses show that the optimum light period is about 12 hours and that longer light periods inhibit starch storage.

Temperature: Adaptable to the hot- lowland tropics. Prefers growth under 25-29C. Growth stops when temperature goes below 10C. Cassava is frost-sensitive.

Altitude: Sea-level to 2000 m.

Day length: Short days promote root enlargement.

b) Soil

Cassava grows well under a wide range of soils but prefers porous, friable soils with some organic matter content and depth of 30-40 cm.

Drainage requirements: Will not survive extended waterlogged conditions.

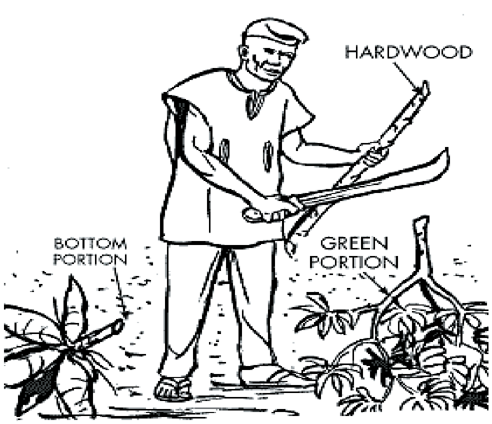
Nutritional Profile of Soil: Prefers soils with pH between 6-7, and clay content < 18% will not tolerate saline conditions. Depending on cultivars, high yields of cassava can be obtained with pH values as low as 4.5 with 60% exchangeable Al^{3+} present.

c) Cultural Requirement

i. Land Preparation

Land for cassava cultivation is first ploughed and then harrowed or disked. Thereafter the cassava may be planted on the flat, on ridges, or in furrows. For furrows, make them 10 cm deep, and place the cuttings horizontally in the direction of the furrow. In areas where drainage is a problem, the land is heaped in mounds or ridges, and the cassava is planted on the crest.

ii. ***Planting***



A total of 10,000 cuttings (20-30cm) with recommended time of planting of during the onset of the main rainy season (April-May). The cuttings should be planted inclined (45^{o}) at a spacing of 1mx1m. Proper planting and ridging is indispensable. All this varieties are under production (EARO, 2004).

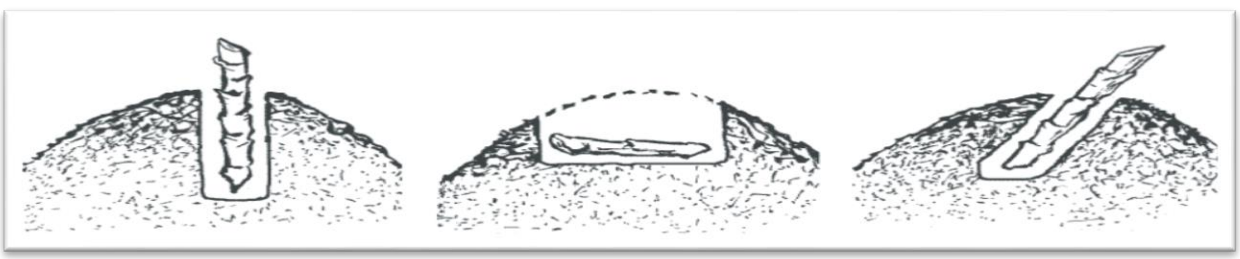
Cassava culture varies with the purposes for which it is grown. Cassava is either planted as a single crop or intercropped with maize, legumes, vegetables, rubber, oil palm or other plants. Mixed planting reduces the danger of loss caused by unfavorable weather and pests by spreading the risk over plants with different susceptibilities.

iii. Propagation

For agricultural purposes, cassava is propagated exclusively from cuttings. It is raised from seed only for the purpose of selection Seeds produce plants with fewer and smaller roots than those of the parents and as many as half of the seeds may fail to germinate. On the other hand, cuttings taken from the stalks of the plant take root rapidly and easily, producing plants identical in character with the parent plants.

iv. Methods of Planting

Cassava stem cuttings may be planted vertically, at an angle or horizontally, depending on soil types as shown below



v. Fertilizers

Nutrients or fertilizers are used and application quantity and methods are important factors in cassava production. Under commercial conditions cassava extracts from the soil the following nutrients: 253Kg N/Ha; 28kg P/Ha; 250kg K/Ha; 42kg Ca/Ha; 29kg Mg/Ha. Fertilizer applications should be made only as a supplement to the nutrients already found in the soil at planting time. The fertilizer should be banded at one or both sides of the rows. A 12-12-18 complete fertilizer is recommended at rates of 450-672kg/ha.

Soils containing less than 0.06% of exchangeable K should be supplied with 90-120 kg/Ha of K2O. Excessive N applications will promote foliage growth at the expense of root production. A urea application of 100-150 kg/Ha is recommended at post-planting time if N deficiency symptoms are observed in the foliage.

vi. Irrigation

Irrigation (water requirements of the plants), requires 150 cm of water well-distributed throughout the year.

vii. Weeding

Weeds are best controlled through a proper rotation scheme and with proper pre-planting cultivation to prevent germination of weed. Pre-emergence herbicides are very effective to control weeds in cassava. Weeding is recommended at 4-5 weeks after planting and at 8 weeks after planting until crop ground-cover is completed.

viii. Harvesting

Most cassava is harvested by hand, lifting the lower part of stem and pulling the roots out of the ground, then removing them from the base of the plant by hand. The upper parts of the stems with the leaves are removed before harvest. Levers and ropes can be used to assist harvesting. A mechanical harvester has been developed in Brazil. It grabs onto the stem and lifts the roots from the ground. Care must be taken during the harvesting process to minimize damage to the roots, as this greatly reduces shelf life. During the harvesting process, the cuttings for the next crop are selected. These must be kept in a protected location to prevent desiccation.

ix. Yield

Cassava is not usually grown on soils where it would be most productive - that is, the light sandy loams, fertile and deep, which are reserved for other crops less tolerant of poor soils. When cassava is grown by traditional tropical methods, yields lie between 5 and 20 tons per hectare, varying with the region, the variety, the soil and other factors. However, when the crop is given more attention, yields of 30 40 tons per hectare are obtained. It has been reported that it is normal for some varieties, under appropriate cultivation methods, to yield over 60 tons per hectare.

Post harvest Handling, Storage and Utilization

Cassava undergoes post-harvest physiological deterioration, or PPD, 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. Hirandan and Advani (1955) measured 12 - 14% post-harvest weight losses in India for chips stored for about five months. Killick (1966) estimated for Ghana that 19% of the harvest cassava roots are lost annually, and Nicol (1991) estimated a 15 - 20% loss of dried chips stored for eight months. Pattinson (1968) estimated for Tanzania a 12% weight loss of cassava chips stored for five months, and Hodges et al. (1985) assessed during a field survey post-harvest losses of up to 19% after 3 months and up to 63% after four to five months due to the infestation of Prostephanus truncatus (Horn). In Togo, Stabrawa (1991) assessed post-harvest weight losses of 5% after one month of storage and 15% after three months of storage due to insect infestation, and Compton (1991) assessed weight losses of about 9% for each store in the survey area in Togo. Wright *et al*. (1993) assessed post-harvest losses of chips of about 14% after four months of storage, about 20% after seven month of storage and up to 30% when P. truncatus attacked the dried chips. In addition, estimated that about 4% of the total national cassava production in Togo is lost during the chip storage. This was about equivalent to 0.05% of the GNP in 1989.

Processing

According to O'Hair (1995**),** the shelf life of cassava is only a few days unless the roots receive special treatment. Removing the leaves two weeks before harvest lengthens the shelf life to two weeks. Dipping the roots in paraffin or a wax or storing them in plastic bags reduces the incidence of vascular streaking and extends the shelf life to three or four weeks. Roots can be peeled and frozen. Traditional methods include packing the roots in moist mulch to extend shelf life.

Dried roots can be milled into flour. Maize may be added during the milling process to add protein to the flour. The flour can be use for baking breads. Typically, cassava flour may be used as partial substitute for wheat flour in making bread. Bread made wholly from cassava has been marketed in the U.S.A. to meet the needs of people with allergies to wheat flour. Fresh roots can be sliced thinly and deep fried to make a product similar to potato chips. They can be cut into larger spear-like pieces and processed into a product similar to french fires.

Roots can be peeled, grated and washed with water to extract the starch which can be used to make breads, crackers, pasta and pearls of tapioca. Unpeeled roots can be grated and dried for use as animal feed. The leaves can add protein to animal feed. Industrial uses where cassava is used in the processing procedures or manufacture of products include paper-making, textiles, adhesives, high fructose syrup and alcohol.

Processing Techniques (Manual Peeling, Washing, soaking and sun drying)

2.4.13. Disease and Insect Pest

In Africa the cassava mealybug (*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 Biological Control Centre for Africa of the IITA. The Centre investigated biological control for cassava pests; two South American natural enemies *Apoanagyrus lopezi* (a parasitoid wasp) and *Typhlodromalus aripo* (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. This mutated virus has been spreading at a rate of 50 miles per year, and as of 2005 may be found throughout Uganda, Rwanda, Burundi, the Democratic Republic of the Congo and the Republic of the Congo.

Table 3: Lists of Bacterial diseases

Bacterial diseases	
Bacterial blight	*Xanthomonas axonopodis* pv. *Manihotis*

Bacterial angular leaf spot	*Xanthomonas campestris* pv. *Cassava*
Bacterial stem gall	*Agrobacterium tumefaciens* Biovar 1
Bacterial stem rot	*Erwinia carotovora* subsp. *Carotovora*
Bacterial wilt	*Erwinia herbicola*

Table 4: Lists of Viral and mycoplasma like organism

Viral and mycoplasma like organism [MLO] diseases	
African cassava mosaic	African cassava mosaic virus
Antholysis	MLO
Cassava common mosaic	Cassava common mosaic virus
Cassava frogskin	Phytoreolike virus (probably)
Cassava green mottle	Cassava green mottle virus
Cassava symptomless infections	Cassava American latent virus Cassava Ivorian bacilliform virus
Cassava vein mosaic	Cassava vein mosaic virus
Indian cassava mosaic	Indian cassava mosaic virus
Witches' broom	MLO

Table 5: List of Cassava's fungal Diseases

Fungal diseases	
Anthracnose	*Colletotrichum gloeosporioides* *Colletotrichum gloeosporoides f.sp. manihotis* *Glomerella cingulata* [teleomorph] *Colletotrichum graminicola* *Glomerella graminicola* [teleomorph]
Armillaria root rot (shoestring root rot)	*Armillaria mellea*

	<u>*Rhizomorpha subcorticalis*</u> [anaomorph]
Black root and stem rot	<u>*Scytalidium*</u> sp. <u>*Hendersonula toruloidea*</u> [syanamorph]
Blight leaf spot	<u>*Cercospora vicosae*</u>
Brown leaf spot	<u>*Cercosporidium henningsii*</u> <u>*Mycosphaerella henningsii*</u> [teleomorph]
Cassava ash	<u>*Oidium manihotis*</u>
Concentric ring leaf spot	<u>*Phyllosticta manihotae*</u> <u>*Phyllosticta manihoticola*</u>
Dematophora root rot (Rosellinia root rot)	<u>*Dematophora necatrix*</u> <u>*Rosellinia necatrix*</u> [teleomorph]
Diplodia root and stem rot	<u>*Diplodia manihoti*</u>
Fusarium root rot	<u>*Fusarium oxysporum*</u> <u>*Fusarium solani*</u> <u>*Nectria haematococca*</u> [teleomorph]
Phytophthora root rot	<u>*Phytophthora cryptogea*</u> <u>*Phytophthora drechsleri*</u> <u>*Phytophthora erythroseptica*</u> <u>*Phytophthora nicotianae var. parasitica*</u>
Pythium root rot	<u>*Pythium*</u> spp.
Rigidopurus root rot	<u>*Rigidoporus microporus*</u> = <u>*Rigidoporus lignosus*</u>
Rust	<u>*Uromyces*</u> spp.
Sclerotium root rot (southern blight)	<u>*Sclerotium rolfsii*</u> <u>*Athelia rolfsii*</u> [teleomorph]
Superelongation	<u>*Sphaceloma manihoticola*</u> <u>*Elsinoë brasiliensis*</u> [teleomorph]
Verticillium root and stem rot	<u>*Verticillium dahliae*</u>
White leaf spot	<u>*Phaeoramularia manihotis*</u>

Source: Wikipedia, 2014

2.4.14. Post harvest Disease of Cassava

There are two major postharvest fungal diseases of cassava. Botryodiplodia rot invades the pulp beneath the skin, initially developing white mold that later becomes dark grey (Snowdon, 1992). Fusarium rot also grows on the pulp, causing a brown discoloration. Other pathogens reported by Snowdon (1992) include: Aspergillus rot bacterial soft rot, Mucor rot, Phytophthora rot, Rhizopus rot, Sclerotium rot and Trichoderma rot.

CHAPTER-5

Major Corm Crops grown in Ethiopia

The principal corm crops that are produced in Ethiopia are:

- Enset (Ensete ventricosum)
- Taro (Colocasia spp)
- Tania (Xanthomonas sagthyfolium) and
- Celeriac (Apium graveolens)

5.1. Enset (Ensete ventricosum)

Introduction

Enset (Ensete ventricosum) is cultivated as a food and fibre crop only in Ethiopia, particularly in the southern, south western and western parts. The Ethiopian highlands to be the primary center of origin for Enset agriculture. For thousands of years it has been used as a food crop in Ethiopia where it was once domesticated. Enset is an important staple and co-staple crop for over 20% of the Ethiopian population living in the southern and southwestern parts of the country, including many ethnic groups.

Based on the level of priority given to enset cultivation in different zones and regions, three enset based farming systems have been identified. Enset is the main food source in Gurage, Kembata, Sidama, Gedeo, Hadya, Arero, Keffa and Sheka zones. It is the second important crop as co-staple food in Wolaita, Gofa and Yem special weredas. It is planted as the third most important food crop in Wollega, Illubabor and in some parts of Southern region.

Ensete consists of three kinds of stems

1. **Pseudostem** (false stem), which is made up of a system of tightly clasping or loose overlapping leaf sheaths
2. **Underground stem** (corm) which has three distinctive outer, middle and inner layers
3. **True stem** which remains short at the base of central shoot from which the infloresence is initiated

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 southwestern 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 pseudo stem and an underground corm called "Hamicho"

5.1.1. 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 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.

5.1.2. The food uses of Enset

The major foods obtained from Enset are **Kocho**, **bulla** and H**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:

a. Scraping the leaf sheath, peduncle, and grated corm into a pulp;

b. Squeezing liquid containing a starch from the pulp;

c. Allowing the resultant starch to concentrate into a white powder; and

d. 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.

Hamicho

Hamicho 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 Hamicho production.

5.1.3. Non-food uses of Enset

Enset provides fiber as a byproduct 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 600 tons of Enset fiber per year is 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 store kocho 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).

5.1.4. 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.

5.1.5. Diseases of Enset

Diseases are caused by bacteria, nematodes, fungi, and viruses. Bacterial wilt, caused by the bacteria 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.

5.1.6. 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. 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:

- ❖ Adequate availability of food in line with present population and demographic growth;
- ❖ The nutritional adequacy of food intake;
- ❖ Annual stability of the food supply;
- ❖ Access to food (through production or the market) and
- ❖ 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 densest rural populations of Ethiopia are located in regions practicing Enset based farming in the southwestern 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 agro-ecology and inputs.

5.2.Taro (Colocasia spp)

Introduction

Colocasia esculenta (commonly known as taro) and Xanthosoma sagittifolium (Tania) are the most important of the edible aroids. Colocasia esculenta is considered by most botanists to be a polymorphic species with several botanical varieties. The two main varieties are, esculenta var. esculenta which produces a large edible main corm and few lateral cormels (commonly between 4 and 10) and C. esculenta var. antiquorum which produces a small or medium size corm and a large number of edible cormels (15-40).

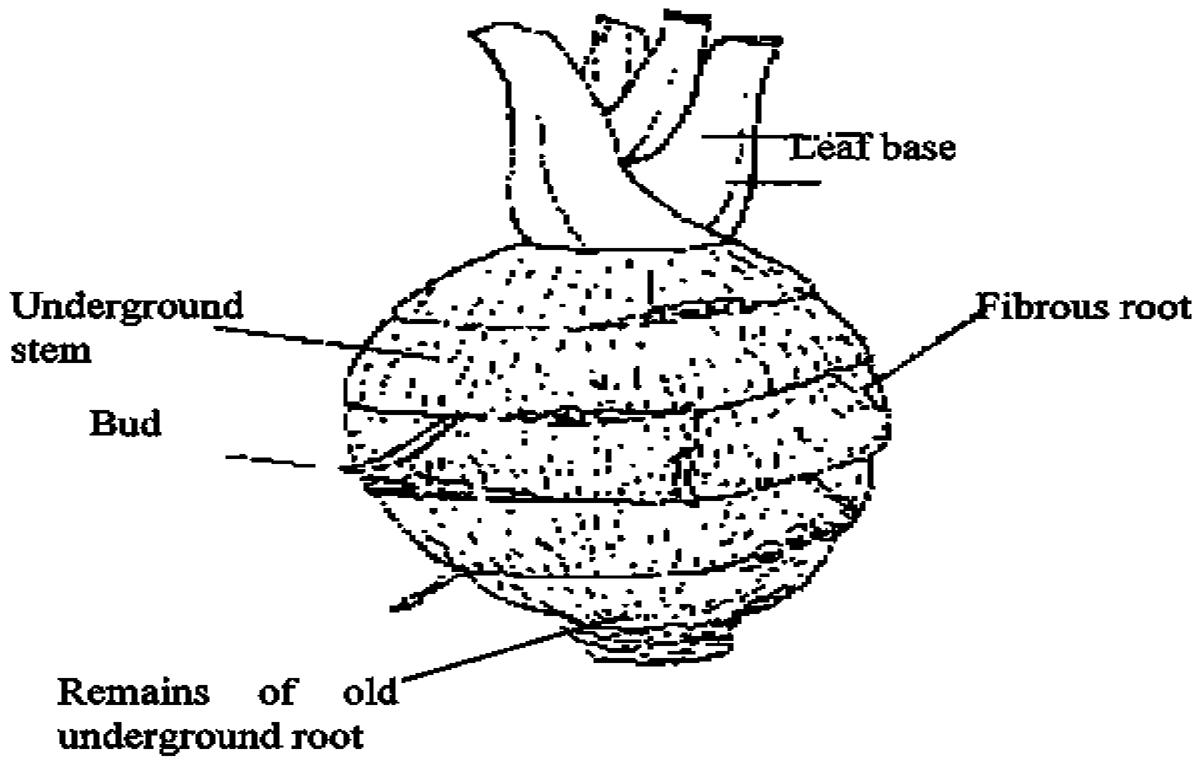


Figure : General view of a taro corm (FAO, 1987)

Table1 : The chemical composition of Taro and Tania (% wb)

Constituent	Taro	Tania
Moisture	63 – 85	70 – 77
Carbohydrates	13 – 29	17 – 26
Protein	1.2 - 3.0	1.3 - 3.7

Fat	0.16 - 1.18	0.2- 0.4
Crude fibre	6.60 - 1.18	0.6 - 1.9
Ash	0.60 -1.3	0.6 -1 .3

Now that many commercial growers and home gardeners are starting to make plans to re-establish and fix up their gardens and taro patches, it may be a good time to go over some of the recommended cultural practices for taro production developed by researchers at the University of Hawaii. Taro is a very hardy and resilient vegetable which when unwanted in vegetable fields may turn into a bothersome weed. In fact cocoyam, which is a close relative of taro, and consumed by the Latin and Caribbean population, was about the only vegetable that survived the devastating freeze that hit South Florida on the early morning of December 26, 1989. A loss for 1990 in Dade County accountable to the vegetable freeze was in the hundreds of millions of dollars. The undamaged cocoyam corms (the underground storage organ, which is actually stem tissue is called a corm) lying below the soil level, however, re-sprouted once the temperatures rose and plants which were ready for harvest were dug a few months later. Similarly in the Pacific Islands, taro, and other relatives of the aroid family are often the first crops grown in islands and atolls which have been hit by hurricanes or flooding tidal waves. The fast recovery of aroids in areas affected by hurricanes or high tides is a sign of their adaptability to flooding, and also to salty irrigation water. This resiliency despite the recurrence of natural disasters, may explain in part the spiritual symbolic value that taro represents to the Hawaiian heritage.

5.2.1. Taro Varieties

Taro can be cultivated under both wetland (paddy-taro) and dry land (upland) conditions. Some varieties do well under both types of culture. Important local varieties include Bun Long or table taro mostly grown in the Big Island for fresh market and making chips; Lehua Maoli for poi taro with most of the state's production concentrated in Kauai; Niue or Samoan Taro; and dasheen or araimo for Japanese taro. Dasheen varieties include Tsurunoko, Miyako, and Akado. The wetland or lo'i system, which takes advantage of taro's flood tolerance, was apparently developed early on by Hawaiians to eliminate weed competition and to lower the growing temperature of the corms (the underground storage organ which is actually an underground stem tissue.

5.2.2. Propagation

For propagation, taro cuttings/hulis are used. The hulis are a part of the stem about 12-18 inches long attached to a 2-3 inch section of the corm. The cuttings are planted vertically with soil covering about one-third to half of the standing huli. Since hulis are difficult to obtain, commercial growers or avid gardeners need to establish their own nurseries with their favorite variety. Initial hulis can be obtained from fellow growers, and also from the Cooperative

Extension Service. Several community organizations throughout the state, such as the Ho'okahe Wai, Ho'oulu 'Aina, a charitable organization in Honolulu, are also making efforts to collect old taro varieties to maintain them in cultural gardens throughout the state. Make sure that you start with disease-free propagating material by closely inspecting each cutting, washing with potable water, soaking hulis in a 10% bleach solution for 30 seconds, and by storing the hulis in a dry, cool, and well-ventilated area for 3 to 5 days before planting to allow for old wounds to heal.

In the dry-land system of production hulis can be planted by hand or with a modified vegetable transplanter. Plants are spaced 18 inches apart, and rows are spaced 3-4 feet apart. Research in Hilo indicates that liming to a soil pH above 6, may result in lower incidence of corm rots, and improved plant vigor. Lime preferably after field plowing and for best results, at least a month before planting. The early liming treatment will allow for the proper soil reaction and rise in pH by the time the taro is ready to be planted. Commercial taro fields in Hawaii, are heavily fertilized compared to traditional practices in other Pacific Islands or in Africa. In high rainfall areas apply a total of 2000 lbs of 23-0-36 fertilizer per acre divided in six equal doses beginning at planting, and the rest at five monthly intervals. In addition, at pre-plant apply 2500 pounds per acre of a 0-45-0 fertilizer. Costly soil amendments such as dolomite and hydrated lime are normally not recommended considering the economics of commercial taro production in Hawaii. Gardeners may broadcast before planting 3 pounds of a 10-20-20 fertilizer, and then side-dress 1 pound of a 16-16-16 fertilizer at two, four, and again at 6 months after planting on a 100 square foot area.

5.2.3. Harvest and Post Harvest Practices

Most taros will mature in 6 to 10 months. Corms in the garden can be dug with a shovel. Modified potato harvesters are available to dig taro under commercial conditions. Such a machine has been employed for demonstration purposes by the Cooperative Extension Service in Molokai. In commercial packing sheds of South Florida the corms are conveyed to a machine with circular brushes which removes the soil, washes the corms, selects by size and the corms are then packed with the help of hand labor. A typically-sized machine packs eighty 50-pound boxes per hour with the help of seven laborers. At this point the product may be shipped to a buyer for placement in a cold room. The recommended temperature for prolonged storage is 45-50 F with a relative humidity of 85. Luau leaves can be harvested at any time during the growth of taro. Only young taro leaves are used for luau. Corms yields will be reduced if more than 3 leaves are picked per-Plant.

5.2.4. Pests and Diseases

Despite its hardiness, taro is susceptible to attack by some important pests and diseases. Slugs may damage corms creating wounds which provide entry of secondary disease organisms. Weed-free fields and hilling may help reduce slug infestations. The golden mystery snail has become a threat to taro production in Hawaii. Yield reductions caused by the golden mystery snail can reach in excess of 60% from feeding in both the foliage and the corm. Hand-picking, irrigation with saline water, and copper based pesticides are among the practices currently being tested for control of this pest Cultural practices to avoid incidence of diseases in taro include the use of disease-free propagating material, avoiding contaminated fields, eliminating diseased plants growing in the field, and increased spacing at planting to improve ventilation. Weeds may also reduce taro yields by competing for space and nutrients. To prevent yield losses from weed competition maintain taro free of weeds during the first three months after planting.

5.2.5. Value of Taro

The value of taro production in Hawaii has increased over the past few years from a farm-gate value of $1.7 million in 1987 to $3 million in 1991. Hawaii taro farmers have an opportunity to capitalize on this trend of increased popularity of taro products by closely working with their present customers, and by establishing new markets with currently unknown buyers. Commercial growers should make careful marketing plans, and identify potential buyers even before the first huli is planted. Costs of production for taro in 1989 were estimated at $6,175 per acre with labor accounting for 49% of total costs, and machinery and equipment for about 23% of the total.

Home-gardeners, growing taro for family reunions, and for self-consumption can plant taro any time of the year. For home-gardeners and part-time farmers taro is a low-maintenance crop that will maintain a ground cover in the field to reduce soil erosion, and will provide a bountiful harvest at 8 to 10 months after planting. Nutritionally the root crop is rich in fiber, calcium, potassium, iron, vitamin A, vitamin B1, vitamin B2, and vitamin C. The quality of the diet of indigenous people living in the Pacific Islands has generally decreased when the consumption of taro has been replaced by other sources of carbohydrates such as white bread. In Hawaii and in other regions taro also has a rich cultural and spiritual value. Traditionally it was prohibited to argue when a bowl of poi was placed on the dinner table, and the kupunas would uncover the poi bowl to end family disputes. Today, that cultural heritage is kept alive by teaching the younger generations about the old spiritual ways, and keeping a taro patch in the field or in the garden is still an easy way to stay in touch with nature.

- **Tania (Xanthomonas sagthyfolium) and Celeriac (Apium graveolens) your assignment!!!**