COURSE GUIDE

CRP 313
PERMANENT CRPS PRODUCTION

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MAIN COURSE

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MODULE 1

UNIT 1: FACTORS AFFECTING PERMANENT CROP PRODUCTION

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1.0 INTRODUCTION

Crops are domesticated plants that we grow on our farms, orchards and gardens. These crops vary in their nutritional requirements, soil and weather needs; susceptibility to pests and diseases, etc. Similarly, the parts of the crop that meet man's need equally vary.

What man needs from the crop may be the tuber, leaves, fruits or even the stem. Therefore, the cultivation and production of crops are based on principles which have inbuilt guidelines that meet the nature of each crop type.
In this unit therefore, you will read and study the general principles of crop production. Some of the factors that influence crop production that you will deal with include: environmental, soil/edaphic and economic factors that you need to put into consideration before you embark on a particular crop production. In addition, pests and diseases constitute threat to your production efforts; they therefore need to be considered before you finally decide on what crop(s) you will produce on your farm, orchard or garden.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Enumerate the factors that influence the production of crops;
- Distinguish between climatic and edaphic factors in crop production;
- Identify economic factors which influence the types of crops you will grow in your area;
- Distinguish between climate and weather;
- Describe crop types that are grown in your community and area;
- Associate particular crop (types) to particular areas and climatic conditions.

3.0 MAIN CONTENT

In this unit you will read about the major factors that influence farmers and agriculturists in the selection, cultivation and production of crops in any given environment. Here you will also read about climatic factors, edaphic/soil, and economic variables which influence the nature of crops that are found in particular area and zone of the world. For example, the crops you find in the southern parts of Nigeria are different from those you find in the northern areas. Similarly, crops grown in the tropics are different from those of the sub- tropics as the Mediterranean or the temperate regions of the world.

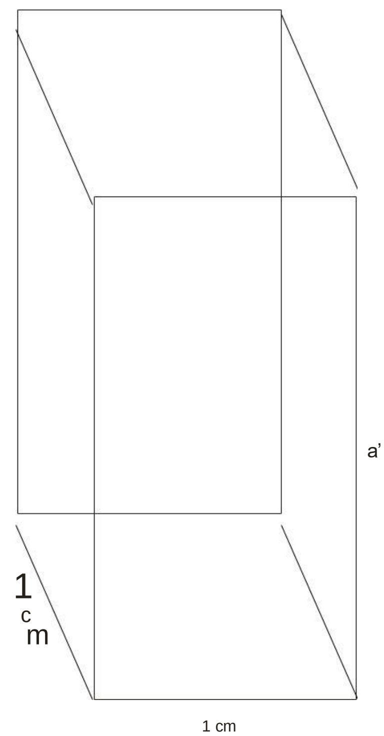
3.1.0 Climatic Factors

The average weather conditions of a place over a period of thirty five to forty (35- 40) years is called climate. The major elements that make up the weather are: rainfall/precipitation, temperature, relative humidity, wind, sunlight and solar radiation. The values of the above listed variables at any particular times constitute the weather of the place.

3.1.1. Rainfall /Precipitation

The collection of water vapour (moisture) in the sky in the form of cloud leads to the formation of water droplets in the cloud. The cloud later releases it's water droplets to the earth surface in the form of precipitation. Collection of precipitations leads to rainfall. The total rainfall of any place is the total amount of precipitation that a place gets during a fiscal year of 365 days. It is measured

Fig. 1.1: Illustration of a'cm of rainfall (after Ogunrinde, Sam.I; 1996)



in centimeters per square centimeter

of land area. "a" cm of precipitation is illustrated in figure 1.1. "a" cm may be distributed among the days of the fiscal year in different patterns. In other words, the rainfall may occur during only three of the twelve months of the year. These months may be: January to March or September to November or June to September. In the alternative, the rains may be evenly distributed within the twelve (12) months of the year. In some areas, the rains for the year may fall within just one month of the year. Four distribution patterns are contained in figure 1.2.

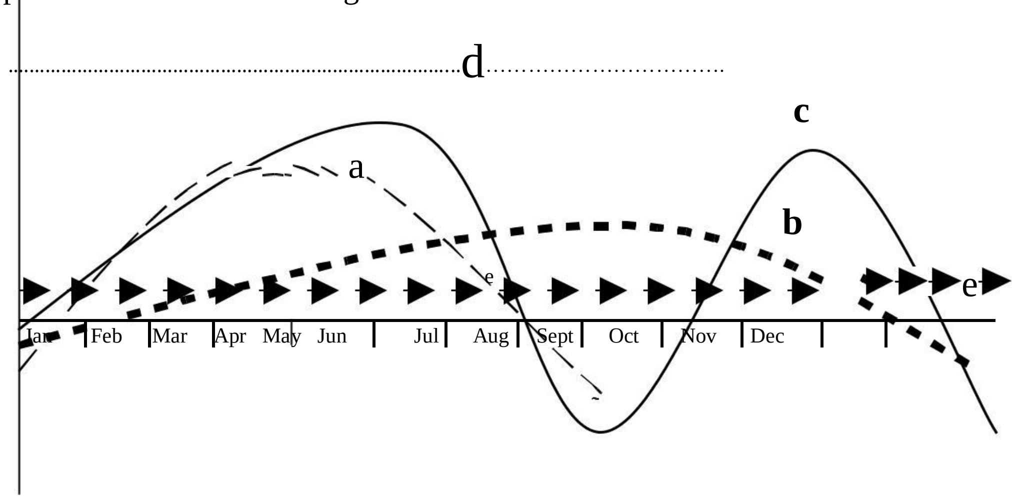


Figure 1.2: Illustration of rainfall patterns in a fiscal year (after Ogunrinde, Sam.I; 1996).

Rainfall in pattern'd', is evenly distributed throughout the fiscal year. Pattern 'b' on the other hand has a peak in August/September. Pattern 'c' has two peaks with a trough in August/September.

Pattern 'e' has equal distribution throughout the fiscal year but the total precipitation (rainfall) is much lower than'd' that has similar distribution. Indeed, the total for pattern 'e' is the lowest.

Crops vary in their requirements for water at different stages of the crop growth and production. While some crops require a large amount of water, some may not withstand nor survive when the precipitation is high.

3.1.2 Solar radiation--sunlight

The solar system is made up of the sun at the centre and satellite objects rotating round it. The sun which is at the centre is a very large object that is burning away every second. The heat and light generated by the burning sun is emitted to the circling satellite objects round it. The earth which is the third object in the solar system and the second to the sun derives its light and heat energy from the sun.

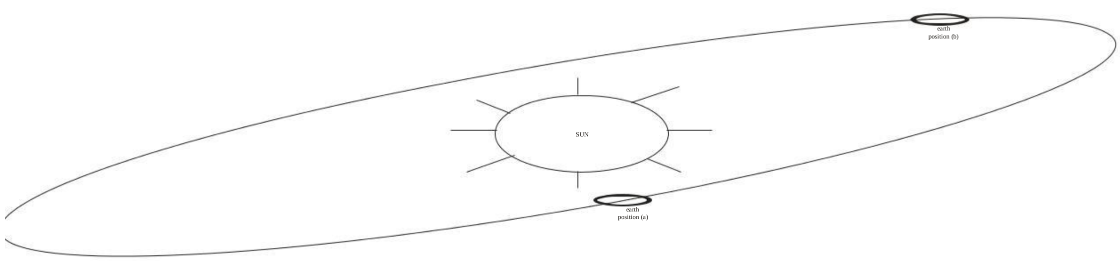


Fig. 1.3: Illustration of the earth in its orbit round the sun (after Ogunrinde, Sam. I.; 1996)

The earth goes round the sun in an orbit that has the shape of an eclipse as illustrated in figure 1.3. The amount of heat and length of the day varies with the exact positions of the earth in its orbit round the sun. When the orbit is closer to the sun, the amount of heat that the earth receives is higher while length of day is shorter than when the earth is at the distal end of the eclipse. Also, as the earth rotates on its own axis to give day and night, the orbiting of the earth round the sun gives rise to the seasons of the year-- rainy and dry seasons (in the tropics); while in the sub-tropical areas, there are four seasons – summer, fall/autumn, winter and spring. Similarly, the length of day varies with the seasons. The length of the day is determined by the time lag (in hours and minutes) between the sun rise in the east and when it sets in the west for a particular day.

Some crops are sensitive to day-length and the amount of heat that is available in the environment. Some crops require longer nights to initiate the process of flowering while some are day-length neutral. Heavy clouds reduce the available light for light-reactions and photosynthesis. Therefore the amount of food that a particular crop can produce during its growing season is a function of the sunlight available for the crop, and other variables – as available nutrients, available soil-water, foliage, presence/absence of diseases.

Low temperatures lead to cold. Cold leads to frost. During frost, most crops die because of the roots inability to absorb nutrients that are contained in the solid (frozen) water. Frost- bite does physical damage to exposed shoots and leaves. Nutrients pump in plants and crops gradually grind to a halt during very low temperatures. Similarly chemical reactions taking place within the crops are affected by temperatures.

3.1.3 Temperature

The resultant effect of solar radiation on the earth's surface is the temperature which is measured in degrees on **Celsius** or **Fahrenheit** scale. During the day, when the rays of the sun alight on the direct surface of earth, the temperature is often higher than what it is in the night. During the night, the sources of heat are: reflections, refractions and radiation/emissions from heated earthly bodies. Heat and temperature affect the rate of transpiration. Where available soil-water is not adequate, high rate of transpiration can lead to (temporary to permanent) wilting.

3.1.4 Relative Humidity

Relative humidity is the measure of moisture present in the air (atmosphere) compared with the maximum moisture (saturation moisture) that the air can take at that particular temperature. Relative humidity affects the assimilation, absorption, transportation and transpiration reactions taking place in crops. Most crops perform optimally when the relative humidity is low. Disease causing organisms perform optimally when the relative humidity is high. Thus high relative humidity is not good for optimum crop performance.

3.1.5 Winds

All crops and indeed all living things need air. Air in motion is called wind. The wind may be mild or strong. Strong winds as storms and cyclones cause damage to crops depending on the nature of the crop. Tender shoot crops as rice, wheat, oats, and rye easily log(fall off) with the slightest storm . In plantation crops like rubber, banana, plantains, strong winds cause heavy damage.

Gentle wind (breeze) is good for crops as it encourages good transpiration

3.2.0 PESTS and DISEASES

Crops respond to other environmental variables that do not constitute climatic elements. These variables include pests and diseases.

3.2.1 Pests

Pests are small animals that damage crops either on the field when growing or cause damage to crop products when they are in the store. Pests range from small insects as bugs, butterflies, locusts, midges, aphids, caterpillars to medium to large animals as rats, rabbits, grass-cutters and antelopes. Some underground worms attack crop roots e.g. nematodes. They all cause physical damage to crops – roots, shoots, leaves, flowers, tubers, stems and seeds/fruits.

3.2.2. Diseases:

Diseases are caused microscopic organisms in crops. Diseased crops are crops that cannot perform all the necessary biological functions at the optimal level of the crop. Oftentimes, the crops exhibit symptoms of stress dysfunction due to the disease. In some cases, dysfunction may be due to non-availability of some necessary nutrients.

3.2.3 Causal agents of crop diseases

Three major groups of organisms are responsible for crop diseases. These are: viruses, bacteria, and fungi.

(i) ***Viruses:*** They have no definite shape. They change forms and cause malfunction in crop nucleus, cytoplasm, protoplasm and tissues. This malfunctioning is through change in the original nature of the crop plant so affected. They attack crop chromosomes and D.N.As to effect changes in their chemical nature to thus change the pathways and messages of life processes in the affected crop.

There are different types of viruses. All the types are very difficult to control because they constantly change form. They are not capable of independent existence i.e. they cannot live on their own – i.e. they cannot perform basic biological activities by themselves, as they do not possess all the parts that perform these basic functions. However, as they gain entrance into any living tissues, they take over all the biological functions and distort as many of the processes as possible. They change the colour, shape and performance of the affected parts. Examples of virus attack on crops are: cassava mosaic virus (CMV) , and rosettes in groundnuts.

(ii) ***Bacteria***: These are living microorganisms that attack crops. Once they attack a crop, they rapidly multiply and make colonies on the crop parts so attacked. The parts so affected become damaged. Sometimes the damaged parts cannot perform their normal function. In very common cases, the resultant effect is the death of the crop parts so affected. Crop products affected by diseases are not acceptable to most buyers and consumers of crop products.

The bacteria can be divided with two major groups:
Aerobic – these need oxygen to perform Anaerobic
– they do not need oxygen to perform.

(iii) ***Fungi***: Fungi cannot manufacture their food needs. They live on other plants albeit crops to perform their normal biological activities. They attack crops to kill the parts so affected in order to feed on the dead rotten parts or they feed directly from the nutrients that the crops require or feed on the food reserves of the crops.

They are of different types. They all thrive better when the relative humidity is very high. This is because the available moisture assists in the rapid decay of the affected parts e.g. black pod disease of cocoa.

. Disorders may also be caused by lack of necessary nutrients in the soil.—such disorders may be called ‘nutritional diseases’

3.3.0 Edaphic / Soil Factors

Soil is the medium on which crops grow and maintain their existence – in other words, soil forms the home of crops. Since soil varies in its composition – component constituents, its nature and reactions, the crops that do well in the different types of the soil also vary. All plants and indeed crops need food to grow. Crop food in the soil is not an elaborated food as you and I put on our dinning tables. Crops like other plants manufacture their food from simple chemical elements through the use of sunlight and other energy sources. Tissue analysis of crops reveal that crops need Carbon, Nitrogen, Phosphorus, Potassium Magnesium And Iron, Calcium, Sulphur in fairly large quantities. On the other hand, some elements as zinc, molybdenum manganese, boron, are needed in small quantities are therefore called micro / trace elements in crop nutrition. Most of these elements are often present in the soil. However, they are not always available to the crops. The availability (rate of release) to the crops depend on very many variables as: soil acidity, soil water, soil air, and other soil properties (soil physics) as texture, structure, porosity, soil-water-air mixture, etc. In the following sub-units, you will read about some of the above identified variables of the soil.

3.3.1 Soil Fertility

A soil that contains large quantities of crop nutrients is said to be fertile. As mentioned earlier, a soil that is rich in macro and micro – elements in required quantities by the crops is a good soil for crop production. The most crucial of these elements include: N, P, K, Fe, Mg, Mn, Mo. and Zn. In all, sixteen (16) chemical elements are needed for crop growth and development. These Are Nitrogen, Phosphorus, Potassium, Calcium, Sulphur, Magnesium, Boron, Manganese, Zinc, Iron, Molybdenum, Sodium, Copper, Chlorine, Aluminum, And Silicon. Six (6) other elements are known to stimulate crop growth under certain conditions – these are: cobalt, arsenic, selenium, lead, lithium, and vanadium. Carbon and additional oxygen are drawn from the air. Oxygen and hydrogen are supplied in water. All the above elements can be present in the soil, the rate at which they are made available to the crops depend on the soil acidity.

3.3.2 Soil Acidity

Soil acidity is the measure of hydroxyl ion concentration in the soil. When the concentration of hydrogen ions is higher than the hydroxyl ions, the soil is said to be acidic. When the concentrations of both the hydroxyl and hydrogen are the same, the soil is said to be neutral.

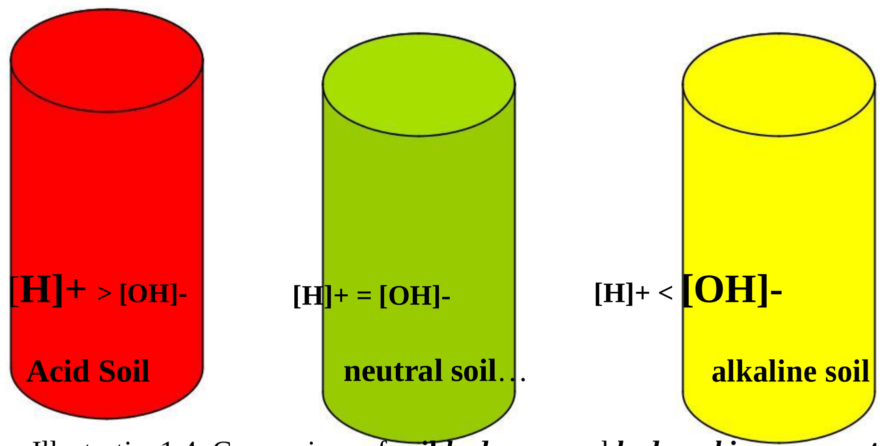


Illustration1.4: Comparison of **soil *hydrogen*** and ***hydroxyl* ion concentrations** (after Ogunrinde, Sam, I.; 1996)

When the soil is acidic, some elements are easily released to the crops while some are tied up. A reversed condition occurs if the soil is alkaline. When the soil pH is 7, the soil is said to be neutral. When the soil pH is less than 7, the soil is said to be acidic when the pH is higher than 7, the soil is said to be alkaline. Crop nutrition is optimal when the soil pH is neutral.

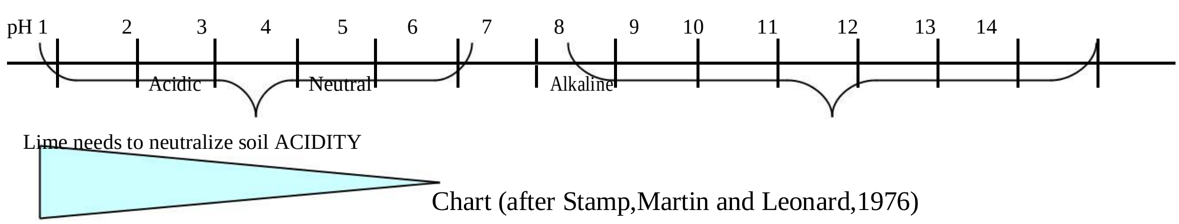


Chart (after Stamp,Martin and Leonard,1976)

Acidic soils are treated with lime (crushed limestone (Ca C03)), burned lime (Ca0) or hydrated lime Ca $(OH)_2$. The active element in all the cases is the calcium. The higher the acidity level, the greater is the quantity of lime required to neutral the soil. Soil acidity can also be treated with organic manure.

3.3.3 Soil Physical Characteristics

Soils are made of physical particles of rocks and minerals matter. The level of integration of the particles determines the nature of soil. The rock particles are classified into aggregates as small stones, sand, coarse particles and fine particles (silt and clay). Similarly, the broken down organic matter can be classified into groups based on size. The organelle is the fine particle size usually called organic matter colloids. Since reactions take place at the surfaces of the particles, the available soil nutrients will depend on the particle surface area compared with the mass / volume of the particle concerned.

Soil particles come together to form soil aggregates of different shapes and forms. These aggregates determine the air-space and water spaces available in the soil. These latter conditions determine the suitability of the soil medium for crop adaptations. For instance, porous soil has large air spaces and thus water spaces in the aggregates. Porous soil in turn allows free flow of water particles through the soil with little or nothing retained in the soil for crop use later. This type of soil aggregate encourage leaching clayey soil on the other hand has very small air spaces and water in its aggregates. Water does not flow through it easily. Besides, whatever water is available is held very tightly to the surface of the clay particles at the expense of the crops. Because of slow downward flow of water (percolation) this type of soil aggregate encourages heavy surface run-off – surface erosion. Physical characteristics of the soil determine which types of soil are prone to flood, swamp, erosion, leaching, etc. These in turn determine what types of crops the soil can support.

Self – Assessment Exercise (SAE)

1. Identify and explain five elements of climate that affect the production of crops.
2. Identify the major elements of soil that affect the selection of crops produced in your Local Government area.
3. What can you do to reduce the acidity of the soil in your area?

3.4 The Nature of Crops

Crops vary in their needs for water, nutrients, sunshine and day length, and agronomic management strategies. For example, water is very critical in the growth and production of sugar care, bananas, plantains, rubber and to some extent, oil palm and pawpaw. Whereas in the production of cotton, groundnut and beans (legumes in general), sunshine and day-length are the most critical. Therefore, in the selection of what to grow, you must bear in mind the variables which encourage the crops to perform optimally. Unless, you are prepared to create a micro-climate or environment for the crops of your choice, you should as a matter of importance check through the list of crops that perform optimally in the (selected) environment where you intend to grow the crops.

For example, swamp rice requires pre-nursery and nursery operations in the production of the rice seedlings; upland rice does not require pre-nursery and nursery operations. Most tuber crops do not perform well in swamps or water logged areas. Similarly, most cereals require heavy sunshine, moderate water / rainfall and well drained soils. The following two units will deal extensively on the nature and types of crops we grow in our environment.

3.5.0 Economic Factors

Besides the innate characteristics of the crops and the environmental factors as climate and soil, other variables that influence permanent crops production are the economic factors. Economic factors include such variables as labour, supply of tools and materials, market forces as supply, demand and price.

3.5.1. Technical Factors

Supplies of inputs as seeds, seedlings, improved stock are considered very important in any production activity in agricultural enterprise.

Sources of energy for farm work include human beings (you and I), machines as: tractors, ploughs, small machines, motors, solar energy, wind energy, water energy, animal power (as bulls, work horses and donkeys), electrical energy, chemical power, etc. The supply of the above forms of power in right quantities and qualities at the appropriate time are critical to successful farm operations. The commonest source of energy is the human power. As at today in Nigeria, the supply of human labour at the critical period of production is indeed a crucial issue. This is mostly because agricultural operations are limited in time. At the critical periods, the available farm hands cannot go round the required activities of the period. Lack of necessary farm hands at the required time may lead to loss in the productivity of the crops so grown. Where relevant farm hands are inadequate, farmers are expected to augment with power from other sources. Such other sources include animal power, mechanical power from machines as tractors and small engines. The supply of these is also inadequate. Where funds are available farmers are advised to own personal sources of mechanical energy or share with other farmers. Farmers are advised to source for funds that assist in the purchase of farm power.

3.5.2 Demand, Supply and Price (Market Forces)

You, as a farmer, must consider the demand for the crop / crop produce that you intend to produce on your farm. You must also consider the total demand for the cop / produce compared with the total supply of the produce in your immediate community. This is necessary as the total demand and supply of the produce will eventually determine its market price. The price at which you sell your produce will determine your total turn-over in the enterprise. Your gain will determine if you will continue to be in business in future.

4.0 CONCLUSION

To embark on rewarding crop production activities, a farmer needs to consider the nature of the immediate environment. S/he also needs to consider the type of crop that will do well in the environment. The environmental variables include the elements of weather, soil and edaphic factors on which the crops will derive their food and living. Besides all of the above, what will determine your success or failure as a farmer are the economic factors. A good farmer should be able to identify all the above discussed variables and relate them to crop choice appropriately if he/she wants to be in business

5.0 SUMMARY

In this unit, you have studied factors that influence crop production. You have been introduced into what climate is all about. In the process, you have studied the elements that make the weather. You have also learnt that the average weather conditions of a place for a period of thirty five (35) years is called climate. Crop requirements for the various elements of weather were briefly introduced. Similarly, the innate capabilities of crops which determine type characteristics were discussed. Classifications based on use of crop products were discussed.

Edaphic/soil factors that influence crop productions were also discussed. The relationship between the chemical and physical characteristics of soil and the crop types were equally identified.

Finally, economic factors of crop productions were identified, and discussed. Land, labour, capital and technical inputs were brought into the fore for discussion

6.0 TUTOR MARKED ASSIGNMENT

1. Identify climatic elements and edaphic variables that influence crop production.
2. Discuss the classification of agricultural crops from:
   a. the farmer perspective.
   b. biological point.

7.0 REFERENCES AND FURTHER READING

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MODULE 1—INTRODUCTION

UNIT 2: PRINCIPLES and OPERATIONS in TREE CROP PRODUCTION

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MODULE 1—INTRODUCTION

UNIT 2: PRINCIPLES and OPERATIONS in TREE CROP PRODUCTION

1.0. INTRODUCTION

The trees found in permanent crop plantations develop from small seeds. The selection and care given to the small seeds at the early stages of the crop plant determine the physical wellbeing of the crop plantations in later life. In this unit, you will study about the selection, care, growth and maintenance of the permanent crop plants. Common features at the Pre- nursery, nursery and field operations in the management of permanent crop plants will be treated. More detailed operations will be treated under each unit where each particular permanent crop is discussed.

2.0. UNIT OBJECTIVES

At the end of the unit, you should be able to:

- Describe basic principles in the selection of seeds, care of seeds, planting of seeds; growing of seedlings, and care for seedlings at the pre-nursery, nursery and the field levels
- Describe the management operations that are critical in the production of permanent crop seedlings—weeds, pests and disease, water and soil nutrient.
- Describe major field operations in permanent crop production-- weeds, pests and disease management, water and soil nutrient management, harvesting, processing and storage.

3.0. SUBJECT-MATTER CONTENT

3.1. Nursery activities and Operations

a. Introduction

Nurseries are places where seedlings are raised for planting purposes. In the nursery the young seedlings are tendered to develop in such a way as to be able to endure the hard field conditions. Nursery seedlings become the planting material for plantations. Nursery seedlings are found to have better survival rate than seeds sown directly in the field. This unit will review the various operations involved in the production of seedlings amongst other activities performed in permanent crop production.

Nurseries are of two types-_Temporary and Permanent nurseries

i. ***Temporary nurseries:*** These are established in or near the planting site. Once the seedlings for planting are raised, the nursery becomes part of the planted site. There are sometimes called "flying nurseries".

ii. Permanent nurseries: These can be large or small depending on the objective and the number of seedlings raised annually. Small nurseries contain less than 100,000 seedlings at a time while large nurseries contain more than this number. In all cases permanent nurseries must be well-designed, properly sited and with adequate water supply. Seedling production is a major expense of plantation agriculture. Every effort should be made to produce good quality seedlings at a reasonable cost. To this end mastering the techniques of nursery operations is essential.

b. Choice of site for the nursery

When the site of a nursery is to be selected, four questions usually arise:

i. What is the type of the nursery?
   a. Is it temporary or permanent?
ii. What is the size of the nursery?
   a. Is it large with over 100,000 seedlings per year, or
   b. Is it small with 50,000 seedling capacity per year or less?
iii. Seedling demand.
   a. How big is the seedling demand? For example, a nursery surrounded by several development projects may demand huge amounts of different seedlings every year, whereas a nursery for small plantation/s may have a low annual seedling production.
iv. Transport or distance from the nursery to places of seedling

demand. When these questions are answered, the **nursery is sited where:**

i. Good water supply source is available, e.g. near a river or a well. Because water is very crucial to the nursery, this is a determining factor.

ii. Good soil source is available; as soil is bulky, it is needed in great quantities. Site soil must be at least free from salinity and alkalinity.
iii. Site is well drained to avoid water-logging and be fairly safe from flood hazards.
iv. There is shelter against prevailing winds: sites which have a natural shelter by vegetation or any other formation are preferred to exposed sites. If the site is exposed then it must be sheltered artificially.
v. There is good access road to places of seedling demand. This will ensure that seedlings can reach the site in good condition. Bad roads and long journeys reduce seedling survival to a great extent.
vi. Labour is available or can easily be obtained and accommodated. Nursery work is labour-intensive and placing nurseries far away from residence areas will be very costly.

c. Design of the nursery

Having decided on the site and size of the nursery, the site is carefully levelled, fenced, and a shelter from the prevailing wind is established.

The nursery must be well designed. The nursery is divided into a suitable number of blocks. These blocks contain adequate roads among them. Blocks are normally labelled by letters, e.g. A, B. C, etc. or by Roman numbers: block I, block II, block III, etc. Roads between the blocks should be wide enough to provide space for on-loading and off-loading and contain turning space with a minimum width of 5 meters.

Each block is further divided into 4-8 sections with paths among them. Sections are labelled by their respective block label followed by a small letter, e.g. Section Ia denotes the first section from the left hand corner of block I.

Each section is further divided into beds. The bed is the smallest unit in the nursery design. Beds are normally one metre wide and their length may vary from 6-10 metres. Beds may be sunk in the ground at a depth of 30-35 cm below general ground level. In this case they may be laid with concrete, stone or bricks.

Also beds may be designed slightly higher than the general ground surface. In this case, the beds are surrounded by stakes, bricks or stones. In every case drainage in these beds is very important for seedling development and for nursery hygiene.

Beds are labelled by their blocks and section followed by Arabic figures, e.g. bed No. Ia1 denotes the first bed in section (a) of block I. Beds are separated by paths one metre wide to facilitate work and transport of seedlings by hand or wheelbarrow, watering and tending of seedlings.

In addition to these, the nursery design should contain adequate space for soil mixing (at least 5 x 5 metres). It should also contain a separate area for making compost. This is better placed slightly away from the nursery beds.

i. Size of the Nursery: The size of the nursery area stacked with containers (when containers are employed) and the total nursery area will vary with the diameter of the containers. The relationship between the diameter of containers/polyethylene bags (from 5 to 15 centimetres) and the surface of the nursery area (in square meters) for the production of 100,000 potted plants needs to be determined. For containers with a diameter of 5 centimetres, 240 square metres of beds are required. To estimate the total nursery area, the area of seedbeds is multiplied by 2.5, to include road and service areas, and 100 square metres are added (for paths), based on the production of 2,000 seedlings per square metre of seedbed. Therefore, in general: the total nursery area = (2.5 x area of seedbed) + 100 square metres and, for this example: the total nursery area = (2.5 x 240) + 100 square metres

Not all nursery operations involve the use of containers. When bare-rooted planting stock is produced, the size of a nursery will depend, in large part, upon the "average" size of the planting stock and the level of production to be maintained.

ii. Nursery water supply

Two aspects should be emphasized: (a) water quality; and (b) daily water requirement.

Water quality: It must be slightly acidic with a pH of less than 7, with dissolved salts less than 550 parts/million, and a conductivity of less than 0.8 mho/cm. Generally, the water must be fairly sweet and clear.

Water quantity: Adequate water of the above description should be supplied daily to the nursery.

The amount of water applied (at any one time) will vary with the weather conditions, the soil infiltration rate, and the size of the plant. During the period of germination, frequent “light" watering is required to keep the seedbeds moist, but not saturated. As plants grow, the total quantity of water applied is increased and the frequency of application is reduced.

As a guide to estimate the quantity of water to apply in one month, the following calculation can be made:

Water quantity = *water loss factor* x *E* x *area of seedbed*

where: *water loss factor* = values between 1.2 and 1.4, averaging 1.3

***E* = monthly Evapo-transpiration**

For example, assuming a ***water loss factor*** of 1.3, a monthly **evapo-transpiration** (E) of **0.2 meter** and a ***seedbed area*** of 10,000 square meters, the water requirement for one month is:

Water quantity = 1.3 x 0.2 x 10,000 = 2,600 cubic metres

Watering can is either by hand or through irrigation. Hand watering with cans, hoses fitted with spray-nozzles, or knapsack mist sprayers are methods used by small nurseries. For watering containers or seedbeds in which seeds have been sown, a fine droplet size is essential. Otherwise, the seeds can be washed out of the ground or the seed covering material can be washed away and the soil surface will be consolidated. Therefore, hand watering of the seedbeds is commonly done with a gardener's watering-can or a knapsack pressure sprayer fitted with a fine mist-producing nozzle.

3.2. Collection, handling, storage and pre-treatment of seeds

i. Seed quality

Seeds are collected from ripe fruits on our farms To ensure good seed quality, fruit collection must be made from trees having the desirable characters. Seeds can also be obtained from a known seed source in the country or abroad. In the latter case, the seed must be of good quality:

- clean from dirt, debris and chaff;
- free from pests and pathogens;
- have a high percentage of germination;
- Must be accompanied by a note, carrying the scientific name of the species, place of collection, date of collection, number of seeds/unit weight and whether any treatment has been applied. (this condition is important if the seeds are obtained from external sources.)

ii. Seed extraction

This is the process of separating the seeds from the fruit. Therefore, the method of extraction varies with the type of fruit. Cocoa seeds are extracted from the cocoa pods. Whereas the seeds of coffee are harvested from the coffee twigs as single seeds. Both may be planted as fresh seeds. For cocoa it is mandatory to plant the seed within 24 hours of its extraction from the mucilaginous pulp of the pod. Oil-palm seeds are extracted from the palm fruit bunches. Kola nut seeds are similarly extracted from Kola fruits. The seeds of rubber are collected from the field in rubber plantations. Citrus fruits contain the citrus seeds. The citrus seeds need to be extracted from the fruits before they can be processed. Both oil-palm seeds and citrus seeds need drying before further processing can take place.

iii. Seed storage

Seeds, whether bought or collected, must be stored in a proper way until needed. Dry seeds can be safely stored in polythene bags at room temperature.

When seeds are stored they are normally labelled, given a number and placed in an air-tight bag.

iv. Seed viability

Some seeds lose their viability in a short period, e.g. rubber seeds lose viability in about 6 months; citrus seeds lose their viability rapidly within three months. Therefore it is important to test seeds which are stored to determine their germination percentage and it is useless to store any seeds that fall below 40% germination unless they are very rare or very expensive. The viability can be tested through germination tests:

v. Germination test:

a. Filter paper method - where seeds are small, about 100 seeds are germinated in a petri-dish over a filter paper.

b. Silt test - 100 seeds are sown in a container with silt soil.

c. Tetrazonium chloride test: This is a chemical that imparts colour to living tissue. The seed is cut and the liquid is smeared onto the cut surface to find whether the embryo is alive.

3.3. Seedling production

There are many operations involved in seedling production. The most essential ones are described below:

i. Nursery soil mixtures

Nursery potting soil should have the following characteristics:

a. be light;
b. be cohesive;
c. have good water retention capacity;
d. high organic matter;
e. be fairly fertile or made so by the addition of 2 kg NPK/M_3 of soil.

In the majority of countries with arid conditions, a mixture of one part sand, one part clay, and one part of animal manure would be adequate. This is called 1:1:1 mixture.

ii. Nursery soil treatment

Potting soil must be acidic (i.e. pH6). If it happens to be alkaline, it can be acidified by a solution of 2% sulphuric acid. Sometimes nursery soil has to be sterilized against pathogens by use of a 40% solution of formaldehyde applied as 80 cc per 5 litres of water and applied to the soil 7 to 10 days before sowing the seeds. Soil fumigation is also a treatment against fungi by methyl bromide gas.

iii. Filling the pots/pot size

Polythene pots of different sizes are now used for raising nursery plants. This does not preclude the use of other containers like boxes, half tins, earth pots, etc. The pots are filled with nursery soil, taking care to have no voids by shaking and knocking regularly. The pots are filled, leaving a small space at the top, and stacked side by side on nursery beds.

It is very important to determine the pot size because: large pots require more soil, take a lot of labour to fill and transport; they occupy a large nursery space and require more water in contrast to small pots. But they produce large plants in a short time. The general rule is that "the harsher the planting site, the larger the pot should be".

The quantity of soil needed in a containerized nursery operation is directly related to the size of the containers used. To fill 100,000 small containers, 28 cubic meters of soil are needed; whereas 442 cubic meters of soil are needed for filling 100,000 of the largest containers (16 times more).

iv. Pre-treatment of seed.

Some tree and shrub seeds are ready for sowing as soon as they are collected; others pass through a dormant stage, during which time the embryo completes its development. Often, a pre-treatment is used to hasten germination or to obtain a more even germination. The methods of pre-treatment vary with the different types of dormancy of tree seeds. The main types of dormancy are:

- *Exogenous dormancy* - associated with the properties of the pericarp or the seed coat (mechanical, physical, or chemical).
- *Endogenous dormancy* - determined by the properties of the embryo or the endosperm (morphological or physiological).
- *Combined exogenous and endogenous dormancy*.

In general, the most frequently encountered type of dormancy in arid zones is exogenous dormancy. Some of the more commonly used methods of attempting to overcome this type of dormancy are described below.

a. Mechanical treatment - A small number of seeds can be scarified by scratching each seed with sandpaper, by cutting each seed with a knife, or by sandpapering the end of the seed that is opposite the radicle until the cotyledon is seen. With large quantities of seed, mechanical scarification can be achieved by pounding the seeds with sand, or by rubbing the seeds over an abrasive slab. A variety of other methods of scarification are also available.

b. Soaking in cold water - For a number of tree and shrub species soaking their seeds in cold water for from one to several days is sufficient to ensure germination. The improvement in germination is caused by the softening of the seed coat and the ensuring of adequate water absorption by the living tissues. When long soaking periods are used, it is recommended that the water be changed at intervals. Usually, it is important to sow the seed immediately after soaking without drying, because drying generally reduces the viability of the seed.

c. Soaking in hot or boiling water - The seeds of many leguminous species have extremely tough outer coats, which can delay germination for months or years after sowing, unless subjected to pre-treatment by immersion in hot or boiling water. The seed is immersed in two to three times its volume of boiling water, and allowed to soak from 1 to 10 minutes, or until the water is cold. The gummy mucilaginous exudations from the seed coat are then washed off by stirring in several lots of clean water.

d. Acid treatments - Soaking in solutions of acid is frequently used in the case of seeds with hard seed coats. Concentrated sulphuric acid (98 per cent) is the chemical used most generally. Most commonly, soaking times vary from 15 to 30 minutes. After soaking, the seed must be washed immediately in clean water. Tests should be made to determine the optimum period of treatment for each tree or shrub species, and even for different provenances, since overexposure to solutions of acid can easily damage the seed.

e. Seed inoculation- Legume trees have root nodules which harbour nitrogen-fixing bacteria. When seeds are planted outside their natural range, the soil should be inoculated with crushed nodules from natural stands. Some inoculum are available on the market which can be mixed with the seeds before germination.

f. Other treatments - For a number of salt bushes and shrubs such as Atriplex, washing seeds in cold water for one to two hours is sufficient to remove salt from the seeds and improve germination.

The germination process in oil-palm seeds is indeed a combination of the some of the processes described above. Rubber seed treatment is a simple scarification process.

3.4. Sowing of seeds

Having determined the soil mixture, kind and size of container, one would proceed to sow the seeds.

i. Depth of sowing: Seeds are sown at a depth of 1-3 times their diameter. When seeds are sown at this depth adequate moisture and optimum temperature will hasten their germination. Excessively deep sowing will impair seedling emergence

ii. Ideal sowing time: This is determined by the period required to raise a plantable seedling of the desired size. For example, if it takes four months in the nursery to raise plantable seedlings to be planted in June; then the ideal sowing date for that species and locality is the first of February. Similarly, for planting in October, the ideal sowing date is the first of June.

Student Self-Assessment Exercise 1

1. List and describe the major Nursery activities in permanent crop production

2. How do you determine the water needs of your nursery?.

3.4.1. Watering plants in the Nursery

After sowing, seed beds should be watered using a fine nozzle spray, producing almost a mist.. Hand watering, whether by a container or with a hose, is the best method of watering. Watering is done frequently until seeds germinate.

3.4.2. Pricking out of seedlings

When seedlings raised in beds and boxes reach the 2-leaf stage, they are carefully picked up using a sharp stick and carefully replanted in pots or other beds. This is a very delicate process which is now avoided by sowing the seeds directly in pots and thinning the excess seedlings leaving only one good seedling per pot.

3.4.3. Care of Nursery Stock

The production of good quality seedlings will depend on how well the following activities have been executed in its nursery:

i. Weeding

Weeds compete for water and soil nutrients. They also block the circulation of air and may harbour insects and disease organisms. Where weeds are permitted to grow in the seedbeds, seedlings will be of poor quality; therefore weed competition must be eliminated.

The methods of ensuring a minimum of weeds in the nursery are: prevention, eradication and control.

Prevention is the practical method. It is accomplished by making sure that weeds are not carelessly introduced in the nursery. Eradication is the complete removal of weeds and their seeds from the nursery.

Control is the process of limiting weed dissemination. Eradication and control are generally carried out as one operation in the nursery.

ii. Pests and Disease-Control

There are many types of pests and diseases prevalent in nurseries of tree crops. When the seeds are carefully selected, most of them may be eliminated. Because of the frequency of watering, diseases related to water and watering may not be ignored. The greatest of them all is Damping-off. **Damping-off** is a common and serious disease in many nurseries. It can occur either in seed beds or in containers after transplanting. Damping-off is a pre-emergent and seedling disease caused by various fungi. Some of these fungi attack the seed just as germination starts, whereas others infect the newly germinated seedlings. Affected seedlings topple over, as though broken at the ground line, or remain erect and dry up. A watery-appearing constriction of the stem at the ground line is generally visible evidence of the disease. Damping-off is favored by high humidity, damp soil surface, heavy soil, cloudy weather, an excess of shade, a dense stand of seedlings, and alkaline conditions.

One of the best preventive measures for damping- off is to maintain a dry soil surface through cultivation, to reduce the sowing density, and to thin the seedlings to create better aeration at the ground line. The need for soil fumigation is minimized in nurseries where fresh soil mixtures are prepared annually.

3.5. Vegetative propagation

a. **Stock planting**

Not all trees and shrubs used in planting programmes are produced from seed. Species whose propagation by seed is difficult can often be reproduced by vegetative propagation. Nursery stock that is obtained by vegetative propagation includes stumps, cuttings, and sets.

"Stump" is a term applied to nursery stock of broad-leaved species which has been subjected to drastic pruning of both the roots and the shoot. The top is generally cut back to 2 centimetres and the root to about 22 centimetres. Stump planting is suitable for "taproot-dominated" species. Frequently, stumped plants are used in sand dune stabilization plantations. Stumps are normally covered with wet sacks or layers of large leaves during transit to the planting site.

“Cuttings” and “sets” are also commonly used as planting stock. A "cutting" is a short length cut from a young living stem or branch for propagating; a cutting produces a whole plant when planted in the field. A rooted cutting is one that has been rooted in the nursery prior to field planting. "Sets" are long, relatively thin, stem cuttings or whole branches.

b. Size and quality of planting stock

There is a considerable range in what is considered the desired size of tree or shrub seedlings for planting. The optimum size varies, depending on whether the seedlings are bare-rooted or containerized, on the tree or shrub species to be planted, and on the characteristics of the planting site.

In general, it is agreed that plants with a well-proportioned root-to-shoot ratio represent good planting stock, but it is difficult to define an "optimum" root-to-shoot ratio. A root-to-shoot ratio based on weight might give a more accurate measure of balance. Stem diameter and height are other criteria for evaluating planting stock that might allow the setting of minimum acceptable limits. Experience indicates that medium-sized stock, between 15 and 40 centimeters, with a woody root collar, have a better survival rate that do smaller plants.

The maximum size for planting potted stock is largely determined by the size of the container. The larger the containers, the larger the plant that can be grown in it; but the period of growth is limited to that free of harmful root restriction. Excessively tall plants can be lessened in the ground or blown over, and root development might be restricted or inadequate to cope with the high transpiration demand of a large top.

3.6. Preparation of seedlings for the planting site—Hardening -Off

: Seedlings continue under nursery care while they develop for 2-3 months. Then the good ones will be selected and placed in separate beds. They are given less water and exposed to the sun gradually to condition them for planting in the site. This hard treatment is called hardening-off. Seedlings will develop a dark green colour and look healthier in the open than under nursery shade.

Seedlings of plantable size are first graded. The grading of planting stock depends, to a large extent, on local experience and the establishment of local standards. The main objectives of a grading system for planting stock are:

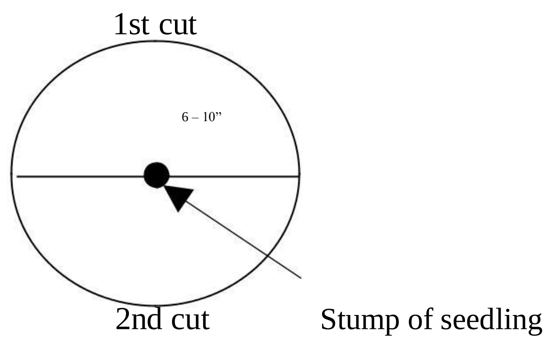
1. To eliminate culls, seedlings with damaged or diseased tops or roots.
2. To eliminate seedlings below minimum standards of size and root development.
3. To segregate the seedlings that exceeds the minimum standards into two or more quality classes.

Before seedlings are to be transferred to the field where they are to be planted into their permanent site, they are usually prepared for the situations they are to meet on the field. Some of the conditions on the field may include: inadequate water supply from irregular rain, severe and intense sunshine (when compared with the situations in the nursery). The areas where the pre-transplanting operations are concentrated are:

- root treatment
- shade treatment

- pests and disease control

Root treatment: In crops that are to be uprooted from the main nursery, the roots are usually disturbed during transplanting operations. Crops that are budded or grafted stay in the nursery for about three to four months before they are ready for transplanting. When it is established that budding or grafting has succeeded, the next stage is to prepare the crop for transplanting into the field. Where the crops are not planted in pots or polythene bags – i.e. they are planted into the main nursery bed, root treatment is definitely required. Using the main stump as the centre, draw a circle of radius 6 – 8 inches (15 – 20 cm) round the stump. Divide the circle into two equal halves by drawing a diameter through the circle. With the aid of a sharp cutlass or spade cut the roots along the first half of the circle to a depth of 12 – 15 inches (30-40 cm),. Three days to the intended date of transplant of the crop, cut the other half of the circle to the same depth of 30 – 40 cm. The purpose of the cutting of the roots in each of the semi-circle is *to* ***induce root formation*** in preparation to field transfer. On the due date for the transplant, uproot the crop seedling along the cut circumference and lift the seedling with the ball of earth that is 6 – 10 inches in diameter. Where transferring with the ball of earth is very difficult, deep the roots in clay slurry so that the roots will **not** be naked.



Shade Treatment: Since the seedlings will be exposed to more harsh condition of heat and sunlight when they are transferred to the field, it is often better to gradually expose the seedling to this type of situation. This is achieved by gradually expose the seedling to this type of situation. This is achieved by gradually reducing the shade in the nursery over a period of 4 – 6 weeks. The seedlings should experience zero shade for about a week before they are transferred to the field.

Water stress is critical in some crops. Crops/seedlings to be transplanted should he heavily watered a day previous to the transplanting. ***Freckle*** is a common disease on palms which is induced by water stress. Seedlings to be transplanted should be treated of all diseases and should be disease-free. Similarly, they should be free of all pests and pest eggs that will hatch later.

3.7. Transporting seedlings to field planting -site

Packing of container- raised plants for transport presents few problems. They are put in trays and loaded into vehicles. The tins which have been used for seedling trays can be used for transporting container plants. Sometimes wooden trays are used, but these are heavy.

Often, plants are damaged during transport to the planting site. Therefore, adequate care must be taken to avoid mishandling of plants during loading and unloading from vehicles. Something that is often forgotten is that plants require protection during transportation, as the air-flow can cause drying. It also is important that the containers are packed tightly, so that they cannot move. Special shelves for stacking pots or trays can be added to the vehicle platform (each layer of trays being placed on a shelf, with one shelf about 50 centimeters above the other). When possible, plants should be transported in the planting season on cool, cloudy, or even rainy days to prevent desiccation during transport.

Shipping schedules should be planned to avoid delays and to allow proper disposition of the plants immediately upon arrival. Normally, plants should arrive one day ahead of planting; where shade and watering facilities are available; supplies can be brought several days in advance. As soon as the plants arrive at the planting site, they must be watered and, if necessary, heeled-in in a cool, moist, shaded place until they are needed for planting.

Student Self-Assessment Exercise 2

1. Why is root treatment needed in seeds before transplanting?
2. What is hardening-off needed in plants?

3.8. Organization of seedling production (summary of nursery operations)

Seedling production must be organized in such a way that plantable *seedlings of good quality* are produced *in time.* As time of planting is critical in deciduous areas - except when irrigation is applied - the organization becomes very important. All the processes which have been described earlier must be done perfectly and on time. These activities include

a) Seeds and their treatment;

b) Soil mixture;

c) Filling of pots;

d) Sowing;

e) Watering;

f) Picking out;

g) Weeding;

h) Provision of shade and shelter;

i) Cutting;

j) Hardening off; and

k) Transport to the field planting site.

Only the number which can be planted in one day should be removed from the nursery to the site. According to the planting programme seedlings are hardened off and transported. The number of plants raised originally in the nursery is about 20% more than that planted in the field. This is to make up for culling and a reserve for replacing dead plants.

Administration is also very important in nursery work to ensure that:

a) Nursery activities (jobs) are done correctly;

b) These activities are done in time;

c) Labour requirement is available (man-days) for performing the work; and

d) materials/tools and equipment required to do the work are suitable.

This requires a nurseryman having a fair knowledge of labour productivity, nursery technique and prices of materials. Records of nursery seedling production as well as costs of materials and labour are kept to show the economics of nursery operations.

Labour and material requirements depend on the size of the nursery.

Forms showing cost of tasks, e.g. seed collection, filling of pots with soil, sieving, mixing and preparing nursery soil, should be designed and filled- in regularly.

3.9. General Field Activities and Operations

3.9.1. Land Acquisition

Land preparation presupposes that land is available. Therefore the first major step is land acquisition. It must be mentioned right from the onset that crops have different types of soil requirements. However, the ecology of any particular area determines the types of forest ecology and the types of land/soil that will be available. For instance, Lagos is located near the Atlantic Ocean where the rainfall is high for a substantial part of the year. Besides, the land available is within the lagoon creeks where the water table is high for most of the year .In other words; the land is water- logged and swampy all the year round. Thus the mangrove terrain has its peculiarities in terms of the land and the

types of crops that can grow therein. To grow or cultivate any crops you need to acquire land.
Land can be acquired through the following processes:

- Outright gift
- Purchase
- Land lease
    - Payment of rent
    - Shared crops
    - Rent and shared crops.
- Inheritance

Once the land is acquired, the next is to prepare it for the crops to be grown. Each crop has its own peculiarity in terms of preparation. Besides, the type of preparation you give to the land depends on the state of the land on acquisition. Is the land a virgin forest, or derived forest or a savannah or a water-logged land, hillside, or valley? Is the soil virgin soil or derived soil?

The types of preparation depend on the answers to the above identified issues. If you desire to plant tree crops or forest trees on a fairly large scale (plantation farming), definitely, you need a large expanse of forest land. All the activities that you undertake right from the acquisition of the land to the stage where you start to plant your crops into the soil are altogether called pre-planting operations or land preparation activities.

All land preparation activities can be performed with the help of energy saving devices of different levels of technology – varying from simple farm tools as cutlass, hoe and axe to and through advanced technology equipment as caterpillars and bulldozers.

3.9.2. Land Clearing/Under -brushing

This is essentially the removal of vegetative cover from a particular parcel of land. If the land is a thick virgin forest, you may need to underbrush the shrubs, and climbers and the undergrowths as a first stage. The second stage may include cutting and felling of trees and then stumping. Depending on the available tools/equipment, the operations can be done in phases or combined together in a single phase when the farmer decides to employ a bulldozer to do stumping, felling and clearing in a single operation.
When the land is meant for the cultivation of tree crops, complete clearing is definitely undesirable. Partial or selected felling is always preferred.

i. ***Stumping:*** This is the removal of big trees and their stems and roots from the cleared site. It is often better to remove a big tree through uprooting the tree. Once the major roots are cut, the whole shoot becomes unstable and thus, easily falls. It is often not desirable to fell the trees by cutting the trunk and then embark on stumping. Once the whole trees fall, they can be cross-cut into legs which can be rolled off the centre of the farm to the boundaries or ends of the farm. It is not desirable to burn big logs in the farm site. Such practices of burning thrashes on farmland lead to soil-nutrition management problems later.

***ii. Packing of Thrash/Debris*:** The small shrubs, twigs, undergrowth and climbers should be packed off the farm site. The leaves should be allowed to rot and decay on the soil. Little or no burning should be encouraged.

3.9.3. Layout and Lining

After you cleared the site, the next operation is dividing the site into blocks—a process known as "blocking". This is a process by which the plantation site is divided into convenient sizes. Each block should be 5-10 hactares depending on the size of the plantation. The blocks are separated from one another by 4metre wide farm roads. The shape of each block should be rectangular or square.

Once the blocks are put in place, the next activity is the lining of the blocks to identify the particular location of individual crop plant in the plantation. The materials required for this operation are land survey equipment—ranging poles, tape, measurement chains, compass, pegs, and stakes

A baseline is adopted at one side of the block in which the planting sites are to be marked. Along the baseline, the various sites are marked at the appropriate distances required for the crop to be planted. All planting sites, once located are marked with wooden pegs pending the preparation of the planting hole. Common dimension of planting hole is 60cm by 60cm by 60cm. During digging, the top-soil is preserved on one sideof the planting hole and the subsoil on the other side. Once the required depth of 60cm has been reached, the subsoil at the base of the hole is loosened. Good topsoil is used in t e planting of the seedling that will eventually be planted into the dug up planting hole.

3.10. Post Planting Maintenance Operations

Post planting operations performed in permanent crop production include: weeding and weed management, pests and pest management, disease control and management, water and soil nutrient management, shade management and in some cases, pruning.

i. Weeding and weed management. During the early years of the young tree crop, attempts must be made to ring-weed each plant crop. Shade trees can be planted. Besides, selective shade -tree elimination can also be practiced e.g. plantains, bananas, glyricidia, . Inter -cropping with some selected farm crops can also be practiced. Cover crops should be incorporated early in the life of the plantation .Integrated weed management is the best form of control

***ii. Pests and Disease Management*.** Pests and diseases abound in the tropics. The prevalence of any particular disease and/or pest depends on the nature of the crops and the sanitation practiced on the farm. Breeds and progenies that are resistant to certain diseases are available in each crop type. Preventive control measures are best in crop management.

iii. Water and soil nutrient management. Though the products harvested from each crop differ, all the crops need water and nutrients to manufacture the produce. Therefore the need for efficient management of water and minerals derivable from the soil can not be stressed enough. Besides, the need to replace nutrient uptake from the soil cannot be over emphasized. Nutrients as Nitrogen, Potassium, Phosphorus, Magnessiun, Sodium, and trace elements need to be supplied to the soil at regular intervals to boost the supply to the crops.

Other operations include harvesting and partial processing at the field/plantation levels.

These operations will be extensively discussed under each permanent crop that will be treated in this course.

4.0. CONCLUSION

This unit has discussed the basic operations that are common to tree crop production. It can not be overemphasized that crops that develop into big trees start from small seeds. These small seeds are grown in nurseries and sometimes from pre-nurseries for upwards of 8-24 months before they can be transferred to the field/plantation site. The performance of the plantation crops depend heavily on the care and type of planting stock selected into the nursery and the management given these stocks early in life.

5.0. SUMMARY

In this unit, you have studied about the major operations that are crucial to the establishment of tree crop production. Seed extraction, seed selection, seed storage and seed planting were treated. Nursery site selection and seed germination in nurseries, nursery operations necessary to maintain the integrity of good nursery seedling were carefully treated. The relevant operations in pre-nursery and nursery were discussed. Pre-planting operations required in field establishment of permanent crop production were treated. Operations necessary for the field maintenance of the tree crops were also treated. Harvesting, processing and storage were briefly mentioned. These operations were to be treated under each tree crop treated in this course.

6.0. TUTOR MARKED ASSIGNMENT

1. In what crops are pre- nursery operations necessary?
2. What constitute nursery operations in permanent crops?
3. Why is hardening off necessary in the final transplanting of seedlings to the field?
4. What constitutes field management operations in permanent crops?
5. What constitutes partial processing in permanent crops?
6. Why is partial processing necessary in permanent crops produce harvesting?

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2: STIMULANT/BEVERAGE CROPS

UNIT 3: CACAO --*Theobroma Cacao*—the Tree of Life

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MODULE 2: STIMULANT/BEVERAGE CROPS

UNIT 2: CACAO --*Theobroma cacao*—the Tree of Life

1.0. INTRODUCTION

Theobroma Cacao—the Tree of Life

One of the world's most magical and incredible trees is the cocoa tree. The botanical name is *theobroma cacao*, which, roughly translated, means "food of the gods" or more literally. "God food." There are actually several trees that are members of the theobroma species, such as t*heobroma bicolor*. Only one is used for making chocolate—*theobroma cacao*.

In order for the cacao tree to produce cacao beans that are later to be used in making chocolate, all the conditions must be absolutely perfect. Any significant deviation, and the cacao tree will not provide much (if any) fruit, or it may not survive.

2.0. UNIT OBJECTIVES:

At the end of this unit, you should be able to:

- Identify a cacao tree.
- Identify the different types and varieties grown in your area.
- Describe the operations performed:
    - at the nursery level,
    - at the field level,
    - during grading,
    - during storage of dry beans.
- Describe fermentation processes.
- List some of the products derived from cocoa.

3.0. SUBJECT-MATTER CONTENT.

The subject matter content of this unit starts with the botanical description of cacao through cultivation activities harvesting and processing of cacao seeds called cocoa. It ends with the chemical analysis and composition of cocoa as they affect the composition and flavour of chocolate and other products of cocoa.

3.1. Botany of Cacao

Scientific classification of cocoa

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Malvales

Family: Sterculiaceae

Genus: *Theobroma*

Species: *cacao*

Binomial name: ***Theobroma cacao*** **Lineus (L)**

3.1.1. Cocoa tree (CACAO) varieties

i. Criollos dominated the market until the middle of the eighteenth century but today only a few, if any, pure Criollo trees remain. Criollo cacao typically has red or yellow pods, some being green or white (as in the case of Porcelana). The pods have bumpy or warty skin with pointed tips.

The beans, on the other hand, vary from light purple to white in color, and they are plump and full. In general, the beans from criollo cacao are considered to have a finer flavor than that of other varieties of cacao.

The criollo trees are not very disease-resistant, and hence they are hard for farmers to grow and keep healthy.

Typically when chocolate is made from the criollo beans, the chocolate is not overly rich, though the resulting chocolate will have a complex flavor that is often reminiscent of various fruits and spices. Criollo beans are therefore considered to be "flavor beans" because of their heightened flavor characteristics.

Criollo Cocoa Pod

Because of trade with Venezuela, Venezuelan criollo cacao may be found throughout the entire Central American region, including Mexico, most notably the states of Tabasco and Oaxaca. Even so, these regions still have their own "native" (or criollo) varieties.

ii. Forastero is a large group containing cultivated, semi-wild and wild populations of which the Amelonado populations are the most extensively planted. Large areas of Brazil and West Africa are planted with Amelonado. Amelonado varieties include, Comum in Brazil, West African Amelonado in Africa, Cacao Nacional in Ecuador and Matina or Ceylan in Costa Rica and Mexico. Recently large plantations throughout the world used Upper Amazon hybrids. Today, Forastero mainly refers to cacao that has its ancestry from the upper Amazon basin. Through trade, this cacao has been spread throughout much of the cacao-growing world, including Africa. Today, the largest producers of cocoa beans are the Ivory Coast and Ghana, where forastero was established very early in the cocoa trade. Because of this and the disease resistance of this variety, the top producing countries are primarily forastero. Most of the chocolate produced in the world today is made from forastero beans.

Forastero Cocoa Pods

The hull of the cocoa pod, rather than being deeply furrowed with a knobby skin and pointed pod, as the criollo pods are, are relatively smooth, with more of a bulbous pod shape. In addition, the hull is also woodier than the criollo, and thus the pods are harder to open. The pods may also be red or yellow, as well as orange or purple. The beans themselves are very dark purple and are relatively flat compared to those of the criollo.

The forastero does not have the complexity of flavor of the criollo, nor does it have nearly the spicy and fruity notes that one may find in the criollo as well. Instead, the forastero has a much richer "chocolate" flavor. Because of this, forastero beans are usually considered "bulk beans," while the criollos are considered "flavor beans." Chocolate makers will typically use primarily the forastero for their chocolate blends to create a rich, chocolate flavor background, then add a variety of flavor beans to make the final flavor of the chocolate more complex and interesting.

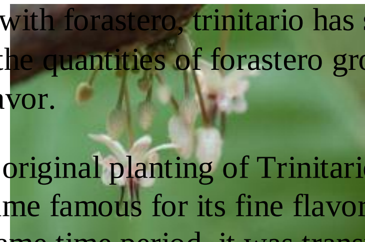
While the cocoa from Ecuador is fine in flavor, it is generally considered to be a Forastero by popular classification. The flavor is very similar to that of other forasteros, with the addition of fruity overtones that other forasteros typically do not have. This cocoa is native to Ecuador, and thus it is a criollo (native) as far as Ecuador is concerned. As may be imagined, this could have caused plenty of confusion except that the native cocoa variety has been named *Nacional* , thus preventing further confusion of the criollo name than already exists.

As mentioned, unlike the criollo, the Forastero varieties are much more hardy and disease-resistant. Because of this, they are favored by farmers who, while they may not be able to command as high a price for the resulting beans, they are guaranteed of a much more saleable crop.

iii. Trinitario is considered to belong to the Forasteros although they are a cross between Criollo and Forastero.

As the name implies, the trinitario originates from the island nation of Trinidad. Today, trinitario along with criollo provides the basis for "flavor beans," used to enhance the flavor of today's chocolate.

As with forastero, trinitario cocoa pods are typically not pointed, and the skin of the pods is relatively smooth (compared to that of the pods of the criollo). The cocoa beans are also flat and purple when cut in half.



It is worth mentioning that as with forastero, trinitario has spread throughout the world as a major cocoa crop. Even so, the quantities of forastero grown dwarf those of trinitario—though trinitario has a finer flavor.

One of the major sites of the original planting of Trinitario was Trinidad and then Sri Lanka (Ceylon), where it became famous for its fine flavor. Trinitario was first planted in Ceylon in 1834. During that same time period, it was transplanted to Fiji, Madagascar, Samoa, Singapore, and Tanzania. Later it spread to Venezuela and then was planted in Ecuador, Cameroon, Java and Papua New Guinea.

Today, trinitario is highly sought after by chocolatiers worldwide for its fine flavor and is used both to provide flavor for chocolate created from "bulk beans" as well as to create super-premium chocolate when used by itself.

Trinitario Cocoa Pod

3.1. Cocoa Flowers

The cacao flower is one of the most beautiful flowers in the world. It does take a keen eye, however, to appreciate them, because they are very small—only about one-half inch across.They are incredibly delicate, in addition to having a complex structure,

Cluster of Cocoa Flowers

Unlike most flowers, they grow directly from the trunk of the tree or from the body of the branches; when the tree is in bloom, the trunk and branches are covered with literally thousands of tiny, yet beautiful cocoa flowers.

It is interesting to note that the cacao flowers have no smell. It is for this reason that bees and other pollinating insects do not fertilize the cacao flowers but instead leave pollination to other insects.

Pollination of the cacao flower occurs by the actions of midges and other jungle insects. Midges are a type of gnat that live on the jungle floor under leaves and other debris.

When they fertilize the cocoa flower, it is not through attraction by the flower by either scent or nectar (because there isn't any of either) but simply through random chance. It is perhaps for this reason that the cocoa tree is furnished with the massive quantities of flowers that it is. It has been estimated that on average only one out of one hundred cacao flowers will become fertilized and grow into a cocoa pod. It is interesting to think how the lowly midge (or gnat) is responsible for fertilizing the cacao tree and creating one of the world's greatest foods.

Cacao flowers

3.1.3. Cocoa Pods

If the flower is fertilized and conditions are perfect, the cacao flowers will start to grow into cacao pods. Even at this stage, a pod is not guaranteed. The vast majority of pods that start to develop will grow until they are a few inches long' then if the conditions are still not just right, the pod will die.

The baby cocoa pod is called a *chileo* because it looks like a baby chili. For one reason or another, many cocoa pods do not make it past the chileo stage. Everything must be perfect in order for the cocoa tree to develop a cocoa pod to full maturity. As the cocoa pod grows and develops, it will begin to take on one of a wide variety of possible shapes and colors.

Cocoa pods are shaped a bit like an American style football. They can be smooth, wrinkly, or warty. They can be long and pointed, or they can be bulbous, like a melon or papaya. The colors of cocoa pods are equally as great. Colors such as red, purple, yellow and green are common.

3.1.4. Other members of the genus Theobroma and their possible origins

Theobroma bicolor is a species, similar to cacao, cultivated from southern Mexico to Bolivia and Brazil. It produces beans that are called pataxte. These are used to make a drink or they can be used to make a poor quality chocolate. The beans are sometimes used to adulterate true cacao produce.

***Theobroma grandiflorum*,** known as cupuaçu in Brazil, is used to produce a drink from the mucilage around the beans.

In modern day Amazonia, the Arawete and Asurini Indians cultivate ***Theobroma speciosum*.** The Indians can make a crude, low quality chocolate from the seeds of T. speciosum, but the pulp is more generally eaten.

3.1.5. Origins of Cocoa and Its Spread around the World

(a).**Centre of Origin**

Cocoa is produced in countries within 10ºN and 10ºS of the equator where the climate is appropriate for growing cocoa trees. The largest producing countries are Côte d'Ivoire, Ghana and Indonesia.

i. The upper Amazon region

This region's rich tropical rainforests are a primary centre of diversity and it is possible the cocoa tree grew here 10,000 to 15,000 years ago.

ii. The upper Orinoco region of north east Colombia and north west Venezuela

Evidence of a large cacao gene pool in the upper Orinoco suggests that this could be where wild cacao originated. The transfer of cacao to Mexico would also be short and easy from here.

iii. The Andean foothills of north west Colombia

It is postulated that cacao originated in the Andean foothills because of the large number of species found there and the comparative ease of dispersal to Mexico.

iv. Central America, from southern Mexico to Guatemala

Other studies give the Lacandon forest of Chiapas in Mexico and the Usumacinta river area on the borders of Mexico and Guatemala as the source of cacao.

Whether by natural dispersal or carriage, cacao spread through northern South America and Central America, eventually splitting into two sub-species, criollo cacao in Central America and forastero cacao in South America.

3.1.5. (b). Spread of Cacao around the World.

The genus Theobroma originated millions of years ago in South America, to the east of the Andes. Theobroma has been divided into twenty-two species of which T. cacao is the most widely known. It is the **Maya** who have provided tangible evidence of cacao as a domesticated crop. Archaeological evidence in Costa Rica indicates that cacao was drunk by Maya traders as early as 400 BC. The **Aztec** culture, dominant in Mesoamerica from the fourteenth century to the Conquest, placed much emphasis on the sanctity of cacao.

Map 3.1: Cacao producing areas of the World (after Dand, R.J.; 1999)

The first outsider to drink chocolate was Christopher Columbus, who reached **Nicaragua in 1502** searching for a sea route to the spices of the East. But it was Hernan Cortés, leader of an expedition in 1519 to the Aztec empire, who returned to Spain in 1528 bearing the Aztec recipe for xocoatl (chocolate drink) with him. The drink was initially received unenthusiastically and it was not until sugar was added that it became a **popular drink in the Spanish courts.**

Caribbean and South America

There were attempts to satisfy Spanish domestic demand by planting cacao in Spanish territories like the Dominican Republic, Trinidad and Haiti but these initially came to nothing. More successful were the Spanish Capuchin friars who grew criollo cacao **in Ecuador in about 1635**. The rush by European, mercantile nations to claim land to cultivate cacao began in earnest in the late seventeenth century. France introduced cacao to Martinique and St Lucia (1660), the Dominican Republic (1665), Brazil (1677), Guianas (1684) and Grenada (1714); England had cacao growing in Jamaica by 1670; and, prior to this the Dutch had taken over **plantations in Curaçao** when they seized the island in 1620.

Africa and Nigeria

Later the explosion in demand brought about by chocolate's affordability required yet more cacao to be cultivated. Amelonado cacao from Brazil was planted in Principe in 1822, Sao Tomé in 1830 and Fernando Po in 1854, then in Nigeria in 1874 and Ghana in 1879. There was already a small plantation in Bonny, eastern Nigeria established by Chief **Iboningi in 1847**, as well as other plantations run by the Coker family established by the Christian missions. The seeds planted in Ghana were brought from Fernando Po by Tetteh Quarshie or his apprentice Adjah, after previous attempts by the Dutch (1815) and the Swiss (1843) to introduce cocoa in Ghana had failed. In Cameroon, cocoa was introduced during the colonial **period of 1925 to 1939.**

3.2. Worldwide distribution of smallholder- producers of cocoa

Proportion of cocoa worldwide produced by smallholders is almost 90% of total production. This comes from smallholdings of under 5 hectares in size.

Smallholders involved in cocoa, International Cocoa Organization (ICCO) global estimates is contained in the table below.

Smallholding 3 hectares (smallholding is usually defined as a farm holding of less than 10 hectares, range 2ha to 5ha)

2.5 million smallholders (could be up to 3 million but this would then include those for whom cocoa is not the main activity)

Smallholder yields 350kg/hectare (range from 200kg in Ecuador to 1,500kg for smallholders in Indonesia - Sulawesi. Ghana 300kg, Cote d'Ivoire 450kg)

Country/Region	**Total no of workers (million)**		
World			14.00
Africa	10.50		
Cameroon		1.60	
Côte d'Ivoire		3.60	
Ghana		3.20	
Nigeria		1.20	
Sierra Leone		0.38	
Togo		0.40	
Others		0.12	
Americas	1.39		
Brazil		0.21	
Colombia		0.28	
Dominican Republic		0.20	
Ecuador		0.28	
Venezuela		0.18	
Others		0.25	
Asia and Oceania	2.11		
Indonesia		1.60	
Malaysia		0.31	
Papua New Guinea		0.10	
Others		0.10	

Source: ICCO, December 1999

Student Self-Assessment Exercise1

1. Distinguish between the three breeds of cocoa.

2. Identify the areas where particular breeds dominate.

3.3. Requirements for cacao production

3.3.1. Climatic Requirements

The natural habitat of the cocoa tree is in the lower storey of the evergreen rainforest and climatic factors, particularly temperature and rainfall, are important in encouraging optimum growth.

Temperature

Cocoa plants respond well to relatively high temperatures with a maximum annual average of 30-32 degrees C and a minimum average of 18-21 degrees C.

Rainfall

Variations in the yield of cocoa trees from year to year are affected more by rainfall than by any other climatic factor. Trees are very sensitive to a soil water deficiency. Rainfall should be plentiful and well distributed through the year. An annual rainfall level of between 1,500mm and 2,000mm is generally preferred. Dry spells where rainfall is less than 100mm per month should not exceed three months.

Humidity

A hot and humid atmosphere is essential for the optimum development of cocoa trees. In cocoa producing countries relative humidity is generally high, often as much as 100% during the day, falling to 70-80% during the night.

Light and shade

The cocoa tree will make optimum use of any light available and has been traditionally grown under shade. It's natural environment is the Amazonian forest which provides natural shade trees. Shading is indispensable in a cocoa tree's early years.

3.3.2 Soil Conditions

Cocoa is grown in a wide variety of soil types.

Physical properties - Cocoa needs a soil containing coarse particles to leave free space for roots and with a reasonable quantity of nutrients to a depth of 1.5m to allow the development of a good root system. Below that level it is desirable not to have impermeable material so that excess water can drain away. Cocoa will withstand water logging for short periods but excess water should not linger. The cocoa tree is sensitive to a lack of water so the soil must have both water retention properties and good drainage.

Chemical properties - The chemical properties of the topsoil are most important as there are a large number of roots here for absorbing nutrients. Cocoa can grow in soils with a pH in the range of 5.0-7.5. It can therefore cope with both acid and alkaline soil, but excessive acidity (pH 4.0 and below) or alkalinity (pH 8.0 and above) must be avoided. Cocoa is tolerant of acid soils provided the nutrient content is high enough. The soil should also have a high content of organic matter, 3.5% in the top 15 centimetres of soil. Soils for cocoa must have certain anionic and cationic balances. Exchangeable bases in the soil should amount to at least 35% of the total cation exchange capacity (CEC) otherwise nutritional problems are likely. The optimum total nitrogen/total phosphorus ratio should be around 1.5.

3.3.3. Other Factors which affect productivity

The following factors affect the productivity and production in any community.

Return on investment - High returns from selling cocoa for little input will naturally cause more cocoa planting to take place. As a tree crop this affects long term production. In the short term higher returns encourage growers to apply more inputs such as fertilisers and pesticides which increases the yield. However, farmer prices are sometimes set by governments or can be influenced by internal market factors other than the world cocoa price.

Government schemes - The role of government in assisting growers is a leading factor in the grower's decision whether or not to plant cocoa. Assistance can take different forms, from assistance with setting up and rehabilitation to cheap loans. For example, in Indonesia in 1990 the government made available loans at low rates of interest for the establishment of plantations and many companies were tempted into cocoa growing. Extension services may also assist smallholders.

Alternative crops - Land suitable for cocoa is also able to support other crops. If cocoa has a low return for a long time, the farmer may switch to another commodity or food crop despite the costs of uprooting and replanting.

Pests, diseases, drought and floods - Pests and diseases, droughts and floods can destroy crops and make the decision to switch to another crop easier.

Yield - Yield depends on the age, type and planting distribution of trees and level of inputs needed. The balance between yield and input costs is important to the grower. For example, Malaysia had high yields of 700 kg per hectare but also had high costs of between 70 cents and $1.30 per kg.

Tree-stock characteristics - The production capability of the trees and their ability to resist disease are also an important factor in productivity. The grower with a large estate and more resources will naturally make more use of the most up-to-date planting material whereas the smallholder will depend on government extension services or neighbours. The age profile of tree-stock is also important when assessing potential production as yields will vary with age.

Breeds resistant to Phytophthora palmivora (black-pod disease) were developed by Cocao Research Institute of Nigeria—CRIN- within the last couple of years. The Clones developed include:

T9/15, T12/11, T19/9, T24/12, T50/32 and T86/2.

Similarly, fifteen (15) progenies that are resistant to Cocoa Swollen Shoot Virus (CSSV) were developed by CRIN. These progenies popularly referred to as CRIN Elites include:

1. T7/12 X Na321 (C64)
2. T12/5 X Pa 35 (C65)
3. T17/11 X Na 32
4. T20/21 X Na 32
5. T30/10 X Na 32
6. T65/7 X Na 32
7. T85/5 X Pa 35
8. T86/45 X Na 32
9. ICS1 X Na 32
10. ICS7 X Na 32
11. C77 X C23 (CSSV Tolerant)
12. C77 X C64 (CSSV Tolerant)
13. C77 X C87 (WACRI Series IIF)
14. C75 X C14 (WACRI Series IIKC)
15. C75 X C25 (WACRI Series IID)

Source: Raw Materials Research and Development Council (RMRDC) Abuja, Report on Survey Selected Agricultural Raw Materials in Nigeria. 2004, October

Environmental influences - The climate, soil, water supply, human actions and other environmental factors can also affect productivity.

Costs - A large part of the cost of establishment and maintenance of production is labour. The next major cost is inputs such as fertilisers and pesticides. Both these costs will vary with the size of the farm and the type of farming carried out. Financial success in setting up a cocoa farm depends on quick returns from the initial investment and increasing yields to cut unit costs.

Student Self-Assessment Exercise 2

1. What are the climatic and soil requirements for the cultivation and production of cocoa?
2. Identify on a world map, possible places where cocoa cultivation is possible.

3.4. Nursery Operations

3.4.1. Propagation of cocoa trees

Cocoa is raised from **seed** . Seeds will germinate and produce good plants when taken from pods not more than 15 days under ripe.

Vegetative propagation can also be used to create clones. Vegetative propagation can be by cuttings, budding or marcotting.

i. *Cuttings* - Tree cuttings are taken with between two and five leaves and one or two buds. The leaves are cut in half and the cutting placed in a pot under polythene until roots begin to grow.

ii. *Budding* - A bud is cut from a tree and placed under a flap of bark on another tree. The budding patch is then bound with raffia, waxed tape of clear plastic to prevent moisture loss. When the bud is growing the old tree above it is cut down.

iii. *Marcotting* - A strip of bark is removed from a branch and the area covered in sawdust and a polythene sheet. The area will produce roots and the branch can then be chopped off and planted.

- **In vitro propagation** is not generally used for cocoa, but research is taking place on the subject to find easier in vitro methods of producing clones. Adu-Ampomah et al managed to produce somatic embryoids from cotyledons and developed a method for their development into plantlets. Somatic embryogenesis is a process by which somatic cells undergo bipolar development to give rise to genetically identical whole plants by means of the development of adventitious embryos that occur without the fusion of gametes. The development of somatic embryogenesis systems of cocoa trees has opened a new avenue for vegetative propagation. Scientists in a Penn State research programme funded by the American Cocoa Research Institute have been researching the method and a field test comparing in vitro cloned cocoa plants with seed grown and grafted plants is to take place at the Union Vale Estate on the island of Saint Lucia in the West Indies. The ForBio Group of companies is researching the propagation of cocoa plants using tissue culture and/or robotic assisted micropropagation technology.

3.4.2. Cacao Nursery Operations

Preparation of the nursery

- all trees and shrubs should be removed

- the sight must be levelled out
- a wire netted fence must be provided
- A fire trace of 3.5m should be constructed round the nursery
- clear site of old materials

Erecting the nursery shed

- Cut poles of 3.1m (10ft) length
- Map out the site
- 3. Erect poles to a depth of 0.7m (2ft.) with 2.45m (8ft) above the ground.
- Erect poles at intervals of 3.1m such that each nursery block is 3.1m x 3.1m (10ft by 10ft)
- Space between blocks should be 0.75 -85m (2ft -2 ⅔) wide. This space should serve as path between blocks
- Cover the shed at the top, and three sides, with the fourth side open

Erecting platforms in nursery sheds

- Nursery beds can be on the ground or on raised platforms The beds serve as base for the polythene bags
- Beds can be made from split bamboos. The split bamboo should face downwards
- Other materials like planks or wood can be used.
- The polythene bags are arranged on the beds in rows and columns. It is best to arrange the polybags in rows of 5 bags(big size) or 10bags(medium size) and length of your choice .The row size is indicated so that effective watering of the seedlings in the bags can be done.
- Erect cross bars at intervals of every 10 polybags for the side- support of the polybags.
- Nursery beds should be erected across the slope of nursery site.

Filling the polybag.

- fill the pot to three-quarters full;
- set the pots on the nursery platform;
- water the bags heavily after filling with good soil.

Planting into the polybags.

- Select the mature cocoa pod to use as planting material
- Open the cocoa pod, the damaged ones first
- Remove the seed from placenta attachment in the pod
- 3 Plant the seed with the blunt end attached to the placenta downwards
- Water the polybags after planting the seeds

*In estimating the number of pods needed to plant your nursery, remember that each cocoa pod contains an average of 30 seeds.

Propagation by other methods

- Seeds –planting at stake.
- 2. Cutting. –
    - gives uniform growth,
    - new plants do not grow tall
    - matures early
    - new plant donot have tap root

- 3. Budding--similar to cutting
- Grafting.—similar to cutting

3.4.3. Nursery Management

- **Label The Nursery** – such a label should contain information on :
    - Type of seed
    - Date of sowing
    - No. Of seeds sown
    - Source of seeds
- **Water Management**. Light and frequent watering is better. Too heavy water could encourage the growth of fungi, wastage of water, starvation before the next watering. Don't allow leaves of seedlings to stick to the soil as such could encourage crocked seedlings.
- **Shade management**. Seedlings should be trained to the conditions on the field hence hardening up is practiced. Reduce the shade level gradually at least two months to the transplanting date.
- **Disease control**. If rainfall is heavy, fungus diseases and damping -off spread easily and fast. Spray with the appropriate chemical and encourage adequate air circulation.
- **Pest control**. Check and control pest population. Use insecticides if necessary.

3.5. Field Operations.

3.5.1. Field Planting of Seedlings.

Cacao should be planted in virgin forest whose soil is deep, friable and fertile. The topography of the land should be gentle, flat or undulating. In plantation farming, the acquired land should be under brushed to reduce the shade and thus allow sunshine to reach the ground level. The cleared land should be mapped out into blocks of manageable sizes. The blocks could be square or rectangular in shape varying between 6 and 10 hectares. Using a spacing of 3.1m x 3.1m (10ft. by 10ft), the pegs should be laid in straight parallel lines within each block, the marked points should be dug into planting holes of 50cm x 50cm x 50cm (18-20 inches length, width and depth). The top soil should be kept separate as it will be used latter to fill the hole after the seedling has been planted into the hole. The dug up holes could be left for a couple of days before the seedlings are ready. When the rains are steady, the potted seedlings are transplanted into the fields. The polythene bags which contain the seedlings should be removed before the seedlings are properly placed in the holes. It is expected that adequate water should be made available within three days of transplanting; else the seedlings will experience water stress –a situation that should be avoided at all costs. After successful transplanting, the other management operations include: weeding, pests and disease control and of course, shade management. Ring- weeding is recommended for the first year of transplanting. at intervals of 6-8weeks. To keep the whole farm clean, slashing should be done at interval of 12-15 weeks. Pests at this stage include termites and caterpillars. Insecticide dusts should be applied as necessary either as ring applications or sprays. Shade should be progressively reduced to allow for the healthy growth of the cacao.

In subsistent cocoa farming (the majority of cocoa farm development strategy of small holders, the cocoa is not sown as a sole crop. Instead, it is sown as an inter-crop with other crops. Since the other crops are usually annuals, land clearing and land preparation methods are usually different. Similarly, weeding, pests, disease and shade management strategies are different for the first three years. Provision of shade becomes crucial as most of the shade trees would have been felled at the initial stage. Bananas and plantains are usually provided as they serve the purpose of alternative income to the farmer.

3.5.2. Growing banana and other crops in conjunction with the cocoa for shade.

It is advisable to provide shade trees for growing cocoa trees. Banana is the best choice. The cocoa tree will make optimum use of any light available and has been traditionally grown under shade. Its natural environment is the Amazonian forest, which provides natural shade trees. Shading is indispensable in a cocoa tree's early years to ensure the right form of growth.

Young cocoa tree on a plantation being sheltered from the wind and elements by "mother trees"

The lack of shade trees can result in cocoa trees being more susceptible to attacks from sap sucking insects or capsids (also known as mirids).

Cocoa trees grown under thin forest cover usually require less pruning than cocoa trees grown without shade.

Bananas can provide shade for young trees, though this shade does not usually continue into maturity due to the short life span of the banana. Growing bananas also provides the farmer with another cash crop. Another tree often used for intercropping is coconut.

Shade can also be provided by thinning the forest or by planting trees, such as Leucaena leucocephala and Gliricidia sepium, to provide permanent shade. Some shade trees are leguminous and therefore return nitrogen to the soil.

3.5.3. WEEDING.

Since cocoa farming is practiced in deep forests, most of the weeds are undergrowth herbaceous plants. Stubborn perennial weeds are rarely experienced. The first year of transplanting, ring-weeding is recommended at intervals of 6-8 weeks, while the entire plantation should be slashed every 12-15weeks. The frequency of weeding should reduce the second year. As from the third year, emphases should be placed on the plantation brushing and shade reduction. When cacao plantation is fully developed, the trees form enough canopies to reduce weeds incidence to the barest minimum. Using of slashers and weedicides or herbicides as needed are encouraged at this period.

3.5.4. PESTS & DISEASE CONTROL IN COCOA

Common pests on cacao area: termites, caterpillars, aphids, mealy-bugs and capsid bugs. They are more prevalent during the dry season. Insecticides as: Gammalin, Aldrex, Aldrin etc., should be used at the recommended dosages.

Common diseases

1. Black Pod Disease. About 40% of annual Produce is lost this disease. The causal agent is a fungus called *Phytophtora palmivora*.

Symptoms— Small brownish spots with irregular fringes looking as though it is wet appear on he leaves. This spots gradually increase in size and in about 2-3 days later, a whitish downy mould (mycelium) is found in the centre of each spot. In about 3 weeks, the whole pod is covered, while chileos (baby cocoa pod) are covered within 3-4 days. The whole pod turns black while the chileo becomes shriveled

Spread/Etiology. The mycelia contain many millions of spores which are tiny and light. The spores are splashed during rainfall and thus spread. The spores do not germinate unless the conditions are right—the climate is humid.

Control:

- Use of chemicals—fungicides. e.g. Copper sulphate, Bordeaux mixture, Perenox, Perepod, Lime on Carbide.
- Removal of infected pod and burn or bury.
- Reduction of humidity through pruning.

2. Swollen Shoot

This is a virus disease caused by *Pseudococcus njalensis* and *Pseudococcus citri*; *Ferisiana vulgata* or *Ferisiana valensis* .The virus is transmitted by mealy bug. The virus is prevalent on Sterculiaceae family—cacao and cola.

Symptoms:

- Swellings on roots and branches
- Stunted growth.
- Leave necrosis and chlorosis
- Small and roundish pods

Control

i. Elimination of infected trees.
ii. Elimination of surrounding healthy trees within a radius of 5-15 metres of the infected tree.
iii. Elimination of vectors.

3.5.5. FERTILIZER APPLICATION.

Where the soil fertility is in doubt, complete fertilizer can be applied. The recommended complete fertilizer is 15-15-5 or 15-15-10. An old mature plantation however needs lots of phosphorus to maintain high level fruit level. Where complete fertilizers are not available, phosphorus is recommended

Phosphorus requirement for growing cocoa

Phosphorus is vital for the growth processes of cocoa trees but only a small quantity is required. In most soils, incorporation of phosphate in planting holes gives a significant improvement in early growth.

One reference suggests that cocoa growing soils must have certain anionic and cationic balances, including:

'The optimum total nitrogen/total phosphorus ratio should be close to 1.5, with the assimilable phosphorus content being at least equal to 180ppm of P or 0,229 per thousand of P2O5.'

Another reference estimates the phosphorus requirements of cocoa plants (based on 1,075 trees per hectare) as follows:

Stage of plant development	**Range of age of plants (months)**	**Average P requirement in kg per hectare**
Seedling	5-12	0.6
Immature	28	14
First year production	39	23
Mature	50-87	48

Phosphorus deficient plants show signs of stunted growth. The mature leaves are paler at the tips and margins which is followed by tip and marginal scorch. Young leaves are reduced in size, often showing interveinal pallor, and are at an acute angle with the stem.

Student Self-Assessment Exercise 3

1. Identify the major nursery operations in the raising of cocoa seedlings
2. Explain any four of the operations.
3. Why is shade management important in cocoa nursery?
4. Why is ‘insitu’ planting not encouraged in cocoa production?

3.3.6. Harvesting and processing of cacao fruits

How long does it take for a cocoa pod to be ripe?
After successful pollination of the flowers the fruits containing the beans, known as cocoa pods, take 5 to 6 months to ripen.

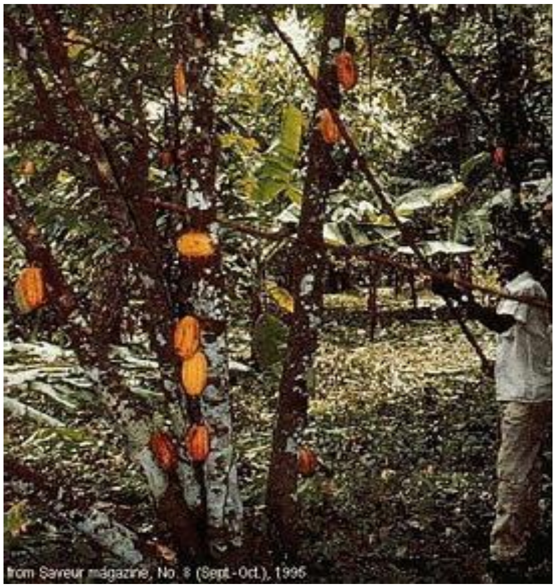
Harvesting of cacao pods.

Pods containing cocoa beans grow from the trunk and branches of the cocoa tree. Harvesting involves removing ripe pods from the trees and opening them to extract the wet beans.

Pods are suitable for harvest for 3 to 4 weeks, after which time the beans begin to germinate. It is therefore necessary to harvest at regular intervals as the pods do not all ripen at the same time. The frequency of harvesting can have an effect on yield.

The pods are harvested manually by making a clean cut through the stalk with a well sharpened blade. For pods high on the tree, a pruning hook type of tool can be used with a handle on the end of a long pole. By pushing or pulling

Cross-section of cocoa farm (pod beingharvested with hook)



according to the position of the fruit, the upper and lower blades of the tool enablethestalkto be cutcleanlywithoutdamaging the branch which bears it.

During harvesting it is important ***not to damage*** the **flower cushion** which will produce the flowers and fruits of subsequent harvests, and care must be taken not to damage the tree, which would make it easy for parasitic fungi to penetrate the tissues of the tree. The ripe pods are opened to remove the beans within a week to 10 days after harvesting.

Harvested Cocoa pods, some depulped(right- hand side)

stopped In general the harvested pods are grouped together and split either in or at the edge of the plantation. Sometimes the pods are transported to a fermentary before splitting. If the pods are opened in the planting areas the discarded husks can be distributed throughout the fields to return nutrients to the soil. The best way of opening the pods is to use a wooden club which, if it strikes the central area of the pod, causes it to split into two halves; it is then easy to remove by hand the beans. A cutting tool, such as a machete, is often used to split the pod though this can damage the beans. Some machinery has been developed for pod opening but smallholders in general carry out the process manually.

After extraction from the pod, the beans undergo a fermentation and drying process before being bagged for delivery.

Fermentation processes in cocoa.

Fermentation can be carried out in a variety of ways, but all methods depend on removing the beans from the pods and heaping them together to allow micro-organisms to develop and initiate the fermentation of the pulp surrounding the beans.

On smallholdings, fermentation is usually done in heaps of beans enclosed by plantain or banana leaves. Heaps can be used to ferment any quantity from about 25kg to 2,500kg of cocoa beans. The fermentation usually lasts about five days and some farmers will mix the beans on the second or third day. Another smallholder method is to use baskets, lined and covered with leaves, to ferment the beans. Similarly, holes or small depressions in the ground can be used but this makes no provision for the juices to drain away.

In plantations or fermentaries, fermentation is normally carried out in large wooden boxes that typically hold 1 to 2 tonnes of beans. The boxes must have provision for the liquefied pulp to drain away and for entry of air. Boxes can measure 1m x 1m by 0.75m deep (3ft to 5ft across and be 3ft deep), but shallow levels –0.5m (10-20 inches) of beans are preferred to promote good aeration. The beans can be covered with banana leaves or sacking to conserve the heat generated during fermentation. Beans can be transferred from one box to another each day to ensure uniform fermentation and increase aeration. The boxes can be tiered to allow easy transfer of beans. Plantations usually ferment for a longer period than smallholders and 6 to 7 days is usual.

In some areas, where particularly acidic beans are produced, the beans are pressed prior to fermentation to reduce the amount of pulp and allow for better aeration of the beans and so reduce the acidity.

The fermentation process begins with the growth of micro-organisms. In particular, yeasts grow on the pulp surrounding the beans. Insects, such as the *Drosophila melanogaster* or vinegar-fly, are probably responsible for the transfer of micro-organisms to the heaps of beans. The yeasts convert the sugars in the pulp surrounding the beans to ethanol. Bacteria then start to oxidise the ethanol to acetic acid and then to carbon dioxide and water, producing more heat and raising the temperature. The pulp starts to break down and drain away during the second day. Lactic acid, which converts the alcohol to lactic acid in anaerobic conditions, is produced but, as the acetic acid more actively oxidises the alcohol to acetic acid, conditions become more aerobic and halt the activity of lactic acid. The temperature is raised to 40oC to 45oC during the first 48 hours of fermentation. In the remaining days, bacterial activity continues under increasing aeration conditions as the pulp drains away and the temperature is maintained. The process of turning or mixing the beans increases aeration and, consequently, bacterial activity. The acetic acid and high temperatures kill the cocoa bean by the second day. The death of the bean causes cell walls to break down and previously segregated substances to mix. This allows complex chemical changes to take place in the bean such as enzyme activity, oxidation and the breakdown of proteins into amino acids. These chemical reactions cause the chocolate flavour and colour to develop. The length of fermentation varies depending on the bean type, Forastero beans require about 5 days and Criollo beans 2-3 days.

Following fermentation the beans are dried. The oxidation reactions begun through fermentation continue during drying.

Roles of yeasts in the cocoa fermentation process.

Cocoa pods are harvested and split open to release the beans. The beans are embedded in a pulp. When the pods are broken, the beans and pulp are sterile but they become contaminated with a variety of microrganisms from the pods, labourers' hands, insects, vessels used for transport, etc.

The pulp surrounding the beans undergoes a fermentation process which develops the colour and flavour of the beans. The initial anaerobic, low pH and high sugar conditions of the pulp favour yeast activity. Some research has found 24 strains of yeast on fermenting cocoa, but research by Rombouts identified 16 species. The fermentation process begins with yeasts converting sugars in the pulp to alcohol and carbon dioxide. Bacteria then start oxidising the alcohol into lactic acid and then, as conditions become more aerobic, acetic acid. This produces heat and raises the temperature in the first 24 hours. As the pulp breaks down and drains away, bacteria continue to be active until fermentation is complete.

The yeasts found during cocoa fermentation come from the surrounding environment, eg soil, trees etc. The species most frequently found at this stage are the Saccharomyces spp (in particular S. cerevisiae, Candida krusei, Kloeckra apiculata, Pichia Fermentans, Hansenula anomola and Schizo-saccharomyces pombe). Research by Hansen and Welty shows that yeasts multiply very rapidly during fermentation and are able to survive drying and storage. One can find up to 107 yeast/gram in stored beans.

Drying cocoa beans

Cocoa beans are dried after fermentation in order to reduce the moisture content from about 60% to about 7.5%. Drying must be carried out carefully to ensure that off-flavours are not developed.

Drying should take place slowly. If the beans are dried too quickly some of the chemical reactions started in the fermentation process are not allowed to complete their work and the beans are acidic with a bitter flavour. However, if the drying is too slow, moulds and off-flavours can develop. Various research studies indicate that bean temperatures during drying should not exceed 65oC.

There are two methods for drying beans - sun drying and artificial drying.

For sun drying, the beans are spread out on mats, trays or on concrete floors in the sun. In some countries in the West Indies and South America drying takes place on wooden drying floors with moveable roofs. The beans are normally turned or raked to ensure uniformity of drying and the beans need to be covered when it rains. Sun drying is used in countries where harvesting occurs in a dry period such as West Africa or the West Indies. With adequate sunshine and little rainfall, sun drying may take about one week, but if the weather is dull or rainy it will take longer.

Artificial drying may be resorted to in countries where there is a lack of pronounced dry periods after harvesting and fermentation, such as Brazil, Ecuador and in South East Asia and sometimes in West Africa. Artificially dried beans can be of poor quality due to contamination from the smoke of fires or because the cocoa is dried too quickly.

The simplest forms of artificial driers are convection driers or Samoan driers which consists of a simple flue in a plenum chamber and a permeable drying platform above. Air inlets must be provided in order to allow the convection current to flow without allowing smoke to taint the beans. These driers are simple to construct and have been used in Western Samoa, Cameroon, Brazil (the Secador drier) and the Solomon Islands.

Other artificial driers are platform driers using heat exchangers, where the hot air is kept separate from the products of combustion which pass to the atmosphere, or direct fired heaters, where the products of combustion mix with the hot air and are blown through the beans. These driers can use oil or solid fuels as a source of power. The addition of a fan forces the hot air through the beans and creates a forced draught dryer.

Another type of dryer uses conduction. Drying platforms built of slate or cement are heated at one end by a fire or heat source. Small versions of these using oil drums with flues embedded in cement were used in Cameroon at one time and were known as Cameroon Dryers. Heat distribution is not uniform with this type of dryer.

Other techniques have been used in association with the above to overcome the problem of turning or raking the beans in the dryer - stirring the beans in a circular bed or turning the beans in a rotary drum.

Time and types of cocoa harvests

The cocoa harvest is not confined to one short period but is spread over several months once or twice a year. The timing of the cocoa harvest varies from country to country, depending on the climate and the variety of cocoa. In countries with a pronounced wet and dry season, the main crop occurs 5-6 months after the start of the wet season.

The percentage of crop harvested in the Main Crop (MC) season and the Light-Crop (LC) season will vary from country to country. The biggest differential between main and mid/light crop harvests is in Africa where the light-crop accounts for about 15%-20% of the total harvest; in other countries the differential is not so obvious.

The following table gives an idea of the main and mid -crop seasons in selected countries.

Country	**Main crop**	**Mid/Light crop**
Brazil	Oct-Mar	Jun-Sep
Cameroon	Sep-Feb	May-Aug

Colombia	Apr-Jun	Oct-Dec
Costa Rica	Jul-Feb	Mar-Jun
Côte d'Ivoire	Oct-Mar	May-Aug
Dominican Republic	Apr-Jul	Oct-Jan
Ecuador	Mar-Jun	Dec-Jans
Ghana	Sep-Mar	May-Aug
Grenada	Apr-Nov	Dec-Mar
Haiti	Mar-Jun	Jul-Feb
Indonesia	Sep-Dec	Mar-Jul
Malaysia	Oct-Dec	Apr-May
Mexico	Oct-Feb	Mar-Aug
Nigeria	Sep-Mar	Jun-Aug
Panama	Mar-Jun	Jul-Feb
Papua New Guinea	Apr-Jul	Oct-Dec
Sri Lanka	Nov-Feb	Mar-Oct
Togo	Oct-Mar	Apr-Sep
Trinidad	Dec-Mar	Apr-Nov
Venezuela	not known	Mar-Sep
Zaire	Oct-Mar	Apr-Sep

Sources: G.A.R. Wood, R.A. Lass, Cocoa. Longman, 4th Edition, 1985)
Cocoa to 1993: a commodity in crisis. Economist Intelligence Unit, 1993,
p34 Gordian 57 (1958)

Student Self-Assessment Exercise 4

1. When should harvesting start in a well maintained cocoa plantation?
2. Discuss the processing of cocoa from harvesting to grading.
3. What are the qualities of first grade cocoa beans?
4. How does the processing of cocoa affect the quality of the beans?

3.7. GRADING, STORAGE and MARKETING OF DRY COCOA BEANS

3.7.1. Checking the quality of cocoa and its marketing

The quality of cocoa is checked through sampling.

The sampler selects at random a significant percentage of the bags for inspection and a stabbing iron is used to draw a number of beans from the selected bags. Or, if the cocoa is in bulk, samples are taken at random from the beans as they enter a hopper or as they are spread on tarpaulins.

Different authorities may set a differing level of beans/samples for inspection. The International Standard recommends that the samples should amount to not less than 300 beans for every tonne of cocoa. For bagged cocoa, samples should be taken from not less than 30% of the bags, and for bulk cocoa there should be not less than 5 samplings per tonne.

The samples are analysed using the cut test. Most exporting countries' authorities specify standards dependent on the International Standards Organization cut test, as do normal physical cocoa contracts. The cut test provides an assessment of the beans from which analysts may infer certain characteristics of the cocoa, which gives an indication of quality.

The cut test involves counting off 300 beans. These 300 beans are then cut lengthwise through the middle and examined. Separate counts are made of the number of beans which are defective in that they are mouldy, slaty, insect damaged, germinated or flat. The results for each kind of defect are expressed as a percentage of the 300 beans examined. The amount of defective beans revealed in the cut test gives manufacturers an indication of the flavour characteristics of the beans.

Bean counts are another measure of quality that producing countries often use, though there is no internationally accepted bean size classification. The Federation of Cocoa Commerce defines the following method for bean counts: A sample of not less than 600 grammes of whole beans, irrespective of size but not including flat beans, will be counted to obtain the number of beans per 100 grammes. The Ministry of Agriculture through the Produce Inspection Unit is responsible for Quality Control in Nigeria.

Further tests are carried out by chocolate manufacturers and cocoa processors, particularly for beans from origins that are inconsistent in quality or prone to off flavours. The manufacturer cannot sift out all the defective beans and so must ensure good quality at the selection stage. Consistency in quality for the production of cocoa mass cannot be achieved when using one source of cocoa beans because of the large natural variability which exists in each lot. The differences can be reduced by having a number of different types and lots of cocoa beans of known quality in stock and making an appropriate blend. Strict control of the roasting and alkalising processes is also required to produce the best quality.

For the chocolate manufacturer the yield of nib is very important, as is the amount of cocoa butter in the nib. Higher levels of cocoa butter mean that lower levels will need to be added later on in the manufacturing process. Nib yields are determined in the laboratory.

Flavour is also important for chocolate manufacturers. Flavour assessment is normally carried out by panels of between five and ten experienced tasters. Off flavours can readily be detected by tasting roasted ground nib of cocoa liquor directly or they can be mixed with sugar and water to make a basic dark chocolate before tasting. Mouldy and smoky off flavours and excessive bitterness cannot be removed during processing. Acid tastes can be altered in processing through neutralisation.

Sub standard beans can be pressed whole to produce expelled cocoa butter which is then refined. Better quality beans are deshelled before pressing to produce pure pressed cocoa butter and cocoa press cake (which ultimately becomes cocoa powder). Chocolate manufacturers have a number of requirements with respect to the quality of cocoa butter: hardness, melting and solidification behaviour.

COCOA TRADE ASSOCIATIONS

Cocoa trade associations and national authorities produce standards or gradings for cocoa beans covering the bean count per 100g and the percentage of permitted faults, moisture and foreign matter, and the International Standards Organization provides a specification for cocoa beans.

Trade associations

i. The Federation of Cocoa Commerce Ltd
Cannon Bridge House
1 Cousin Lane
London
EC4R 3XX
UNITED KINGDOM
Tel: (020) 7379 2884
Fax: (020) 7379 2389
Website: http://www.cocoafederation.com/

ii. Cocoa Merchants Association of America
26 Broadway - Suite 707
New York
NY 10004-1703
USA
Tel: (212) 3637334
Fax: (212) 3637678
Website: http://www.cocoamerchants.com/

International organisations

Food and Agriculture Organization - Model Ordinance
International Standards Organization - ISO 2451

National authorities

Brazil - National Foreign Trade Council
Cameroon - ONCC
Congo - ONCC
Côte d'Ivoire - Ministry of Agriculture
Dominican Republic - Cocoa Department, Ministry of
Agriculture Ecuador - Ministry of Industry, Commerce Ghana -
Ministry of Agriculture
Indonesia - Indonesian Cocoa Association
Malaysia - Federal Agricultural Marketing Authority/Malaysian Cocoa Board

Nigeria - Federal Produce Inspection Service
Papua New Guinea - Papua New Guinea Cocoa Board
Sierra Leone - SLPMB
Solomon Islands - Commodities Export Marketing Authority
Vanuatu - Dept of Agriculture
USA - 21 Code of Federal Regulations, Food and Drug Administration (FDA)
Western Samoa - 1989 Cocoa Act

3.7.2. Factors to consider in the storage of cocoa beans in order to minimize risk

- The warehouse should have cement or non-flammable floors without cracks and crevices for insects to hide in;
- Ideally the floor level should be higher than the surrounding land to prevent flooding and to allow water to flow away;
- Walls should be of non-flammable material without cracks and crevices;
- Adequate ventilation is necessary to prevent an increase in mould;
- The roof should be insulated but should not be made of wood;
- Bags may be bulk-stowed but ideally the bottom layer should be on pallets allowing an air space of 5-10cm and the top layer should be at least 1m away from the roof. The stacks should also be positioned away from outside walls;
- Fumigation and other forms of insect control can be carried out to ensure that the products are pest-free;
- The cocoa should be regularly inspected;
- No other products should be stored with the cocoa to prevent contamination;
- Access to the storage areas can be controlled.

Source:ICCO 2006

Processing of Dried Cocoa beans

During the subsequent processing of the cocoa beans the beans are cleaned and can then undergo a form of thermal pre-treatment to separate the shell from the bean. One form of thermal pre-treatment uses infra- red technology in which the beans undergo infra-red radiation on a fluidised bed or vibrating conveyor. Water accumulates on the surface of the bean and bursts the shell. The high surface temperature induced by this process brings about a drop in the amount of microbiological contamination, especially yeast and other fungi.

The beans are then separated from the shells and roasted. Following roasting the beans are turned into **cocoa mass** by grinding.

The quality of the cocoa mass is important due to the natural variability which exists in cocoa. Quality criteria for cocoa mass include figures for the number of yeasts found per gram - maximum 50, and for alkalised cocoa powder - a normal maximum of 50 with a limit of 100.

3.8. Products of Cocoa

Physical and chemical information on cocoa beans, butter, mass and powder

The physics and chemistry of cocoa beans and cocoa products is very complex and changes throughout the life of the bean, depending on the processing it receives.

The following gives an indication of the changes in the bean through its life, together with some references that give further more detailed information on the physics and chemistry of cocoa beans.

Cocoa beans

Cocoa beans are the seeds of the tree Theobroma cacao. Each seed consists of two cotyledons (the nib) and a small embryo plant, all enclosed in a skin (the shell). The cotyledons store the food for the developing plant and become the first two leaves of the plant when the seed germinates. The food store consists of fat, known as cocoa butter, which amounts to about half the weight of the dry seed. The quantity of fat and its properties such as melting point and hardness depend on the variety of cocoa and the environmental conditions.

The seeds are fermented which causes many chemical changes in both the pulp surrounding the seeds and within the seeds themselves. These changes cause the chocolate flavour to develop and the seeds to change colour. The seeds are then dried and despatched to processors as the raw material for the production of cocoa mass, cocoa powder and cocoa butter. The first stage of processing includes roasting the beans, to change the colour and flavour, and shell removal. After roasting and deshelling an alkalising process can take place, to alter flavour and colour.

One analysis of the chemical composition of beans after fermentation and drying is as follows:

	Nib % Maximum	Shell % Maximum
Water	3.2	6.6
Fat (cocoa butter, shell fat)	57	5.9
Ash	4.2	20.7
Nitrogen		
Total nitrogen	2.5	3.2
Theobromine	1.3	0.9
Caffeine	0.7	0.3
Starch	9	5.2
Crude fibre	3.2	19.2

This gives an indication of the chemical composition of the bean but it must be remembered that this will vary depending on the type of bean, the quality of the fermentation and drying and the subsequent processing of the bean.

Cocoa mass or liquor

Cocoa mass is produced by grinding the nib of the cocoa bean. The quality of the cocoa liquor will depend on the beans used. Manufacturers often blend different types of beans to gain the required quality, flavour and taste. The cocoa liquor can undergo further roasting and alkalisation to alter the colour and flavour which will also alter its chemical composition.

Cocoa butter

The fat or cocoa butter can be extracted from the bean in a number of ways. Pure press butter is extracted from the cocoa mass by horizontal presses. Sub-standard cocoa beans can be pressed without deshelling by using continuous expeller presses. Pure press butter needs no cleaning but it is often deodourised. A solvent extraction process can be used to extract butter from the cake residue left after the expeller process; this type of butter must be refined.

Cocoa butter obtained by pressing the cocoa nib exhibits the following properties: brittle fracture below 20ºC, a melting point about 35ºC with softening around 30-32ºC.

Cocoa butter is composed of a number of glycerides. Two studies established that the percentage of the constituent glycerides is as follows:

Glycerides	Percentage
Trisaturated	2.5 to 3.0
Triunsaturated (triolein)	1.0
Diunsaturated	
Stearo-diolein	6 to 12
Palmito-diolein	7 to 8
Monounsaturated	
Oleo-distearin	18 to 22
Oleo-palmitostearin	52 to 57
Oleo-dipalmitin	4 to 6

Cocoa powder

Cocoa powder is formed from the cocoa mass. Presses are used to remove some of the fat and leave a solid material called cocoa press cake. These cakes are then crushed to form cocoa powder. The processing can be altered to produce cocoa powders of different composition and with different levels of fat.

An indication of the composition of cocoa powder is as follows, but it must be remembered that this will be different depending on the roasting, alkalisation and pressing processes undertaken:

Components	Percentage
Moisture %	3.0
Cocoa butter	11.0
pH (10% suspension)	5.7
Ash %	5.5
Water soluble ash %	2.2
Alkalinity of water soluble ash as	
K2O in original cocoa %	0.8
Phosphate (as P2O5) %	1.9
Chloride (as NaCl) %	0.04
Ash insoluble in 50% HCl	0.08
Shell % (calculated to unalkalised nib)	1.4
Total nitrogen	4.3
Nitrogen (corrected for alkaloids) %	3.4
Protein	
Nitrogen corrected for alkaloids x 6.25 %	21.2
Theobromine %	2.8

3.8.2. Products that can be made from cocoa

Many different sorts of products can be derived from cocoa.

The husks of cocoa pods and the pulp, or sweatings, surrounding the beans and the cocoa bean shells can be used. Some examples of these uses are:

Animal feed from cocoa husk - As pelletised dry 100% cocoa pod husk, it can be used as an animal feed. The animal feed is produced by first slicing the fresh cocoa husks into small flakes and then partially drying the flakes, followed by mincing and pelleting and drying of the pellets.

Production of soft drinks and alcohol - In the preparation of soft drinks, fresh cocoa pulp juice (sweatings) is collected, sterilised and bottled. For the production of alcoholic drinks, such as brandy, the fresh juice is boiled, cooled and fermented with yeast. After 4 days of fermentation the alcohol is distilled.

Potash from cocoa pod husk - Cocoa pod husk ash is used mainly for soft soap manufacture. It may also be used as fertiliser for cocoa, vegetables, and food crops. To prepare the ash, fresh husks are spread out in the open to dry for one to two weeks. The dried husks are then incinerated in an ashing kiln.

Jam and marmalade - Pectin for jam and marmalade is extracted from the sweatings by precipitation with alcohol, followed by distillation and recycling of the alcohol in further extractions.

Mulch - Cocoa bean shells can be used an organic mulch and soil conditioner for the garden.

Once the beans have been fermented and dried, they can be processed to produce a variety of products. These products include:

Cocoa butter - Cocoa butter is used in the manufacture of chocolate. It is also widely used in cosmetic products such as moisturising creams and soaps.

Cocoa powder - Cocoa powder can be used as an ingredient in almost any foodstuff. For example, it is used in chocolate flavoured drinks, chocolate flavoured desserts such as ice cream and mousse, chocolate spreads and sauces, and cakes and biscuits.

Cocoa liquor - Cocoa liquor is used, with other ingredients, to produce chocolate. Chocolate is used as a product on its own or combined with other ingredients to form confectionery products.

3.8.3. Information on the flavour assessment/tasting and of chocolate

Assessment of flavour can take place at the cocoa liquor stage or when made up fully into chocolate. Liquor tasting allows the tasting to be done without the addition of cocoa butter, sugar and milk products which dilute the taste impression. Tasting can be carried out by a panel of tasters. Samples are evaluated for strength of cocoa or chocolate flavour, residual acidity, bitterness and astringency, and off-flavours.

***Off-flavours*: causes and effects**

- Can arise from the presence of mould in the beans which gives a mouldy/musty flavour to the chocolate.
- Can arise from contamination by wood smoke during drying or storage which gives a characteristic smoky off-flavour. This flavour is often reminiscent of smoke cured bacon.
- An acid taste can arise through excessive acidity developing during fermentation and it generally inhibits the chocolate flavour from developing
- Bitterness is part of the chocolate flavour but it becomes a problem if it is excessive. Bitterness and astringency are caused by poor fermentation or poor planting materials.

- Cocoa beans can absorb flavours from other products such as rubber, oil based paints etc. during storage and transport.

The International Confectionery Association (ICA), formerly the International Office of Cocoa, Chocolate and Sugar Confectionery (IOCCC), have a procedure for identifying flavour defects and off-flavours in cocoa liquor. It is a test that can be carried out by a panel of five to ten people and does not require any specialised training or equipment. The ICA can be contacted at: 1 rue Defacqz, B1000 Brussels, Belgium. Tel; +32 (2) 539 18 00 Fax: +32 (2) 539 15 75

Student Self-Assessment Exercise 5

1. What are the products derivable from cocoa beans?
2. What are the uses of cocoa bean product?

4.0. CONCLUSION.

The cocoa tree is very particular about where it is grown. It grows almost exclusively from 10 degrees north of the equator to 10 degrees south of the equator, an area known as the tropical belt; and because it is rather narrow, the number of countries in which it may be grown productively is very limited. Today, the top ten producing cocoa-growing countries are (in order) the Ivory Coast, Ghana, Indonesia, Nigeria, Brazil, Cameroon, Ecuador, Dominican Republic, New Guinea, and Malaysia. Interestingly, the Ivory Coast grows more cocoa than the next six producers combined. It is from the Ivory Coast that most of the world's consumer and industrial grade cocoa originates.

The cocoa tree is actually quite forgiving in the amount of rain it requires. Anywhere from 45 to 200 inches of rain is typical in cocoa growing regions. The trees may be grown in areas that have less rain, but in these cases, irrigation is needed to provide adequate water. While cocoa trees will grow in areas with relatively low humidity and rainfall, the cocoa tree is sensitive to wide fluctuations in temperature or humidity, so they must be grown in areas where weather is consistent. Furthermore, cocoa trees are very susceptible to wind, because their branches break easily. Strong winds will quickly tear through a cocoa plantation, breaking trees and destroying fruit. To avoid this, many plantations build windbreaks to assist in sheltering the cocoa trees from possible harsh winds.

The rich, bush soil found in cocoa-growing regions and the varying amounts of rain available to cocoa crops are but two of the key factors responsible for creating cocoa's widely varying and unique flavours. Just as flavors in wine are dependant on when the grapes are harvested, the flavours of the cocoa bean will vary depending on whether the cocoa was harvested in the fall or spring season. The amounts of rain and sun the cocoa tree receives, in addition to the nutrients found in the rich tropical soil, are like the paint and brushstrokes through which the flavours of the cocoa are enjoyed.

Varieties

Much can be said about cacao tree varieties. Most references divide them into three groups: *Criollo* (pronounced cree-yo-yo), *Forastero*, and *Trinitario*. This view, though simplistic, is helpful in our discussion.

Beside the fact that many botanists disagree about these incredibly broad classifications, it must be remembered that cacao is grown in regions where the growers are generally not interested in these distinctions. For them, cacao is a cash crop they use to feed their families. When a tree dies on their plantation, a new tree is planted, and rather than being obtained from a nursery or government- or university-sponsored cacao gene bank, the genetic material is usually obtained from another tree on the same or neighboring plantation. Very often the variety is not given much consideration; instead other factors are considered more important, such as what is convenient, how many pods a cacao tree produces, as well as the number of seeds in a cacao pod.

Because of all this, many if not most plantations have a mix of genetic material, and thus it becomes almost impossible to specify what variety or varieties a plantation has on hand. When the cacao beans are harvested from a tree, they are mixed with beans that have been harvested from other trees as well. This is one of the reasons why, as far as the chocolate manufacturer is concerned, it is better to think of each plantation as having its own unique genetics.

The current classification system, criollo, forastero, or trinitario, originated from Venezuela well over 100 years ago, and just mentioned, it is showing its age. Venezuela has long been known for providing some of the highest quality cocoa beans. In fact, Venezuela was the first country to provide cocoa beans to the European cocoa markets. At the time, there was a wide variety of cocoa trees found throughout Venezuela's plantations. While the cocoa pods were of great variety in shape and color, they had two main things in common. The cocoa beans had a plump, almost round cross-section before they were fermented and dried. Further, the quality of the beans was excellent compared to quality found elsewhere.

In order to differentiate between the native varieties of cacao and the new varieties, the native cacao was called *Criollo* (native), while the new cocoa was called *Forastero* (foreign), and *Trinitario* (from Trinidad). The terms continue to be used in trade until today, even though their meanings have shifted slightly over time.

Criollo

Criollo cacao typically has red or yellow pods, some being green or white (as in the case of Porcelana). The pods have bumpy or warty skin with pointed tips.

The beans, on the other hand, vary from light purple to white in color, and they are plump and full. In general, the beans from criollo cacao are considered to have a finer flavor than that of other varieties of cacao.

The criollo trees are not very disease-resistant, and hence they are hard for farmers to grow and keep healthy.

Typically when chocolate is made from the criollo beans, the chocolate is not overly rich, though the resulting chocolate will have a complex flavor that is often reminiscent of various fruits and spices. Criollo beans are therefore considered to be "flavor beans" because of their heightened flavor characteristics.

Forastero

Today, Forastero mainly refers to cacao that has its ancestry from the upper Amazon basin. Through trade, this cacao has been spread throughout much of the cacao-growing world, including Africa. Today, the largest producers of cocoa beans are the Ivory Coast and Ghana, where forastero was established very early in the cocoa trade. Because of this and the disease resistance of this variety, the top producing countries primarily grow forastero. Most of the chocolate produced in the world today is made from forastero beans.

The hull of the cocoa pod, rather than being deeply furrowed with a knobby skin and pointed pod, as the criollo pods are, are relatively smooth, with more of a bulbous pod shape. In addition, the hull is also woodier than the criollo, and thus the pods are harder to open. The pods may also be red or yellow, as well as orange or purple. The beans themselves are very dark purple and are relatively flat compared to those of the criollo.

Unlike the criollo, the Forastero varieties are much more hardy and disease-resistant. Because of this, they are favored by farmers who, while they may not be able to command as high a price for the resulting beans, they are guaranteed of a much more saleable crop.

Trinitario

As the name implies, the trinitario originates from the island nation of Trinidad. Today, trinitario along with criollo provides the basis for "flavor beans," used to enhance the flavor of today's chocolate.

As with forastero, trinitario cocoa pods are typically not pointed, and the skin of the pods is relatively smooth (compared to that of the pods of the criollo). The cocoa beans are also flat and purple when cut in half.

It is worth mentioning that as with forastero, trinitario has spread throughout the world as a major cocoa crop. Even so, the quantities of forastero grown dwarf to those of trinitario.

One of the major sites of the original planting of Trinitario was Sri Lanka (Ceylon), where it became famous for its fine flavor. Trinitario was first planted in Ceylon in 1834, and then again planted in 1880. During that same time period, it was transplanted to Fiji, Madagascar, Samoa, Singapore, and Tanzania.

Today, trinitario is highly sought after by chocolatiers worldwide for its fine flavor and is used both to provide flavor for chocolate created from "bulk beans" as well as to create super-premium chocolate when used by itself.

Cocoa Flowers

Incredibly delicate, in addition to having a complex structure, the cacao flower is one of the most beautiful flowers in the world. It does take a keen eye, however, to appreciate them, because they are very small—only about 10-12mm in diameter. Unlike most flowers, they grow directly from the trunk of the tree or from the body of the branches; when the tree is in bloom, the trunk and branches are covered with literally thousands of tiny, yet beautiful cocoa flowers.

It is interesting to note that the cacao flower's beauty does not extend to its scent. In fact, if you are waiting for some enterprising chocolate company to come out with perfume you will have to wait a very long time. The reason is simply that the cacao flower has no smell. It is also for this reason that bees and other pollinating insects do not fertilize the cacao flowers but instead leave pollination to other insects.

Pollination of the cacao flower occurs by the actions of midges and other jungle insects. Midges are a type of gnat that live on the jungle floor under leaves and other debris. When they fertilize the cocoa flower, it is not through attraction by the flower by either scent or nectar (because there isn't any of either) but simply through random chance. It is perhaps for this reason that the cocoa tree is furnished with the massive quantities of flowers that it is. It has been estimated that on average only one out of one hundred (1%) cacao flowers will become fertilized and grow into a cocoa pod. It is interesting to think how the lowly midge (or gnat) is responsible for fertilizing the cacao tree and creating one of the world's greatest foods.

Cocoa Pods

If the flower is fertilized and conditions are perfect, the cacao flowers will start to grow into cacao pods. Even at this stage, a pod is not guaranteed. The vast majority of pods that start to develop will grow until they are a few inches long' then if the conditions are still not just right, the pod will die.

The baby cocoa pod is called a *chileo* because it looks like a baby chili. For one reason or another, many cocoa pods do not make it past the chileo stage. Everything must be perfect in order for the cocoa tree to develop a cocoa pod to full maturity. As the cocoa pod grows and develops, it will begin to take on one of a wide variety of possible shapes and colors.

Cocoa pods are shaped a bit like an American style football. They can be smooth, wrinkly, or warty. They can be long and pointed, or they can be bulbous, like a melon or papaya. The colors of cocoa pods are equally as great. Colors such as red, purple, yellow and green are common. There are even white cocoa pods from the rare Porcelana variety (though the name refers to the white cocoa beans, not the pod itself).

Technically, the cocoa pod is considered to be a berry. Each pod contains on average between 20-40 beans with the vast majority producing between 38 to 40 beans. The cocoa pod itself is relatively hard—especially when compared to other berries. The pod has a soft wooden-like shell approximately 8-10mm (one quarter of an inch) thick. While hard, the shell may be easily broken open with the use of a machete or by hitting the pod sharply with a heavy stick or rock. Each bean is surrounded by white mucilage-like material that many call a *placenta*. It is sweet, yet bitter, like a very sweet and yet mild floral lemon. On a hot day in the cocoa field, the workers often suck it off the bean as a refreshing treat. During fermentation, the mucilage material -like placenta undergo thermal decay with the liquid content turning alcoholic through the activities of yeasts

Propagation

There are two main forms of propagation for cocoa trees. In the first, the cacao pods may be harvested and their seeds used to plant new trees. The cacao tree is unique in that the cacao seeds begin to germinate at the time the pods are picked from the tree. Planting from the seed helps preserve genetic diversity among the crop. However, this can be a problem on plantations where multiple varieties of cacao trees are present in close proximity. Because it is possible for pollen from neighboring cacao trees to fertilize the pods on the tree that is being propagated, it is likely that its cacao pods will carry a variety of genetic material. In addition, having a wide genetic diversity makes judging when cocoa pods are ripe difficult. Since cocoa trees typically have a wide variety in the shapes, sizes and colors of their pods, judging when the pods are ripe can be difficult. Having a narrow genetic diversity helps the farmer, since all the trees behave the same and the farmer can simply learn how "one" tree ripens, instead of having to remember how individual trees throughout an entire plantation ripen.

To avoid these problems, many farmers instead prefer to propagate the cacao trees through cuttings. The most common form is through the use of grafting. In this case, a cutting is removed from the tree that is being propagated. A bud is found on the branch that has been removed for cuttings. The bud is typically at a leaf juncture, and if the branch were to grow on its own, this would be where a new branch would form. The bud is cut off the branch by cutting the bark around it in the shape of an elongated diamond. The bud is carefully removed, while care is taken not to touch the newly exposed surface area.

A tree approximately 18 inches tall is chosen to be host to the cutting. This host tree may be virtually any variety, since in the end only the roots will be utilized, and for that reason it is called *rootstock* . Optimally, the host tree will be the same diameter as the branch from which the bud was cut. A grafting knife is used to make a cut in the shape of

a triangle in the bark of the host tree, and the bud is inserted. The grafting is placed about one - third of the way from the bottom of the rootstock. The area is now wrapped with grafting tape, which helps to keep the bud placed closely on the host tree, in addition to keeping it moist.

After a week, it is apparent whether the graft has taken or not; and after a month, if the graft has taken, it will be completely fused to the rootstock. At this point, the wrapping may be removed. As the graft grows, new growth on the rootstock is trimmed, forcing nutrients into the graft. As the graft grows, it is tied to the remaining "trunk" of the rootstock, where it is guided to grow parallel to the original trunk. Eventually, all the remaining growth from the original rootstock is trimmed. The remains of the trunk will eventually dry and drop off. Five to six months after the original grafting, the cocoa tree is ready for replanting.

Interestingly, cocoa trees grown from cuttings differ significantly from those grown from the bean. Trees grown from a planted bean tend to grow vertically and can achieve great heights (on the order of 25 feet or more), while those grown from grafts or other cuttings tend to grow outward. This benefits the farmer, because the cocoa pods are closer to the ground and the tree is easier to trim and otherwise shape.

Unfortunately, when trees are propagated through the use of cuttings, the overall genetic diversity of the crop is reduced. This is ordinarily not a problem. However, when one of the varieties of diseases infects one tree of a plantation, all the rest of the trees with similar genetics have a greater likelihood of infection.

In the wild, the cocoa pods do not naturally drop off the tree when they are fully ripe, nor do they break open to release the beans. Because of this, the cocoa tree is dependent on wild animals to break open the pods and scatter its seeds. Rats, monkeys, and squirrels, as well as other small animals, will break into the cocoa pods in order to eat the sweet mucilage placenta that surrounds each bean. The high levels of tannins in unfermented beans give them an astringent taste and make them generally unpalatable.

Cocoa pod whose beans have been removed

and spread on the bush floor by wild animals

After eating the bean's placenta, The animals, will scatter the astringent seeds on the forest floor and thus help guarantee another generation of cacao trees. It is fascinating to think that the cocoa beans the animals scatter carelessly on the jungle floor turn out in the end to be the real treasure.

5.0. Summary.

In this unit we discussed about the origin, botany and propagation of cacao. We learnt that cacao is the tree that bears the fruit known and called cocoa. Climatic and soil requirements for the cultivation of cacao were identified. World regions where cocoa trees are grown were described. Nursery and field operations that are critical to the cultivation of cacao were treated. Harvesting, processing, grading and storage of processed cocoa beans were equally treated. The chemical composition of cocoa beans as they affect chocolate flavour was treated.

6.0. Tutor Marked Assignment (TMA)

1.a..Describe nursery operations and nursery management. in

cocoa b.Describe fermentation in cocoa processing.

2.What relationship exists between cocoa breeds, cocoa processing and chocolate quality?

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MODULE 2: STIMULANT CROPS

UNIT 4: COFFEE

Contents

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UNIT 4: COFFEE

1.0 INTRODUCTION.

Coffee belongs to the family Rubiaceae and genus Coffea. Coffee is a small tree, usually reaching 2.5-5m (10-20ft) in height. It is a hardy plant that cannot be successfully grown where temperatures dip below freezing point of water (32F/00C) for any length of time. It may succeed marginally in subtropical areas. An optimum temperature range falls roughly between 200-360 C. Superior varieties can be propagated by cuttings and grafting, but coffee varieties usually come fairly true to seed, so seed is often used for propagation.

In this unit, we shall discuss Coffee as a tree crop grown in plantations in the tropics. First, we will trace the history, spread, and the botany of the crop. Then we shall discuss the agro-climatic and edaphic requirements for the growth and production of the crop. Nursery and field management operations including harvesting and partial processing of ripe fruits will be treated. Post -harvest management of coffee beans and their uses will be discussed.

2.0 . UNIT OBJECTIVES.

At the end of the unit, you should be able to:

- Distinguish coffee tree from other trees
- Identify the different species of coffee
- Describe the agro-climatic and edaphic requirements for the cultivation and production of coffee.
- Describe the nursery and field management operations necessary for the cultivation of coffee.
- Describe the Harvesting and Processing of coffee beans
- Identify the uses of coffee.

3.0 . SUBJECT-MATTER CONTENT

3.1. History of Coffee

The history of coffee can be traced to early 9th century, when it appeared in the ***highlands of Ethiopia***. Shepherds were the first to observe the influences of caffeine from the coffee beans when, after their goats consumed some naturally occurring coffee beans in the pasture, the goats appeared to 'dance' and have an increased level of energy. From Ethiopia, it spread to ***Egypt*** and ***Yemen,*** and by the fifteenth century had reached ***Persia, Turkey,*** and ***northern Africa***.

When coffee reached the American colonies, it was initially not as successful as it had been in Europe, as colonists found it a poor substitute for alcohol. However, during the Revolutionary War, the demand for coffee increased so much that dealers had to hoard their scarce supplies and raise prices dramatically; this was partly owing to the reduced availability of tea from British merchants. After the War of 1812, in which Britain had temporarily cut off access to tea imports, the Americans' taste for coffee grew during the early nineteenth century, and high demand during the American Civil War together with the advancements of brewing technology secured the position of coffee as an everyday commodity in the United States. Today coffee is a common beverage of the North American breakfast and morning commute.

3.2. BOTANY OF COFFEE

Coffee belongs to the family ***Rubiaceae*** and genus ***Coffea*** . There are two main species of the coffee plant, the older one being ***Coffea arabica*** while the second species is ***Coffea canephora (robusta).*** Coffee is indigenous to south-western Ethiopia, specifically from Kaffa, from which it may have acquired its name. ***Coffea arabica*** is more susceptible to disease, and considered by most to taste better than the second species, ***Coffea canephora (robusta).*** *Robusta*, which probably originated in Uganda, contains about 40– 50% more caffeine, can be cultivated in environments where *arabica* will not thrive. For this reason it is used as an inexpensive substitute for *arabica* in many commercial coffee blends. Compared to *arabica*, *robusta* tends to be bitter and has little flavor, with a telltale "burnt rubber" or "wet cardboard" aroma and flavour. Other species include

Coffea liberica and Coffea esliaca, believed to be *indigenous to* ***Liberia*** *and* ***southern Sudan*** *respectively*.

A peaberry, (also sometimes called a "Caracoli" bean) is a coffee bean that develops singly inside the coffee cherry instead of the usual pair of beans. This situation occurs 5– 10% of the time. Since flavour is concentrated when only a single bean is grown inside the cherry, these beans (especially Arabica) are highly prized.

Related Species

3.3. Agroclimatic and Edaphic Requirements

Climatic requirements

All of the coffee species require a tropical or semitropical climate and produce best when they receive 70 or more inches of rain annually. Elevations of 1067m-1829m (3,500 to 6,000 feet) produce the premium coffees. Notable exceptions do exist, such as the Hawaiian Kona coast and Molokai that have moderate climate conditions nearer sea level.

Alibertia edulis -- Marmelada
Coffea arabica -- Coffee
Coffea canephora-- Robusta Coffee
Coffea fadenii-- Wild *Coffee*
Coffea liberica -- Liberian Coffee
Coffea mongensis-- Wild Coffee
Gardenia thunbergia-- White Gardenia
Ixora coccinea-- Ixora, Flame of the Woods
Morinda citrifolia-- *Noni*
Psychotria carthaginensis-- *Sameruca*
Randia fitzalanii-- Yellow Mangosteen, Native Gardenia
Randia formosa-- Blackberry Jam Fruit
Sarcocephalus xanthoxylon-- Ndea

C. arabica requires a relatively frost-free environment similar to papaya. Mature trees can be expected to withstand short periods of 0° C, although new shoots may not be produced readily afterwards.

Coffee likes moist conditions and does not tolerate hot, dry winds. For these reasons much of the world's coffee is grown under shade trees which also protect against the overhead tropical sun. The coffee produced under such conditions brings a premium price.

Temperature

Temperature is a key factor in coffee production, and the strongest influences on temperature are latitude and elevation. Coffee is grown around the world at latitudes from 24°N to 25°S and elevations ranging from sea level to as high as 2133m (7000 ft). In general, high- elevation coffee regions are found in countries at or near the equator, such as Kenya, the New Guinea highlands, and Colombia, while low-elevation coffee regions, such as Hawaii and Sao Paulo, Brazil, are usually at subtropical latitudes (22-25°). At any given latitude, coffee is often grown over a wide range of elevations. In Hawaii, it seems that most elevations between sea level and 762m (2500 ft) should be suitable for coffee, provided that rainfall and soil factors are favorable.

Coffee tolerates wide annual variations in temperature. In parts of Brazil's Sao Paulo and Parana states, coffee trees are injured by frost almost every year, and freezes occasionally kill them. In the summer, however, coffee in these regions experiences very hot and humid conditions. A more moderate climate for coffee is found in one of the most important coffee-growing districts of Colombia, Chinchina, where the mean minimum temperature is 15°C, the mean maximum is about 28°C, and the mean monthly temperatures seldom vary more than 1-2°C throughout the year.

High temperatures (> 33°C) before and during flowering may result in abnormal coffee flowering and poor fruit set. In Kona (as in Brazil), the low winter temperature and rainfall seem conducive to regular annual flowering. In Colombia, on the other hand, where temperatures are neither too high nor too low and extremes are not encountered, dry periods seem to be of greater significance in affecting flowering.

Cloudless, dry, high-temperature areas are not favorable to coffee. However, successful coffee production is found in low-rainfall areas at elevations as low as 61m (200 ft), In windward areas of Hawaii, where rainfall is abundant and temperatures are relatively constant, coffee flowering and harvesting seasons may be more irregular and unpredictable In such windward areas, special crop management practices may be necessary for coffee production to be commercially feasible.

Shade management

Shading with one or more layers of trees is practiced in some ***tropical*** coffee-growing areas as southern Nigeria, but in the ***subtropics*** of Hawaii and Brazil it has been found to be unnecessary. If an area is too warm for coffee, shade might help. In the countries where shade is traditionally used, fertilizers are often in short supply, and the soil fertility is often inadequate to support a large crop. Under these conditions, restricting light with shade reduces the number of flowers per node, limiting production and helping prevent dieback due to overbearing. With adequate fertilizer and good management however, high yields can be supported under full sun without dieback

Wind

Coffee should not be planted in sites exposed to trade- winds or severe storms without a well established windbreak. Wind bends young coffee trees, causing more vertical stems than desired to be produced, and this may reduce yield. Severe winds cause "cupping," tearing, and removal of leaves-and sometimes removal of ripe cherries.

Temporary windbreaks are essential for newly transplanted trees in windy areas

Windbreaks should be planted at least six months before the coffee seedlings are transplanted into the field. The windbreak should receive fertilizer, and irrigation may be necessary. It should be 1.2m (3-4 ft) tall when the coffee is transplanted.

Coffee hedgerows can serve to break wind velocity for the orchard, although severe wind-pruning will likely occur in the rows exposed to wind intensity. A system of taller, permanent windbreak plants is preferred. A windbreak protects a downwind distance as much as 10 times its height. Some farms combine two types of tree windbreak

Rainfall

Some coffee-producing areas have annual rainfall of only 762mm (30 inches), while other areas receiving over 2540mm (100 inches) of rain also have good production. Optimum annual rainfall for coffee is considered to be 1524mm-2159mm (60-85 inches). However, the most important factor is the rainfall distribution pattern as it relates to the various phases in the coffee growth cycle: vegetative growth, flowering, maturing of coffee cherries, ripening, and harvesting. ***Excessive moisture stimulates vegetative growth at the expense of fruiting***. *If rainfall is uniformly distributed, flowering and fruiting will occur almost throughout the year. A short dry period, ideally occurring during the coldest part of the year, helps to synchronize the cropping cycle, inducing flower bud growth by satisfying coffee's requirement for dormancy prior to flowering.*

Soil

Coffee grows best on deep, porous, well drained soils, especially those of volcanic origin. Soils with excessively leached topsoil, impervious subsoil layers, or solid rock close to the surface will not support healthy coffee trees. Coffee will not do well and can die on heavy soils if drainage is a problem or if the soil is kept continually waterlogged below the surface.

Coffee will succeed on many types of soil but will develop a better root system in deep well-drained soils. A pH of 4.2 to 6 is preferred. Above 7, chlorosis can be expected.

Site selection for coffee fields is ultimately dependent on the soil and rainfall conditions, but slope and aspect must also be taken into consideration. Steep slopes may be suitable for growing coffee, but not if tractors or other machinery are going to be used in the care and harvesting of the crop. Considerations must be made for the navigation by equipment and general access to the field. If the coffee is to be tended and harvested by hand, steep slopes and many hills are then not as detrimental to the site selection.

Spacing

Trees are normally planted on 1-2.5m (3 to 8 foot) centers. Tighter centers are used where intensive pruning is employed.

Propagation

Seed has good viability if stored properly and is considered an economical way to obtain trees that are sufficiently if not completely 'true' to the parent(s). Although seedlings have a good probability of producing good coffee, trees are grafted on seedling rootstock to ensure reliable results. Grafting is done in the spring at or before leaf drop. Clonal reproduction is also done with cuttings. Cuttings are collected from main or upright growing branches to avoid vine-like growth characteristics. They need to be kept moist until they are placed in the rooting medium. During rooting, they should be maintained at high (90%) humidity. Rooting will take about 75 days. Tissue culture is also employed to produce clonal stock. Recently, genetic engineering efforts have been initiated to I resistance disease and herbicides.

Coffee Varieties:

Three species of coffee trees exist: *Robusta*, A*rabica* and L*iberica*. *Robusta* and L*iberica* are used in the mass produced commercial operations because they have a higher yield than the *arabica* varieties. Beans of the R*obusta* and L*iberica* species are considered to be flavoured more harshly than the A*rabica*.

Arabica varieties are considered to be the more important type of coffee beans. Their production is almost solely to produce coffee for the gourmet coffee market. *Arabica* trees produce less fruit than the other two varieties. In general, *arabica* trees require more effort to grow. Specific environmental conditions must be correct. They do not grow in as wide of climatic conditions as the *robusta* and *liberica*. *Arabica* tree is more fragile by nature. This requires them to be hand harvested in order to not damage the plant.

Student Self-Assessment Exercise 1

1. What are the different breeds of Coffee available in Nigeria?
2. Distinguish between the robusta and Arabica coffee.
3. What are the climatic and edaphic requirements needed for Arabica Coffee?

3.4. Nursery Operations

Fertilization and watering.

Watering needs to be consistent. A dry period is needed to induce blossoming. Gibberillic acid sprays have been successfully used to break dormancy. Coffee responds to nitrogen, potassium, and minor elements in tropical settings.

3.5. Field Operations

3.5.1.Maintenance of a Coffee Crop:

Maintaining a coffee crop, outside of planting and harvesting, is not as involved as other activities in processing coffee. Unless the crop is in an area where annual rainfall must be augmented by irrigation, there are no irrigation needs for the crop. The usual weed and pest control measures are in place as they are with any agricultural operation. Fertilizer is applied to ensure the crop receives the proper required nutrients.

One of the biggest activities in a maintenance program is pruning the coffee trees. Pruning is performed for several reasons. The first reason is to maintain the physical size and appearance of the bush to allow for ease of maintenance and to allow for harvest activities. Second is to encourage productive growth and to keep the canopy at the right density. Deadwood and branches do not produce coffee berries. A canopy that is too thick can choke out the productive parts of the bush located under the plant. (Clarke,1985)

3.5.2. Pests and diseases

Many pests and diseases can affect the coffee plant or its fruits, the most dangerous being:

- Fungal diseases
- Nematodes infestation of the roots
- Insect attack of the leaves
- Insect attack of the cherries
- Fungal disease of the seed

3.5.2.1. Insect pests

i. Green coffee scale

Green coffee scale *(Coccus viridis)* is a common and serious problem. Scales suck the plant sap resulting in reduced growth and crop yield. Sooty mould (a black, loose, sooty-like cover) often develops on leaves. It grows on the sweet exudate from the scales (honeydew) that also attracts ants.

Symptoms

Green oval shaped scales about 2 to 3 mm long. Often found concentrated on leaf veins and tips of new shoots. Infestations then produce spots of honeydew, which become covered with a black sooty mould. Defoliation of badly affected trees can occur.

Control/Preventative: There are a number of natural predators of coffee scale such as wasps, ladybugs and Verticillium fungus. In many instances, these will reduce the level of scale infestation.

Green coffee scale on leaf .

Chemical:

Mineral spraying oils at 200 ml/ 20 L water applied as a spray to affected plants. Only spray if 10 or more leaves are infested with one or more scales. The spray must completely wet and cover the scales. Do not use automotive oil!

Carbaryl 85 % wettable powder at 20 g/10 L water applied as a spray. Apply weekly until scales disappear.

Traditional: 1 kg strong tobacco per 2 L water. Soak for 2 nights. Then remove tobacco. Add 500 g of washing powder and make up to 20 L. Spray weekly until scales disappear.

Ants, black sooty mould and scale on coffee stem

ii. Aphids. Aphids *(Toxoptera aurantii)* can occur in large numbers on new shoots in the rainy season. Aphids suck sap from young shoots and cause damage to these developing shoots.

Symptoms. Large numbers of small black aphids (2 to 3 mm long) concentrated on new growth. Often associated with black sooty mould.

Control /Chemical: Neem oil 10 to 20 ml/L, plus soft, finely grated laundry soap at about 7 g/L water.

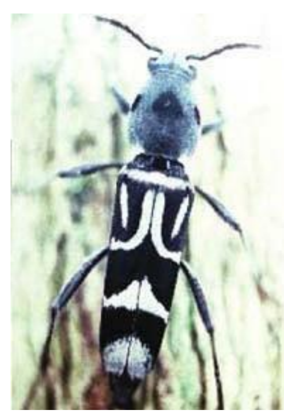
iii. Stemborers. There are usually two species of stemborers.

Red stemborer (*Zeuzera coffeae*). The adult has white and black spotted wings. The red coloured larvae tunnel through the coffee branches, normally in the upper part of the coffee trees. Branches and the top part of the main stem easily break off, but the tree usually survives.

White stemborer *(Xylotrechus quadripes)*. The adult is a black and white banded beetle (about 1 to 2 cm long); the head of the male beetle has distinctive raised black ridges. Adults are active during daylight. Damage is caused by the white larvae, which hatch from eggs deposited in cracks and crevices and under loose scaly bark of the main stem and thick primary branches, especially on plants exposed to sunlight. Young larvae feed on the corky tissue just under the bark, which splits making the stem appear ridged. Later, larvae enter the heartwood and tunnel in all directions, even into the roots.

Symptoms.

white stemborer



Wilting of leaves and dead trees or branches. Affected branches are easily broken off. When trees are first infested there maybe evidence of frass (sawdust-like residues) on the ground. The trunk may be ringbarked.

The lifecycle of both pests is completed during the rainy season, but often damage is more evident during the dry season.

Larvae remain inside the tree and are normally not seen. Usually damage is not economically important, although individual trees can be lost.

Control/Preventative: Less damage occurs under conditions of good shade.

Higher altitude (above 800 m.a.s.l.) seems to reduce the incidence of infestation.

Burn affected trees or branches with borers inside.

Do not plant trees with twisted taproots. These deformed roots result in weak trees that have been shown to have a high incidence of stemborer infestation.

Chemical control:

No effective chemical control known. Biological control is not known at this time.

Ste
m borers' damage in a field

iv. Coffee berry borer

Coffee berry borer *(Hypothenemus hampei)* is a relativity new, but very serious problem in Lao. It is causing significant damage, with perhaps as high as 50% yield loss. The adult is a small black beetle (about 2.5 mm long) and covered in thick hairs. The female beetle bores into berries through the navel region. Cherries are attacked in various stages but tunnelling and laying of about 15 eggs occurs only in hard beans. The eggs hatch in about 10 days and the larvae feed on the beans making small tunnels. Beetles in the cherries either on the plant or on the ground, can survive for more than five months.

Symptoms drop of young, green cherries. A small hole is evident on the cherry. Cherries that do not drop often have defective, damaged beans.

Control

Orchard hygiene (keeping the area clean, removing dropped cherries, removing carry-over fruit from coffee bushes are suggested), but it is reported to have limited impact and can be expensive. Cherries on the ground and old berries remaining on the trees are sources of new infection.

There are few natural enemies of the borer. One wasp *(Phymastichus coffea)* has shown promise in Columbia, but its effectiveness and that of other wasps is not yet fully known. The wasp may make a contribution in an IPM system. Lao should procure this and other effective parasitoids from Cenicafe in Colombia and technical biocontrol support.

Coffee berry borer beetle on a bean

Interest is now focused on the commonly found fungus, *Beauverai bassiana*. Research in South America has shown promising results, but it is not a cheap alternative to chemicals and has to be re-applied.

Research is required to develop the best means of bio-control.

Chemical control is difficult as the borer spends most of its life cycle deep inside the coffee berry. Endosulfan 35 EC at a rate of 6 ml/4.5 L of water applied at early fruit set (2 mm cherry size) and later 120 to 150 days after fruit set if required. Cypermetrin and Deltametrin, pyrethroids (0.01%) at 26 ml/15L of water are an alternative, or Chlorpyrifos used at recommended rate on label.

Quarantine. The pest cannot migrate any distance on its own. Do not allow cherries or coffee bags from other farms onto the farm property. Crop bags should be fumigated before being transported to other coffee growing areas.

Ethyl alcohol and methyl alcohol at a rate of 1:1 is effective in trapping CBB and can be used most effectively at processing/ washing places to prevent re-infestation. Place traps in the first five rows of coffee growing near the processing area.

Coating pieces of plastic with axle grease and engine oil and attaching these to pulpers and machines in the coffee processing area can also be used to capture CBB.

berry borer trap.

Careful drying of coffee cherry or parchment reduces reproduction of the pest as they cannot survive in coffee beans that are properly dried to 12% moisture.

v. Mealybug

Mealybugs *(Planococcus* spp.) are small sucking insects (about 3 mm long) covered with a white mealy wax that feed on young shoots and young roots. There are several species similar in appearance to the naked eye. They are generally more of a problem in the dry season when water is lacking. However, serious infestations of mealybug are often found where there has been use of insecticide sprays, especially highly toxic organo-phosphate sprays. These kill almost all insects, including natural enemies of mealybug.

Symptoms: White waxy colonies are usually found on the underside of tender leaves and in soft stem areas around berries. Also, they are found on young roots near the main root, especially where soil is loose around the trunk. Mealybugs are often associated with a heavy infestation of sooty mould.

Large white mealybug on a leaf

Control: Biological.The most important predator is the mealybug ladybird *Cryptolaemus montrouzieri*. The adults are reddish brown with black wings and about 4 mm long. A parasitic wasp, *Leptmastix dactylopii*, is also very effective. Lacewings such as *Oligochrysa lutea* are also predators of mealybug.

Chemical: *Cryptolaemus montrouzieri.* Mealybug ladybird adult feeding on scale

Spray Chlorpyrifos on the soil around the tree to kill ants. Ants disrupt the natural enemies of the mealybug. Malathion and Carbaryl sprays can also be effective. Apply according to label recommendations.

vi. Termites

Termites *(Macrotermes* spp.) can be a problem on older coffee and shade trees with dead wood where termites breed.

Control

Plant coffee in clean ground where all tree parts, including roots have been removed. Termites cannot survive as there is no dead wood on which to feed.

Effective pruning of dead wood on coffee trees. Remove all dead wood from the coffee plantation.

Permetrin 60 to 80 g/L sprayed on the ground and on base of coffee trees after planting will assist.

3.5.2.2: Diseases

A number of diseases can affect coffee plants in the nursery as seedlings, in the field while young and later as bearing trees.

a. Nursery diseases

Coffee seedlings are susceptible to two main diseases in the nursery - Damping-off and Cercospora leaf spot (brown eye spot).

i. **Damping-off:** This disease occurs on young coffee seedlings in the germination bed, after germination and before transplanting. It is caused by a *Pythium* spp. fungus.

Symptoms. Patches of coffee die quickly. Coffee stem is soft and rotten.

Causes:

i. Soil borne fungi.
ii. Soil too wet.
iii. Too much shade (insufficient drying of soil).
iv. High planting density (too many plants in a small area).

Preventative Control:

Damping off disease. Note the brown, rotting stems

Don't use old soil from nursery beds or bags as disease is soil borne and can be carried over. Use new soil for nursery beds and potting-up.

Avoid over-watering. Do not plant seed too close; seeds should be 25 mm apart in rows 100 mm apart.

Chemical control:

Soil drenches of either Benlate (Benomyl) or Captan (Follow label directions as formulations differ).

ii. Cercospora leaf spot (brown eye spot)

Cercospora leaf spot is a fungus that occurs on leaves when the plants are under stress. The fungus can develop both in seedbeds and after plants have been transplanted into bags. It is the most common nursery disease and a sign of poor management.

Symptoms

- Brown spots on leaves gradually expanding with reddish brown margin.
- Spots on both sides of the leaf.
- When there are many spots, leaves appear to have been burnt.

Causes

i. Soil too wet.

ii. Too much shade or too much sun.

iii. Lack of air movement.

iv. Lack of nitrogen and potassium.

Nursery leaves affected with Cercospora

Preventative Control:

- Avoid over-watering.
- Maintain at least 50% shade cover.
- Space plant bags to allow air movement.
- Proper fertiliser application (refer section on nursery management).

Chemical Control

Copper sprays such as the following will give control:

Copper Cupravit (85% WP)	80 g/20 L water
Copper oxychloride	80 g/20 L water
Copper hydroxide	40 g/20 L water

b. Field diseases and disorders

There are several field diseases and disorders affecting the leaves and berries. The diseases include Cercospora leaf spot (all ages of coffee); coffee leaf rust (all ages but more on bearing coffee); black sooty mould (all ages) and Anthracnose (more prevalent on bearing coffee). Dieback, a severe disorder occurs on bearing coffee.

i. Cercospora (berry blotch & brown eye spot). This occurs on the leaf but can also occur on berries where it is known as berry blotch.

Symptoms

- Brown spots on leaves gradually expanding with reddish brown margin.
- Spots on both sides of the leaf.
- Brown sunken lesion on green berries surrounded by a bright red ring (berry blotch).

Causes

- Low leaf nitrogen and potassium.
- Insufficient shade.
- Stress from drought, sun exposure, poor fertiliser management, excessive weed competition.

Cercospora affected berries

Preventative Control. Maintain well-fertilised plants with 50% shade cover.

Chemical Control: In severe cases, treat the isolated plants with any of the followings Copper sprays:

- Copper Cupravit (85% WP) 80 g/20 L water
- Copper oxychloride 80 g/20 L water
- Copper hydroxide 40 g/20 L water

ii. Coffee leaf rust

Coffee leaf rust *(Hemileia vatatrix)* occurs on leaves and can cause leaf drop if severe.

Symptoms:

- The first symptom is the formation of pale yellow spots up to 3 mm in diameter on the underside of the leaves.
- As the spots expand, they become powdery and yellow to orange in colour and may reach 20 mm in diameter. Occasionally the whole leaf becomes covered with rust spots.
- Older rust spores become brown at the centre surrounded by powdery orange spots.
- Leaf drop occurs, which if severe, can lead to dieback and berry loss and a loss of both yield and quality.

- Berries tend to be very small, not fully ripe and turn black.

Causes

Arabicas are susceptible under poorly shaded conditions and at altitudes of less than 1000 m.a.s.l.

Plant health: Healthy plants are less susceptible.

Preventive control:

- Plant tolerant varieties such as good selections of S 795.

Early symptoms of rust spots.

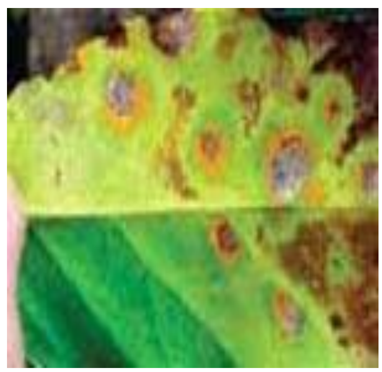
- Follow the recommended nutrition programme.

- Plant pure Arabica at high elevation only and always use good shade.

Chemical control:

Monthly copper sprays (May to October). See label directions for rates.

More advanced symptoms of rustspots



iii. Sooty mould.

Sooty mould *(Capnodium* spp.) develops when the plant is infested with scale, mealybugs, aphids or other sucking insects.

Symptoms

i. Leaves and fruits are covered with black, powdery soot.

ii. The fungus grows on honeydew produced by green coffee scale and sucking insects. Ants care for the scales and spread the sooty mould.

Preventative control:

Reduce levels of coffee scale, aphids and mealybugs by using recommended control procedures.

Leaves affected by sooty mould

Chemical Control: Not needed if sucking insects are controlled. Control the insects, not the disease.

Fruits affected by sooty mould

iv. Anthracnose

Anthracnose *(Colletotrichum gloeosporioides* Penz.) is a minor flower, twig and cherry disease. It can cause three different coffee diseases - twig dieback, brown blight of ripening cherries and leaf necrosis.

Symptoms

i. Twig dieback - yellowing and blight of affected leaves. Twigs wilt, defoliate and die at the tips.

ii. Brown blight - brown sunken lesions on fully developed cherries which turn black and hard (can be confused with Cercospora).

iii. Leaf necrosis - round brown necrotic spots up to 25 mm diameter.

Control

Maintain healthy coffee plants and plantation.

Brown blight lessions on berries

v. Dieback.

Causes

- Insufficient nutrition.
- Insufficient shade.
- Insufficient irrigation.

Variety mostly affected

Dwarf Catimors are much more susceptible.

Preventative Control:

Once the problem exists it is very hard to break the cycle if it is left too long.

i. Maintain good plant health.

ii. Maintain good shade (50%).

iii. Plant only recommended varieties.

iv. Use a well-balanced fertiliser programme and apply adequate nitrogen and potassium as recommended earlier.

Dieback in tips and lack of leaves on stems

Birds, rats, rabbits and squirrels are some of the vertebrates that are attracted to coffee berries.

vi. Overbearing.

Not a true disease but a physiological problem.

Symptoms

- Severe leaf loss and branch dieback.
- Root dieback.
- Cherries ripen prematurely and become hard and black.
- Overbearing causes alternating bearing (heavy crop one year and poor crop the next).
- Plants decline and eventually die if the problem is not corrected in early tages.

Note. Coffee needs one leaf pair to support five to six berries through to maturity.

If there are too many cherries and not enough leaves, all the food goes from the leaf to the developing cherry. Leaves then drop off, causing dieback. Some varieties, especially dwarf Catimors, are more susceptible to this condition. Loss of leaf depletes plant carbohydrate reserves resulting in weakened plants.

Roots also die back, then the tree cannot take up enough nutrients and water, thus more leaves are lost and cherry quality is reduced.

Plant health decline continues and if plants are not well cared for with adequate watering and nutrients; the plants will succumb and die.

Student Self Assessment Exercise 2

1. Identify six major pests of coffee and describe the pests.
2. Identify eight major diseases of coffee. What are the control measures for these diseases?

3.6. Harvesting of coffee fruits

Techniques:

Depending on the region where the coffee is being grown, the coffee beans can be harvested as little as once per year to as much as year round, depending on the plant and the climate. When the plant flowers and fruits is dependent on the cycle of rainy seasons. Growing coffee closer to the Equator gives more and more opportunities to harvest.

The coffee berries are ready 8 to 9 months after the plant flowers. The desired berry is shiny, red and firm to the touch. There are both mechanical and manual ways to harvest the berries. When the berries are harvested by hand, only the ripe berries are chosen, leaving the unripe fruit to be picked later.

Mechanical harvesting is faster and more productive. The machines strip all the berries from the branches at once, regardless of ripeness. This not only damages the trees by taking the berries, small branches and leaves, but means that the ripe and unripe berries have to be sorted out at a later date. Mechanical harvesting can also consist of a shaker that shakes the tree causing the ripe berries to fall to the ground and even tractors with rotating brushes are used to take the berries off the tree, this too can damage the plant.

Harvesting Equipment:

The materials needed for the picking of coffee are pretty simple and inexpensive. The items required include: baskets for the individual picker, holding hooks for bringing branches into position for picking, ladders and containers for transporting large quantities of berries from the orchards to the processing area.

Each basket holds an average of (4-6Kg) 20 to 25 pounds of harvested berries, and are suspended from the shoulder or fastened with a belt around the picker's waist. The holding hooks are approximately three to four foot-long sticks to which a string or cord is attached. The length of the cord is adjusted to the picker's height, in relation to the average height of the trees. The sticks are usually about 1 _ inches in diameter at the thickest end. A loop of wire tied onto the cord affords a place for the picker's foot, which can be inserted to hold the hooked branch in place while the picker removes coffee with both hands free. The picker must be carefully instructed not to bend branches to the breaking point. Ladders are needed for picking when cherries are too high off the ground to be reached with the aid of holding hooks alone. It is recommended that pruning practices which will keep the trees low enough to make ladders unnecessary be used, but when this is not possible, a combination of ladder and hook will usually facilitate picking. The ladders are generally constructed in such a way as to fold for easy carrying, with a center hinge inserted in a divided top crosspiece so that the picker's weight will hold the ladder rigidly in place. This type of ladder seems to be one of the safest, especially since coffee is often grown in rough and irregular terrain.

How to Harvest Coffee Beans

Each year coffee is harvested during the dry season when the coffee cherries are bright red, glossy, and firm. Ripe cherries are either picked by hand, stripped from the tree with both unripe and overripe beans, or all the coffee beans are collected using a harvesting machine. These processes are called selective picking, stripping, and mechanical harvesting, respectively. To maximize the amount of ripe coffee harvested, it is necessary to selectively pick the ripe coffee beans from the tree by hand and leave behind unripe, green beans to be harvested at a later time. About 12-20 kg of export ready coffee will be produced from every 100 kg of coffee cherries harvested.

Freshly harvested berries of *Coffea robusta*

Brazil's Process of Coffee Bean Harvesting

In Brazil, harvesting the same coffee tree several times is less cost effective than separating and discarding the unripe or overripe cherries. Therefore, Brazil typically harvests using the stripping method when 75% of the coffee crop is perfectly ripe. Stripping is feasible and cost effective in Brazil due to the uniform maturation of Brazilian coffees. In stripping, the coffee beans are pulled from the tree and fall to the ground where they are caught by sheets. The beans are removed from tree debris by tossing the coffee in the air allowing the wind to carry away sticks and leaves. The coffee is then put in 60 L green baskets, which is the tool measurement used by coffee producers to determine wages. Some coffee estates, such as Fazenda Monte Alegre in Sul de Minas Brazil, have a computerized system to determine wages for picking coffee beans. This system accounts for the amount of coffee collected from each person, the difficulty of the coffee harvesting conditions, and the production of the region being harvested.

General Recommendations for Harvesting Coffee

The cost of labor associated with picking and sorting can put the price of the final product beyond what the customer is willing to pay. Reducing the diligence, during pickings or berry selection results in the inclusion of over and under ripe berries that reduce the quality of the final product. This in turn will impact the selling price. Mechanical picking and mechanized sorting can be employed to reduce labor costs, but the capital investment would be difficult to recapture even for large operations. Another approach is to apply ***gibberellin*** to concentrate the blossoming period. Further, spraying immature cherries with ***ethephon***, a chemical that produces ethylene, induces more uniform ripening. The attendant fiscal tradeoffs are not easy to establish at this time since the California growing factors and market are not well known.

3.7. Coffee Processing (Farm level).

The highest quality coffee is obtained by hand picking the ripe berries at intervals of several weeks. In some areas berries are gathered from the ground, but the resultant beans are usually are of low quality. In Java the beans that have passed through the digestive tracks of birds bring a premium price. After collecting the berries, they usually are sorted to eliminate poor berries and sized to improve processing uniformity.

After picking, the berries must be processed quickly to prevent spoilage. Two methods are employed, 'dry' and 'wet'. In the dry approach berries are sun-dried and then hulled in cylinders to free the seeds. The remaining thin parchment over the bean is then removed by a sieving action that requires uniform bean size to be effective. In the wet method the berries are washed, pulped, and macerated in water. Fermentation then ensues, and in a little over 35 minutes the beans are freed. Sometimes a caustic solution is added to expedite the process. After a final wash the beans are placed in dryers which eliminate the parchment, or it is removed mechanically. The beans can now be stored for brief periods under carefully controlled conditions to enhance flavor. Before shipping, beans are normally graded. Unfortunately, many grading systems exist and the criteria vary greatly.

Dried berries of *Coffea robusta*

Student Self-Assessment Exercise 3

1. Why are nursery operations very important in coffee propagation?
2. What are the major coffee diseases at the nursery stage?
3. Why are pests and diseases control very important in coffee plantation maintenance?
4. At what stages will the seeds of coffee be harvested in a plantation?

3.8. Processing Coffee Beans into Coffee Drinks

Factory Coffee processing (roasting)

Much processing and human labour is required before coffee berries and their seeds can be processed into the roasted coffee with which most Western consumers are familiar. Coffee berries must be picked, defruited, dried, sorted, and factory processed (roasted)

All coffee is roasted before being consumed. In the groceries, coffee is usually sold in a roasted state. . Coffee can be sold roasted by the supplier; alternatively it can be home roasted. The roasting process has a considerable degree of influence on the taste of the final product

Coffee roasting is a complicated chemical process that creates the distinctive flavour of coffee from a bland bean. Unroasted beans contain all of coffee's acids, protein, and caffeine — but none of its taste. It takes heat to spark the chemical reactions that turn carbohydrates and fats into *aromatic oils,* burn off moisture and carbon dioxide, and alternately break down and build up acids, unlocking the characteristic coffee flavour. One of these aromatic oils is *caffeol* , which is largely responsible for coffee's aroma and flavour. When coffee beans are roasted, they turn much darker because their sucrose *caramelizes.*

Roasted coffee beans

Decaffeination is often done by processing companies, and the extracted caffeine is sold to the pharmaceutical industry.

3.9. Uses of coffee

i. Health and pharmacology of coffee.

Coffee is a widely consumed **beverage** prepared from the roasted **seeds** of the **coffee plant**. A typical 7 fluid ounce (**ca.** 207 mL) cup of coffee contains 80–140 milligrams of **caffeine**, depending on the bean and method of roasting and preparation. Some people drink coffee "black" (plain), others sweeten their coffee or add **milk**, **cream** or **non-dairy creamer**. The majority of all caffeine consumed worldwide comes from coffee,

Many studies have been performed on the relationship between coffee consumption and many medical conditions, ranging from diabetes and cardiovascular disease to cancer and cirrhosis. Studies are contradictory as to whether coffee has any specific health benefits, and results are similarly conflicting with respect to negative effects of coffee consumption

One fairly consistent finding has been the reduction of diabetes mellitus type 2 in coffee consumers, an association that cannot be explained by the caffeine content alone and indeed may be stronger in decaffeinated coffee.

There exists research to suggest that drinking coffee can cause a temporary increase in the stiffening of arterial walls·

ii. Economics of coffee

Coffee is one of the world's most important primary commodities due to being one of the world's most popular beverages. In total, 6.7 million tonnes of coffee were produced annually in 1998–2000, and the forecast is a rise to 7 million tonnes annually by 2010. Coffee also has several types of classifications used to determine environmental and labor standards.

Brazil remains the largest coffee exporting nation, but in recent years the green coffee market has been flooded by large quantities of *robusta* beans from Vietnam

iii. Nutrition

Roasted coffee beans have the following nutritional content per 1 gram of beans. (Note that analyses vary depending on the type, roasting, etc. and the values here are only a relative guide whose accuracy is approximately +/- 20%.)					
calories	2.3	calories	iron	0.029	milligrams
carbohydrates	0.63	grams	thiamin	0.706	milligrams
fats	0.18	grams	riboflavin	0.508	milligrams
proteins	0.13	grams	niacin	0.170	milligrams
fiber	0.076	grams	ascorbic acid		no data
calcium	1.5	milligrams	beta-caritene		no data
phosphorus	2.0	milligrams	caffeine	11-14	milligrams

Source:Facts About Caffein: Addictions Research Foundation,2003

3.10. Coffee preparation

The processing of coffee typically designates the agricultural and industrial processes needed to deliver whole roasted coffee beans to the consumer. Grinding the roasted coffee beans is done at a roastery, in a grocery store, or at home. It is most commonly ground at the roastery and sold to the consumer ground and packaged, though "whole-bean" coffee that is ground at home is becoming more popular, despite the extra effort required. A grind is referred to by its brewing method. "Turkish" grind, the finest, is meant for mixing straight with water, while the coarsest grinds, such as coffee percolator or French press, are at the other extreme. Midway between the extremes are the most common: "drip" and "paper filter" grinds, which are used in the most common home coffee brewing machines. The "drip" machines operate with near-boiling water passed in a slow stream through the ground coffee in a filter. The espresso method uses more advanced technology to force very hot (not boiling) water, through the ground coffee, resulting in a stronger flavor and chemical changes with more coffee bean matter in the drink. Once brewed, it may be presented in a variety of ways: on its own, with sugar, with milk or cream, hot or cold, and so on. Roasted arabica beans are also eaten plain and covered with chocolate.

A number of products are sold for the convenience of consumers who do not want to prepare their own coffee . Instant coffee has been dried into soluble powder or freeze dried into granules, which can be quickly dissolved in hot water for consumption. Canned coffee is a beverage that has been popular in Asian countries for many years, particularly in Japan and South Korea.

Student Self-Assessment Exercise 4

1. **Describe the processing of coffee fruits just harvested from the field.**

2. **What are the various products that can be derived from coffee beans.**

Caffeine content

Depending on the type of coffee and method of preparation the caffeine content of a cup of coffee can vary greatly. However, on average the following amounts of caffeine can be expected in a single serving. A serving cup of coffee (about 350 milliliters) contains differrent amounts of caffein as revealed in the table below:

Caffeine content of coffee is a major concern for many consumers. Decaffeination is about 98% effective in its removal. The table lists the caffeine content of 12 ounce (350ml) cup of some common beverages.		
Drip coffee	170-275	milligrams
Percolator coffee	120-200	milligrams
Instant coffee	90-150	milligrams
Espresso	600-900	milligrams
Tea	45-100	milligrams
Hot chocolate	15-30	milligrams
Cola	37-45	milligrams
JoltTM	71	milligrams

ource:Facts About Caffein: Addictions Research Foundation,2003

4.0. Conclusion

Planting and Raising Coffee:

In general coffee is able to grow between the Tropic of Capricorn and the Tropic of Cancer. This region around the Equator includes Central America, Northern South America, Africa, the Middle East, India, Indonesia and even Hawaii. These regions are considered to be in the Coffee Growing Belt.

The Equatorial climate is ideal for growing coffee. It provides the preferred temperature range of 15-24$_{o}$C, without severe temperature swings. Outside of this range, the plant does not survive or produce very well outside of this range. Lower temperatures inhibit plant growth. Extreme lower temperatures can produce frost that can damage or kill the coffee plant. Temperatures above the preferred range are usually indicative of direct sunlight and those conditions lower the rate of photosynthesis.

The type and condition of the soil is important to the growth of the coffee plant. Within the Coffee Growing Belt, the soil is derived from many different sources. Parent material can range from volcanic materials in Hawaii and Indonesia to sandstone, limestone and gneiss in the other areas. While these soils are of different origins, they are still suitable for the cultivation of coffee.

Field soils must be well drained, well aerated and deep. Coffee plants require a large amount of oxygen for their root systems. Providing oxygen is one reason why soils must be well aerated. Clay soils lack the drainage and aeration and sandy soils may have the drainage and aeration, but they lack the water holding capacity. Coffee also grows best in a soil that is slightly acidic.

Rainfall in ideal coffee growing regions is in the range of 1500mm to 2000mm annually. In east and south Africa, coffee can be raised with an annual rainfall of about 1000mm,

but only with irrigation to make up for the deficit in moisture.

Raising and planting the coffee plant starts with collecting the ripe coffee cherry, pulping the seed to remove the outside mucilage. The seed is then either dried and planted or planted without the drying process. Often times the seedlings are raised in a greenhouse until they are between 20cm and 40cm tall. The small seedlings are then transferred to the field and planted. Vegetative propagation of coffee plants is also accomplished by rooting green wood into soil so that it will take root. The practice of grafting is also used to propagate some varieties.

5.0. Summary

In this unit, we discussed Coffee as a tree crop grown in plantations in the tropics. First, we traced the history, spread, and the botany of the crop. Then we discussed the agro-climatic and edaphic requirements for the growth and production of the crop. Nursery and field management operations including harvesting and partial processing of ripe fruits were treated. Post -harvest management of coffee beans and their uses was also discussed.

6.0. Tutor Marked Assignment

1. **Describe the agroclimatic and edaphic factors required in the cultivation of coffee.**
2. **Describe nursery and field operations in coffee cultivation.**
3. **Discuss coffee beans harvesting and how to improve on beans final quality.**
4. **What are the uses of coffee?**

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MODULE 2: STIMULANT/BEVERAGE CROPS

Unit 5: COLA (KOLA)

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MODULE 2: STIMULANT/BEVERAGE CROPS

Unit 5: COLA (KOLA)

1.0.INTRODUCTION

Cola belongs to the family **Sterculiaceae** and genus; ***Cola***. The kola nut is native to Africa, with Nigeria as the primary producing country. An estimated 140,000 tons were produced in 1960 mostly in Nigeria. The kola tree is a dome-shaped evergreen tree, usually 35 to 50 feet in height. Trees are usually planted from seed, about 20 to 27 feet apart, although vegetative production can be accomplished. Growth of this tropical tree is in flushes. The fruit matures about 41/2 months after flowering. Full fruit production is reached by the 20th year, and the tree may continue bearing until it is 70 to 100 years old. The main harvest period of nuts extends from October to December, but some nuts may be available throughout the year. The pod is harvested before the nuts are ripe. The follicle is split and the three to six nuts are removed, fermented in heaps for 5 days, washed clean, and stored. They will keep for several months. Average yield is 210 to 250 salable nuts per tree or 12,000 nuts (about 500 pounds) per acre. . In Africa, the kolanut is chewed for its alkaloid properties (kolanin), which dispels sleep, thirst, and hunger A few hundred tons are exported to the United States, where they are used in the preparation of beverages and in pharmaceuticals. In this unit, we shall discuss the agro-climatic and edaphic requirement in the cultivation and production of kola. We shall also discuss into details, the cultivation, production, harvesting, processing, curing and uses of kola.

2.0.UNIT OBJECTIVES

At the end of this unit, you should be able to:

- Identify Kola tree and kola-nut.fruits
- Describe Nursery and Field operations required in the cultivation and production of Kola.
- Perform harvesting and processing of fresh kola nuts
- Identify the uses of Kola

3.0.COURSE CONTENT

3.1.History and Spread of COLA.

Kola nuts were widely used in West and Central Africa long before the arrival of European Voyagers . Leo Africanus referred to a kola nut with the name '*goro'* which he encountered during a visit to western Sudan in 1556. This is the name that is used to refer to kola in Nigeria. However, the first definite description of kola nuts was made by Edouado Lopez, a Portuguese traveler, who saw seeds with four cotyledons in 1593 (Chevalier and Perrot, 1911).

In 1805 Palisot de Beauvois published an account of specimens that he had collected during a visit in 1786 to parts of what is now Nigeria. Among the species he described was the local kola tree, named by him as *Sterculia acuminata* (Russell, 1955). In the same year Ventenat described a species he was sent from Mauritius as *Sterculia nitida*. Both species subsequently became part of the genus *Cola* when Schott and Endlicher created it in 1932.

According to Russell (1955), the systematics of kola species was in a state of "indescribable confusion" by the beginning of the Twentieth Century as a result of a profusion of new species, named on the basis of very meagre evidence. It was not until the French botanists Auguste Chevalier and Emile Perrot's (1911) taxonomic account that clarity was restored. Chevalier created the subgenus Eucola to contain the five species of edible kola nut: *C. nitida* (important for trade), *C. acuminata* (important for socio-cultural values), *C. ballayi, C. verticillata* and *C. sphaerocarpa.* The latter three species are not known to be cultivated, but their seeds are sometimes use to adulterate the produce of the commercial species when it is scarce.

3.2 Botany of Cola/Kola Plant

Cola belongs to the family **Sterculiaceae** and genus; ***Cola.*** **The genus *Cola*** comprises about one hundred and twenty five species. *Cola* species are evergreen, mostly small or moderately sized trees although a few grow to 25 metres. A number of species are widely cultivated in tropical countries, especially in Africa. The most commonly used are *C. verticillata* (Thonn.) Stapf, *C.acuminata* (Pal. de Beauv.) Schott and Endl. and *C. nitida* (Vent.) Schott and Endl., with the latter two having the greatest economic importance (Lovejoy, 1980).

The following description of the genus is given in (Opeke, 1992):
Trees or shrubs with alternate leaves; stipules present although sooner or later dropping. Male and hermaphrodite flowers grouped into a panicle of cymes, or in fascicles on the branches or on the trunks. Five sepals; male flower: the anther loculi are placed laterally at the top of the androecium in one or two superimposed rings; hermaphrodite flower, style short, stigma fleshy, more or less recurved, a vestigial androecium at the base of the gynaecium. Fruit: five to ten follicles, placed perpendicularly on the peduncle, radicles directed towards the hilum. After germination of the seedling the cotyledons are subhypogynous.
The leaves of *Cola* species are simple, entire and narrowed or rounded towards the base. The arrangement of the leaves on the stem is alternate in some species and verticiliate, in whorls of 3 or 4, in others.
The flowers of both *C. nitida* and *C. acuminata* have a white or coloured perianth. Typically, trees bare two types of flowers; male, with anthers fused into a single column or hermaphrodite with one or two rings of anthers at the base of the superior ovary. After fertilisation, the ovary divides forming separate fruiting carpels or follicles, usually five to ten in number. Fruits are sessile, placed at the end of a short peduncle, from which they radiate in star-shaped fashion. As the fruit increases in weight, the stem hangs vertically and the follicles are borne horizontally or ascending in recurred fashion, containing one to ten seeds. The nuts of a small number of *Cola* species, including *C. nitida* and *C. acuminata,* are good to eat though most species produce seed that is hard and inedible.

Inflorescence:

The fetid kola flowers are in several- to many flowered determinate panicles. The five-sepal, petal-less flower is white, with maroon to reddish blotches and streaks emanating from the inner base of the corolla-like perianth. Some trees produce only male flowers, but some hermaphrodite flowers are usually on every tree. Usually, the earliest flowers to develop are male; followed by both male and hermaphrodite flowers intermixed. The hermaphrodite flower is 30 to 40 mm across; the male flower, half to two-thirds the size. The male flower is sub-spherical, the hermaphrodite one is more oval. The hermaphrodite flower produces pollen that will germinate on a proper agar solution but will not fertilize a stigma, so the flower is basically nonfunctional, and should be considered as a pistillate one.

The hermaphrodite flower opens between 4 and 8 a.m. and is apparently receptive only one day, as the majority withers and drop on the second to the fourth day. Naturally, all male flowers shed. When the flower matures, the anthers release the sticky pollen, which largely remains on the anthers. This would indicate that the kola flower is insect pollinated. No reference was found indicating that kola flowers secrete nectar, but since flies are attracted to the flowers quite probably nectar is secreted.

Pollination Requirements.

The evidence indicates that pollen must be transferred from the staminate or male flowers to the hermaphrodite or basically female flowers. The pollen must be transferred as soon as possible after the flower opens. Many trees, and probably the majority of them, are self- incompatible, in which case the pollen must come from flowers of other appropriate kola trees.

Considering the large number of flowers on a tree that must set fruit to produce an excellent crop, and considering that the pollen must come from other compatible plants and within a limited time period, it becomes evident that pollen must be transported rather freely between trees.

Pollinators.

The pollen of kola trees is not wind transported. Van Eijnatten (1969) said that pollination is probably affected by insects, but indicated that relatively few insects visit the numerous flowers. Purseglove (1968*) stated that the flowers have a fetid odour that attracts flies, which may be the pollinating agent. Cecidomyids, mirids, and ants have also been mentioned (Anonymous 1957). Nothing is said about bee visitation to these flowers. It is of interest that this is a relatively self- sterile crop, and van Eijnatten (1969) stated that, "The low productivity of many kola trees has been a thorn in the flesh of the farmer wherever this crop is cultivated in West Africa." The saturation pollination with one to several honey bee colonies per acre, forcing the bees to forage on what may be a relatively unattractive source of pollen or nectar, might remove that objectionable "thorn in the flesh." It might lift total production to a new plateau or cause a more concentrated set of fruit at a definite period.

3.3. Ecology and Climatic zones

Cola species occur in the hot tropical lowland forest with rainfall extending over a period of 8 months or more and a temperature of between 23°C and 28°C (Ekanade, 1989). Species have also been cultivated in the transitional zones where the forest gives way to the savanna (Opeke, 1992). It is mainly grown between 6° and 7° north of the equator, but has also been found up to 10º N on the West Coast of Africa. The species requires a hot, humid climate with well- marked wet and dry seasons, and it is capable of withstanding three or more months of dry season (Keay *et al*., 1960).
The preferred annual rainfall for *Cola* species is about 1700 mm. However, further inland towards the moist deciduous forest and the savanna, where the dry season extends up to seven 10 months or more, kola can grow with annual rainfall of about 1200 mm. It is also relevant to note that small patches of *Cola nitida* could be cultivated far beyond the drier areas to the north where growth could only be made possible by the occurrence of wet land with a high water-table (Russell, 1955).

Student Self-Assessment Exercise 1

1. Distinguish between the two major types of Cola using:

- fruit colour
- leave structure
- nut qualities

3.4. Propagation

Kola has been traditionally propagated from seed, but today cultivation by cuttings is fast becoming very common. In ***southern Nigeria seeds are germinated in boxes or polythene bags filled with top soil and lined in equal parts with sand or sawdust*** or raised in nursery beds. Germination is slow, but under favourable conditions *C. nitida* germinates within 80 days and *C. acuminata* within 60 days. Seedlings are usually planted out at six to eight (6-8) months old at a depth of 7 to 10 cm. Soil sterilisation is important in nurseries. Over-watering should be avoided since the seedlings are liable to various fungal and other pathogenic infections (Oludemokun, 1979; Opeke, 1992).
This method costs more in material and labour than sowing directly on the field, but where valuable seed is being used the additional cost is justified (Russell, 1955). Propagation by cuttings is preferred as a means of multiplying the white -seeded strain of kola nuts that is favoured by the market.
Vegetative reproduction is a relatively straightforward means to multiply, test, select and utilise the wide range of genetic diversity that is present in the *Cola* species. This is the most promising method to produce highly productive clones that could be used locally and for industrial purposes (Tchoundjeu *et al*., 1998). It would seem that, at present, there is little selection by farmers for varieties with improved performance (Russell, 1955). Farmers should therefore be encouraged to plant highly productive improved seeds.
The time for transplanting the young seedlings is ideally during the rainy season when enough moisture and nutrients are available for plant growth. In West Africa, the suitable time for kola transplanting is April in the southern kola belt, and June in the transitional zone (north of the kola belt).

Cola species are tolerant of a wide range of environmental conditions and have few cultural requirements are therefore needed once the tree is established, yet more careful treatment, suitable technical packaging and advice on pruning, fertiliser application and other cultural practices would be desirable (Ekanade and Egbe, 1990; Fereday *et al*., 1997). Initial growth is slow, with the young plants only reaching three meters in four years, during which period they should be kept clear of weeds. Flowers may occur in the fifth year, but it is not usually until the seventh year that any fruit is seen, and this is scanty. By the eleventh year a fair crop should be obtained, and peak production begins after twelve years. Full production is normally reached about the twentieth year, and trees may continue to bear fruits until they are seventy to hundred years old (Russell, 1955). Productivity mainly depends on environmental factors like excessive drought, or changes in weather pattern that alter the period of flowering and fruiting of the species.

3.5. Pests and diseases

C. nitida and *C. acuminata* were believed to be resistant and biologically robust species and to have no important diseases associated with them (Russell, 1955). On the contrary, current publications have shown that *Cola* species are vulnerable to a host of fungal diseases that can attack all parts of the crop. Many fungi are capable of infecting kola fruits at an early stage of development, but the disease symptoms will only develop when conditions are favourable. Many diseases that kola is susceptible to can easily attack related agriculture crops or other tree species. For instance, *Fomes lignosus* (Klotzsch) Bres. and *Fomes noxius* (Corner) may affect kola, cacao, rubber, coffee and other tree crops (Adebayo, 1975). Care should therefore be taken with a suitable combination of crops to minimize disease attack as well as for optimum yield.

i.Fruit and seeds

Kola nuts are vulnerable to various fungi diseases. *Botryodiplodia theobromae* Pat has been found to be the most common single species of pathogen associated with kola (Oludemokun, 1979). It has been identified infesting the follicles, which develop a black rot and subsequently affect the nuts. Rusty brown spots develop on the nuts, which later turn black and become hard and dry. The tissues may fall out, living small pits in the surface. *Botryodiplodia theobromae* can also attack other parts of the kola tree. Recent publication have shown that, storage of kola nuts in baskets lined with fresh leaves at a high temperature and high humidity provokes development of various parasitic fungi, especially wet rots caused by *Fusarium* and *Penicillium* species (Oludemokun, 1979; Opeke, 1992). Besides these pathogens *Aspergillus niger* has also been found to cause black, hard rot and pink soft rot respectively on kola nuts.The extent of loss in storage assessed in northern Nigeria was estimated as high as 30% Olunloyo (1979) found that the rate of development of fungi actively growing on nuts of *C. nitida* depended more on the ambient relative humidity than on nut moisture content. The principal postharvest pathogens were found to be *Botryodiplodia theobromae* and *Fusarium* spp. Milton (1% sodium hypochlorite) sol. was slightly fungicidal at 0.5 and 0.75% and highly so at 0.95 and 1%, depending on exposure period. Substantial reduction of postharvest rot (particularly in nuts stored in baskets lined with polyethylene sheet over banana leaves)was achieved when the nuts were soaked in 1% Milton for 30 min before storage.

Agbeniyi (1999) tested the efficacy of Milton solution (containing 1% v/v sodium hypochlorite) and wood ash in controlling storage rot of kola nuts (*C. nitida*). The effects of the nut treatments on microbial contamination caused principally by *Botryodiplodia theobromae* and *Fusarium pallidoroseum* were also investigated. Both the Milton solution and ash treatments (at a rate of 3 g/kg of kolanuts (dry powder)) gave a significant reduction in percentage incidence of storage rot. This suggests that kolanut treatment with wood ash should be a cheap, alternative preservative for the control of storage rot of kolanut. *Balannogastric kolae* is one of the most common weevils to attack kola nuts, though many other species occur. Prevention of kola weevils is very important during harvesting and storage. Field losses have been estimated up to 50 and 70 percent (Opeke, 1992). A careful farmer ensures regular and thorough harvesting of fruits before they reach the point of splitting, as well as avoiding damage to the seeds through breaking of kola pods in order to avert weevil infection.

Eggs are laid into the nuts, or on other parts of the fruits, and the adult weevil emerges within one month. *Balannogastric kolae* have an average lifespan of 53 days, and 20 days for *Sophrorhinus imperata.* They can breed throughout the year if conditions are favourable (high humidity) (Opeke, 1992). Storing the kola nuts at the appropriate temperature and relative humidity could prevent nut rot diseases. Oludemokun and McDonald (1976) reported that a temperature of 20ºC and relative humidity of 75-100% were the most favourable conditions for storage of kola nuts. Spraying storage rooms with DDT could also prevent the kola weevil.

Both *C. nitida* and *C. acuminata* seeds are vulnerable to attack from the curculionid kola weevil, *Sophrorhinus gbanjaensis* . The oviposition and development of larvae on nuts of *C. nitida*, *C. acuminata* and the wild species *C. verticillata* were studied by Daramola (1980). Significantly higher numbers of eggs were laid in nuts of *C. nitida* and *C. verticillata* than in those of *C. acuminata* when mated females were caged with 35 nuts of each species separately for 35 days. *C. nitida* and *C. verticillata* were preferred to *C. acuminata* as oviposition sites when nuts of the three species were offered together.
An assessment of the effect of weevil infestation on the caffeine content of red and white cultivars of *C. nitida* was carried out in Nigeria (Lale and Okunade, 2000). Results showed significant decreases in the amount of caffeine with increasing levels of infestation, especially in the red cultivar. Mean reductions in caffeine content ranged from 8.8 to 62.6 % in the red cultivar and from 18.8 to 25 % in the white cultivar.

ii. Leaves and twigs

Leaf disease is very common in young leaves and usually occurs in the latter part of the rainy season, seriously affecting many of kola shoots, and leaving them leafless (Opeke, 1992). The infected leaves turn brown, and start to die back from the tip to the petiole and from the margin to the midribs before they finally drop. *Phomopsis* species have been observed to cause tip dieback diseases of kola. *Guignardia citricarpa* Keily is associated with yellow or orange discoloration of leaves while *Botryodiplodia theobromae* causes a twig blight and a brown coloured blight of leaves (Adebayo, 1975). The diseased twigs die and turn black with leaves remaining attached. *Glomerrella cingulata* causes greenish spots with a mouldy appearance on kola leaves (Oludemokun, 1979).
The larvae of kola, *Ceretitis colae* and the stem borers, *Phosphorus virescens* and *P. gabonator* have been found to cause serious losses in kola plantations in both Ghana and Nigeria (Ghana, 1917; Opeke, 1992).
The ant species *Crematogaster buchneri* Forel is known to attack the flowers, leaves, young branches and pods of *C. nitida* in Nigeria. The ants scrape off the epidermis, so that affected leaves fall and pods become shriveled (Eguagie, 1973)
.

iii. Roots

In nurseries, seedlings are often infected with fungal diseases. Common among them are *Botryodiplodia theobromae* and *Fusarium* species that cause the roots of the infected seedling to rot and turn their leaves brown. Aldrex T, pesticides containing 25% aldrin and 50% thiram, have been reported to reduce incidence of fungal infection in nurseries (Adebayo, 1975; Oludemokun, 1979).
In the field, infected roots often cause yellowing of leaves before eventually killing the plant. *Rigidoporus lignosis* (Klotzsch) Imazeki, *Fomes lignosus* (Klotzsch) Bresodola and *F. noxius* Corner commonly cause this type of problem in both *C. nitida* and *C. acuminata* in Nigeria and Sierra Leone (Adebayo, 1975; Opeke, 1992). Adebayo (1975) reports that collar inspection was found to be more reliable method of detection than foliage inspection.

3.6a. Harvesting

A careful farmer cuts the fruit from the tree before the follicle splits open ensuring that fruits are free from pest attack. The approach of maturity can be predicted by a change in colour from deep green to a light brown. At the beginning of the harvest period undergrowth beneath the kola trees is cleared to reduce the risk of infestation by the larvae of the kola weevil, *Ceratitis colae* and infection by the fungus *Botryodiplodia theobromae* (Opeke, 1992; Russell, 1955).

Kola nuts are harvested twice a year by collecting the fruits with a curved knife-blade (hook) attached to the tip of long poles. Farmers usually climb the tree with this harvesting hook (equipment) and cut all the fruits they see approaching ripeness. This practice is repeated monthly during the fruiting season from September to January. The greatest production is usually from October to December for cultivated species in Nigeria with smaller harvest period in March and April (Fereday *et al*., 1997; Keay, 1958; Russell, 1955)

Student Self-Assessment Exercise 2

1. Describe the agroclimatic factors that favour Cola cultivation
2. Why is plantation hygiene important in Cola farming?
3. When should Cola fruits be harvested?

3.6b. Post harvest treatment Harvested fruits are usually heaped on the ground at a convenient place under trees and the follicles are split open. The large green kola pods are cracked under the tree and the nuts carried back to villages where the thin outer skin is removed to reveal the nuts. In order to facilitate removal of the testa, the nuts are either soaked in water or by heaping them into a large basket where they are left to ferment for about five days The nuts are then rinsed in water and the softened testa wiped off. The cleaned nuts are transferred to baskets, often of enormous size and without lining, and kept here for three or four days with frequent stirring.
Defective nuts are picked out during this stage and the process is known as curing. A lot of sweating occurs here with the purpose of gently reducing the water -content of the seeds. The seeds are then graded and may be stored to wait a favourable market, wrapped in green leaves and deposited on the ground or in a cool corner of a hut and regularly checked for weevil damage. Periodically the nuts are examined and fresh wrapping leaves applied to keep it moist. The leaves used are of various species but some Marantaceous plants are preferred including *Marantochloa* and *Thauma tococcus*, whose large leaves show resistance to rotting. The quality of the nuts depends greatly on the care with which the harvesting, cleaning, and curing were carried out. Under the best conditions the seed may be stored for many months

without decline in quality (Masefield, 1949). Kola can be stored for up to two years usually in baskets or old fertiliser bags if kept dry (Fereday *et al*., 1997). Oludemokun and McDonald (1976) reported that, a temperature of 20°C and relative humidity of 75 —100% were the most favourable conditions for storage of kola nuts.

3.6c. Quality of products

Unlike other non-wood forest products kola nuts are often graded. Retailers inspect the nuts by setting aside anyone showing insect damage and then grade them according to colour and size. The most careful and repeated examination is for weevil infestation (Opeke, 1992; Russell,1955). The quality of the product is very important for the value and determination of market price. Right from the harvesting, the farmer makes sure to prevent the harvest of immature fruits as the nut becomes thin and shrunken after curing. Post-harvest attack from insect pests can seriously affect products market acceptability. Apart from weevil damage, environmental factors such as high humidity and temperature can affect the rate at which the quality of the nuts decline --including discolouring the nuts and prevalence of fungal attack *(Botryodiplodia theobromae).* Mechanical damage to the nuts especially during extraction of nuts with machetes also reduces quality significantly. In most cases, appropriate variations in prices are applied to justify farmers' efforts during the curing process and storage to ensure good flavour. However, customer's preference depends on colour, size, flavour, and level of adulteration and keeping quality (Ladipo, 1997). Usually, white nuts are preferred to pink or purple in both traditional and commercial markets

.

3.7. Kola nut composition

The seed of kola comprises 13.5% water, 9.5% crude protein, 1.4% fat, 45% sugar and starch, 7.0% cellulose, 3.8% tannin and 3% ash. The seed is also rich in caffeine (2.8%) and theobromine (0.05%) (Purseglove, 1968). Moloney (1887) compared the nutritive constituent of kola nuts to other species used as stimulants such as cocoa (Sterculiaceae) and coffee (Rubiaceae). He stated that kola contains more caffeine than coffee, and has an appreciable quantity of theobromine and considerable quantity of glucose. It has a quantity of starch three times greater than contained in cocoa, but relatively little fat. He found it also to contain a special form of tannin. Most fruits are rich in polyphenolic compounds which play an important role in determining colour and flavour. Chromatogram analysis of kola nuts has indicated the presence of phenolic constituents in quantities that are higher than those typical for many fruits. Apples for instance contain 0.1 – 2.0 g / 100 g fresh weight of polyphenolic compounds (van Buren, 1970), compared with in excess of 4.0 g/ 100 g fresh weight in kola nuts. Many polyphenolic compounds are highly reactive with human body constituents and have an impact on metabolic processes. Kola nuts have long been highly valued in both the traditional and industrial pharmacopoeia. The total phenol content is greater in *C. nitida* than *C. acuminata* . In *Cola nitida,* the quantity of total phenol in red nuts was up to three times that of white and pink nuts; but in *Cola acuminata* the difference was not significant. This investigation supports the general view that *Cola nitida* is more astringent than *Cola acuminata,* because astringency is related to the phenolic content of fruits (Odebode, 1996).

3.8. Uses of Kola.

Kola nuts are widely cultivated in West Africa because they contain two alkaloid-kolatin, which is powerful stimulant that counteracts fatigue, suppresses thirst and hunger, and is believed to enhance intellectual activity (Nickalls, 1986; Sundstrom, 1966). Due to their unique bitter taste, kola nuts are effective for refreshing the mouth, and the twigs are used as "chewing sticks" to clean the teeth and gums (Lewis and P.F., 1985). Kola nuts are also used as a source of alkaloids in pharmaceutical preparations. Large quantities of the nuts are exported to Europe and North America, where they are used chiefly for flavouring cola drinks such as Coca-Cola, which are refreshing or stimulating substitutes for tea or coffee (Irvine, 1956). Beverages such as kola wine, kola cocoa and kola chocolate – a type of chocolate containing cacao and kola powder in cocoa butterfat (Opeke,1992)

.

i. Medicinal uses

Traditionally, the leaves, twigs, flowers, fruits follicles, and the bark of both C. *nitida* and C. *acuminata* were used to prepare a tonic as a remedy for dysentery, coughs, diarrhoea, vomiting (Ayensu, 1978) and chest complaints (Irvine, 1961). The nuts have considerable potential for the development of new pharmaceuticals and foods (Fereday *et al*., 1997). Extracts of *C. nitida* bark have been tested on various pathogenic bacteria (*Staphylococcus aureus, Kle bsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosa* , beta-haemolytic streptococci, *Escherichia coli* and *Neisseria gonorrhoeae*) (Ebana *et al*., 1991). All the extracts showed inhibitory activity against these organisms.

Benie *et al.* (1987) report that stem bark extracts of *C. nitida* inhibited the release of luteinizing hormone (LH) from rat pituitary cells and may therefore regulate gonadotropin release. This has potential to be used as a natural fertility regulator.

ii. Socio-cultural values and uses

Chewing of kola nuts is a widespread habit in the Sub-Saharan countries of Africa, especially in northern Nigeria and Sudan. Kola chewing plays a similar social role to tea and coffee drinking or cigarette smoking in Western countries (Purseglove, 1968; Rosengarten, 1984; Russell, 1955). *C. acuminata* is widely used ceremonially and socially by the people of West and Central Africa. At a birth a kola tree may be planted for the new-born child. The child remains the lifelong owner of the tree. A kola tree is a lso often planted at the head of a grave as part of local death rites (Tindall, 1998).

Russell (1955) described cultural uses of kola in the Yorubaland of western Nigeria. He reported that the seed is normally kept in the house and an offering of kola forms part of the

greeting to an honoured guest. The older the kola the more highly it is regarded, and white and pink nuts are kept for particularly favoured guests. The gift of kola and especially the splitting and sharing of kola nuts between two or more pe ople signifies a special bond of friendship. Similarly, the sharing of kola nuts is a necessary prerequisite to business dealings that involve a strict etiquette in presenting, dividing, and eating of the fruits. Proposals of marriage may be made by a young man's presentation of kola nuts to the prospective bride's father and her acceptance or refusal may be conveyed by a reciprocal gift of nuts, with the meaning depending upon the quality and colour. Kola nuts presented by the bride's family signify fertility, productivity, prosperity, contentment and desire for the union (Johnson and Johnson, 1976; Sundstrom, 1966).

Kola figures prominently in religion and magic. It is used in divination and to learn the mind or intent of a god for healing the sick or against barrenness. In some areas it is a component of an oath-taking process. The possession and use of kola nuts may be a symbol of wealth and prestige (Hauenstein, 1974; Lovejoy, 1980).

3.9. Kola trade

Kola is traded in three stages (Opeke, 1992): unprocessed wet nuts; the bulk sale of processed nuts; and the retail trade in both unprocessed and processed nuts. *Cola nitida* is the main commercial species traded world wide, whereas *C. acuminata* is of local trading importance, especially among the Yoruba tribes in West Africa. Fresh nuts are only exported to countries within or neighbouring West Africa. Only dried nuts are exported beyond the region.
In southern parts of West Africa, the most commonly consumed species is *C. acuminata* and *C. nitida* is preferred in northern parts. For example, *C. acuminata* is the preferred species in western Cameroon and its trade is limited to this region. *C. nitida*, however, is produced though generally not consumed in this region; what is collected is traded to the North. Activities involved in harvesting/gathering and sales of kola nuts in the humid forest of the sub-region can be categorised into:

- Farmers, who harvest or gather products for sale;
- Assemblers/ retailers, who buy from village markets or direct door-to-door from farmers, and sort and package them in large baskets or units of a bag.
- Wholesalers, who conduct their transactions in bags and export to neighbouring countries, Europe or America.

i. Domestic market

Farmers mostly sell all produce immediately after gathering or harvesting due to lack efficient storage facilities and lack of transport. The price is usually determined by the farmer's effort in maintaining a high quality product. The quality of the nuts depends greatly on the methods used to extract the nuts from the pod, and in curing and cleaning and storage. Within West Africa nuts are sorted according to colour and size, and each class commands its own prices according to quality .Marketing of kola is typically informal, conducted usually through verbal agreement.

ii. Local market

During the main harvesting season many kola nuts traders, especially the Hausa traders from Nigeria, tour a number of villages and towns buying stocks of kola. They usually hire a

storeroom where they keep their produce Their main focus is the local markets in the humid forest zones of Cameroon, Ghana, Sierra -Leone and other nearby countries, including the Central African Republic (CAR), Equatorial Guinea and Gabon (CIFOR, 1997)

iii. International trade

Large quantities of kola nuts have been traded both among the countries of West and Central Africa and the Sub-Saharan Africa for centuries. Until the establishment of kola nut plantations in South and Central America, the West Indies, Sri Lanka and Malaya, there was considerable export from this region to the rest of the world. Exports from Lagos to Brazil

were valued at £2,949 in 1878 and £3,560 in 1882. Exports to Western Europe were very small. In 1887 exports to Britain and France were valued at £20 and £40 compared with a total value of local consumption of £32,400.00 (Moloney, 1887). Exports declined drastically once kola plantations were established elsewhere. Yet this never caused severe competition with African production since vast majority of the kola production is utilised within the African continent, particularly in Sub-Saharan Africa (McIlroy, 1963)
Today, kola nuts are exported to Europe and North America for flavouring kola drinks and for use in the manufacture of pharmaceuticals. Industrial exploitation is mainly for the caffeine. Beverages like kola wine, kola cocoa and kola-chocolates and assorted medicinal products have been derived from kola nuts. Oyedade (1973) stated that a few hundred tons annually are exported for these purposes. At any rate, off -continent exports appear to absorb only a minor part of the world production estimated at 180,000 tonnes of which 120,000 tonnes are produced by Nigeria and used either internally or in neighbouring countries (FAO, 1982; Lovejoy, 1980; Rosengarten, 1984). *C. nitida* is preferred in international trade because of its high caffeine content and the white strain is most valued.
United Nations' Food and Agriculture Organisation (FAO, 1982) estimated that from a total West and Central African production of kola nuts of 180,000 tonnes only 60,000tonnes are exported; the rest are consumed internally. Thus, it is clear that the product remains virtually unknown in other part of the world (FAO, 1995)
.

Student Self-Assessment Exercise 3

1. Identify some uses of Cola
2. Describe the different levels of Cola trade in Africa

4.0. Conclusion

The kola tree is a dome-shaped evergreen tree, usually 10-16m (35 to 50 feet) in height. Trees are usually planted from seed, about 6-8m (20 to 27 feet) apart, although vegetative production can be accomplished. Growth of this tropical tree is in flushes. The fruit matures about 4⅓ months after flowering. Full fruit production is reached by the 20th year, and the tree may continue bearing until it is 70 to 100 years old. The main harvest period of nuts extends from October to December, but some nuts may be available throughout the year. The pod is harvested before the nuts are ripe. The follicle is split and the three to six nuts are removed, fermented in heaps for 5 days, washed clean, and stored. They will keep for several months. Average yield is 210 to 250 salable nuts per tree or 30,000 nuts per hectare.

5.0.SUMMARY

In this unit, you have studied about Kola. In particular, you have studied the botany of Kola and related species, the agro-climatic requirement, its propagation and production techniques. We have also discussed the harvesting and the processing of the nuts and how the quality of processing affects the trade of the nuts. Finally, the composition and uses of kola were discussed.

6.0.TUTOR MARKED ASSIGNMENT

1. Distinguish between *Cola nitida* and *Cola acuminata*.
2. Discuss the Propagation of cola.
3. Discuss the Harvesting and Processing of Kola.
4. Mention some of the uses of Cola.

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MODULE 3: OIL CROPS

Unit 6: OILPALM

Table of Content

Unit 6: The OILPALM-- *Elaeis guineensis*

1.0. Introduction

This unit introduces you to the cultivation, production and processing of oil palm. In view of the wide distribution of palms and the varying types, attempts were also made to treat and discuss the cultivation of other types of palms.

2.0. Objectives

At the end of this unit, you are expected to :

- Enumerate the botanical characteristics of palms
- Enumerate the different types of palms that exist in your environment
- Enumerate and describe the operations at the
    - pre-nursery,
    - nursery and
    - field levels
- Identify and describe field management operations as:
    - fertilizer application,
    - harvesting, processing,
    - grading, and
    - storage
- Identify the uses of palm produce
- Clarify how you can meet international standards of palm produce

3.0. Subject -Matter Content.

3.1. Oil palm History

Palm oil (from the African oil palm, *Elaeis guineensis*) was long recognized in **West African** countries, and among West African peoples it is in widespread use as cooking oil. European merchants trading with West Africa occasionally purchased palm oil for use in **Europe**. But as the oil was bulky and cheap, and due to the much higher profits available from **slave-trading**, palm oil remained rare outside West Africa. During the early **nineteenth century**, the decline of the **Atlantic slave trade** and Europe's demand for legitimate commerce (trade in material goods rather than human lives) obliged African countries to seek new sources of trade revenue. In the **Asante Confederacy**, state-owned **slaves** built large plantations of **oil palm** trees, while in the neighbouring **Kingdom of Dahomey** (Benin Republic), King **Ghezo** passed a law in **1856** forbidding his subjects from cutting down oil palms**.** Palm oil became a highly sought-after commodity by **British** traders, the oil being used as industrial **lubricant** for the machines of Britain's ongoing **Industrial Revolution**, as well as forming the basis for different brands of **soap** such as **Palmolive**. By c.1870, palm oil constituted the primary export of some West African countries such as Ghana and Nigeria. By the 1880s, **cocoa** had become more highly sought-after, leading to the decline of the palm oil industry and trade within these countries.

3.2. Botany of Palms

Arecaceae (sometimes known by the names **Palmae)** is a family of flowering plants belonging to the monocot order, **Arecales**. There are roughly 202 currently known genera with around 2600 species, most of which are restricted to tropical or subtropical climates. Most palms are distinguished by their large, compound, evergreen leaves arranged at the top of an unbranched stem. However, many palms are exceptions to this statement, and palms in fact exhibit an enormous diversity in physical characteristics. As well as being morphologically diverse, palms also inhabit nearly every type of habitat within their range, from rainforests to deserts.

Palms are one of the most well-known and extensively cultivated plant families. They have had an important role to humans throughout much of history. Many common products and foods are derived from palms, and palms are also widely used in landscaping for their exotic appearance making them one of the most economically important plants. In many historical cultures, palms were symbols for such ideas as victory, peace, and fertility. Today, palms remain a popular symbol for the tropics and vacations.

The growth habit of palms is usually a straight, unbranched stem, and rarely a dichotomous branching stem or a creeping vine-like habit (liana). They have large evergreen leaves that are either palmately ('fan-leaved') or pinnately ('feather-leaved') compound and spirally arranged at the top of the stem. The leaves have a tubular sheath at the base that usually splits open on one side at maturity. The inflorescence is a panicle or spike surrounded by one or more bracts or spathes that become woody at maturity. The flowers are generally small and white, radially symmetric, and can be either uni- or bisexual. The sepals and petals usually number three each and may be distinct or joined at the base. The stamens generally number six, with filaments that may be separate, attached to each other, or attached to the pistil at the base. The fruit is usually a single-seeded drupe, but some genera (e.g. *Salacca*) may contain two or more seeds in each fruit.

3.3. Oilpalm *(Elaeis guineensis Jacq.)*

French: Palmier à l'huile; Spanish: Palma de aceite; Italian: Palma da olio; German: Oelpalme

Scientific classification

KINGDOM:	Plantae
Division:	Magnoliophyta
Class:	Liliopsida
Order:	Arecales
Family:	Arecaceae
Genus :	Elaeis
Species	Elaeis guineensis
	Elaeis oleifera

The **oil palms** (*Elaeis*) comprise two species of the Arecaceae, or palm family. They are used in commercial agriculture in the production of palm oil. The African Oil Palm *Elaeis guineensis* is native to west Africa, occurring between Angola and Gambia, while the American Oil Palm *Elaeis oleifera* is native to tropical Central America and South America.

Mature trees are single-stemmed, and grow to 20 m tall. The leaves are pinnate, and reach between 3-5 m long. A young tree produces about 30 leaves a year. Established trees over 10 years produce about 20 leaves a year. The flowers are produced in dense clusters; each individual flower is small, with three sepals and three petals. The fruit takes five to six months to mature from pollination to maturity; it comprises an oily, fleshy outer layer (the pericarp), with a single seed (kernel), also rich in oil. Unlike its relative, the Coconut Palm, the oil palm does not produce offshoots; propagation is by sowing the seeds.

Palms have an extraordinary diversity of sizes and shapes. We have scored palm genera based on their size and impact on the landscape rather than on their height. Large palms have wide, spreading crowns and require unusually large planting spaces. Moderate palms can be planted in smaller spaces, usually within several meters of one another. Small palms take very little space in the landscape and usually need to be planted near a pathway in order to be appreciated. Some of these palms are excellent container plants. Palms cannot grow where the soil freezes for extended periods of time, but many can be found in surprisingly cold regions. Some genera thrive in cool, high altitude habitats. Others tolerate wide temperature extremes.

3.3.1. African Oil Palm (*Elaeis guineensis*)

Oil palms are grown for their clusters of fruit, which can weigh 40-50 kg. Upon harvest, the drupe, pericarp and seeds are used for production of soap and edible vegetable oil; different grades of oil quality are obtained from the pericarp and the kernel, with the pericarp oil used mainly for cooking oil, and the kernel oil used in processed foods.

For each hectare of oil palm, which is harvested year-round, the annual production averages 10 tonnes of fruit, which yields 3,000 kg of pericarp oil, and 750 kg of seed kernels, which yield 250 kg of high quality palm kernel oil as well as 500 kg of kernel meal. The kernel meal is used to feed livestock. Some varieties have even higher productivities which has led to their consideration for producing the vegetable oil needed for biodiesel.

The African Oil Palm was introduced to **Sumatra** and the **Malaya** area in the early **1900s**; many of the largest **plantations** of oil palms are now in this area, with **Malaysia** growing over 20,000 square kilometres. By 1995Malaysia became the world's largest producer with 51% of world production.

3.3.2.Requirements for Growth of Oil palms

i. Light requirements

Palms are found in an extremely wide range of tropical and subtropical habitats. Savanna and desert palms thrive in blazing sun and have high light requirements in the landscape. Many rainforest palms occur in completely shaded habitats and require low light in the landscape. Palms with moderate light requirements grow well with partial shade. It is important to be aware of light requirements before palms are planted in the ground. Be sure to give young palms a gradual transition into full sunlight if they have been grown in partially shaded nursery conditions.

ii. .Water requirements

Most of the world's palm species occur in rainforests with abundant water throughout the year. Palms with high water requirements grow best when planted close to the water table and thrive with regular irrigation. Palms with moderate water requirements should be watered when dry but do not need constant moisture. Many savanna or desert palms grow best with very little moisture and can survive without supplemental irrigation. Palms with low water requirements grow best when the soil drains rapidly between watering.

iii. Soil pH

One of the most important factors affecting South Florida palm horticulture is the alkalinity of our soil. Many of the world's palms grow best with a soil pH in the low (acidic) to moderate (neutral) range. These palms require specialized fertilizers or soil modifications in South Florida. However, many palms can tolerate a wide range of soil conditions and can thrive in our generally high (alkaline) pH soil.

3.4. Agronomic considerations

3.4.1. Nursery Operations

i).Germination of oil palm seeds – The oil palm seed is very difficult to germinate. In order to obtain a high percentage of germination in a short time, the following conditions must be fulfilled.

- A constantly maintained temperature of 39º±1º C. (103ºF).
- A carefully controlled seed moist medium
- Controlled aeration

To satisfy these conditions, the oil palm seeds are germinated in artificial germinators which are of two types:

(a). Oven type germinator whose heat is supplied by an oven, and

(b). Water heated germinator. This is supplied through hot water in pipes.

ii The Technique of Germinating Seeds

The viability of the oil palm seeds deteriorates with the length of storage time. It is advised not to set seeds that had been stored for more than 6 months in germinators. Preferably, set fresh seeds always. The technique described below had been perfected by National Institute for Oil Palm Research (NIFOR), (located in Benin City, Edo State of Nigeria) for the germinating of oil palm seeds.

Soak the seeds in buckets for 5 – 7 days with a daily change of water. Remove; wipe off excess water and shade-dry for about 2 hours until the shine produced by the adhering water disappears. Set the seeds in polythene bags and secure with elastic bands, each bag containing 500 – 1000 seeds depending on the type(variety) of seeds set – less number if *Dura* and more if *Tenera*.

Put the bags in 30cm x 20cm x 10cm boxes inside germinators and maintain a constant T0 of 39º + or – lºC. (103ºF). Examine twice weekly and water with a fine spray if dry and remove any germinated seeds into the pre-nursery tray. Remove the boxes with the polythene bags on the 81st day (after 80 days) into a cool place. Examine and water as before. Rapid germination starts a few days later and is completed in about 15 days. The ungerminated seeds should be discarded thereafter.

All germinated seeds must be removed immediately they are noticed and planted into:

- ***polythene bag*** that had been filled with good top soil or
- ***pre-nursery trays*** and not directly into the nursery.

As the newly germinated seeds are very delicate, they need a period of very careful husbandry.

3.4.2. Pre-Nursery Operations

This is where germinated seeds are first of all planted and left to remain for a period of 4 – 5 months (December – April or June – December) before they are transplanted into the nursery.

The germinated seeds are planted into a cement slab or wooden trays of 120cm x 60cm x 15cm which are placed on a raised platform and filled with good top soils that have been sterilized.

Collect top soil in iron trays or steel sheet framework and bake on open fire for about 10 minutes with an average of 100ºC. During this period, weed seeds are first killed. Fill the trays with partially sterilized soil treated with 1 percent Dieldrin and allow to settle for a few days before planting- in your seed. It is important to plant seeds the right way--upwards in order to present defunct and twisted growth.

Germinated seeds are planted 7.5cm x 7.5cm (3”x 3”) to give 105 seeds per standard tray (5cm x 5cm spacing (2”x2”) = 205). If closer, etiolation due to over-crowding and effective control made difficult. The trays should be perforated at the bottom to allow drainage. Water properly immediately after planting.

i. Watering

Water about twice per week in wet weather. Increase the frequency as the dry weather sets in. Watering may be as frequent as twice daily in extreme harmattan conditions.

ii. Monitoring

When yellowing of leaves is observed, which is not the result of over-crowding; it may be caused by nutrient deficiency. Then application of a weak solution of the following will be of advantage:

a. Phosphate 14gm (½ oz) per gallow of water per standard tray with potash and muriate of potash at ½ oz per week + Magnessium as kieserite i.e. dehydrate ($Mg SO_4$. H_20) at 14gm (½ oz) per gallon of water fortnightly.
b. Sulphate of Ammonia and Super phosphate weekly as the same mixtures with potash + magnesium applied as above.

Water immediately after fertilizer application so as to wash down all traces of chemical that may settle on the leaves. This is to prevent scorching of the leaves.

iii.. Pre- Nursery Diseases and their Control

a) The most common oil palm pre-nursery disease is ***Anthraxnose*** which can cause serious losses. Its symptom is black leave batches which develop either at the margins or the centre of the leaves. It is enhanced by weakness of the seedlings which is the result of overcrowding.

Control

(1) Plant at low population density per tray

(2) Spray at the 2 leaf stage (6 weeks) with Captan water at 900gm/450litres (21b / 100 gallon) with Cuman at 450gm/450 litres (1 lb / 100 gallons) of water. Do not use Perenox or any of the Capric fungicide, because the oil palm susceptibility to copper burn.

b). Freckle –disease

This is another disease characterized and recognized by the discrete brown spots often surrounded by yellow orange halo (circle of light).

Control

Spray with Dieldrene.

General Observation

Mulch the pre-nursery with spikelets. To prevent losses due to blast and drought or severe harmattan, shade lightly and water heavily. The shade should be progressively thinned out towards the end of seedlings preparatory to planting out into the nursery.

3.4.3. Nursery Operations

There are two types of nursery – Dry season and wet season nursery. The seedlings which go into the nursery during the wet season – wet season nursery go into the pre-nursery by December to April.

The dry season nursery, seedlings go to the preparatory Pre-nursery by June to October and finally go to the nursery in October.

Pre-nursery:

(1) December to April – wet season nursery

(2) June to October – dry season nursery

After choosing site, clear and burn. Carry away the ashes or scatter all over the field. Plough and make sure the area is fairly flat and well drained. Then incorporate F.Y.M. at the rate of 50 tons per acre. In old nurseries, weed, and then double dig to loosen the soil.

Then transfer seedlings from pre-nursery to main nursery with ***ball of earth*** at a spacing of 0.75m squared (2½ feet square). Plant at the level (depth) at which seedlings leave the pre-nursery. Water after planting if there is no rain.

i .Maintenance

Continue the Pre-nursery maintenance. In addition, mulch with old bunch refuses.

ii. Fertilizer application –

1 part of Sulphate of ammonia + 1 part Super phosphate + 1 part Sulphate of potash + 2 parts Magnesium sulphate. Apply as follows:

14gm (½ oz) per seedling in May (6 weeks after transplanting)

42.5gm (1½ oz) per seedling in July and

56gm (2 oz) per seedling in October.

Ring application of 5 -7.5cm (2 – 3 inches) radius. Mulch about 4 weeks after transplanting with whole bunch refuses which contains high percentage of potash.

iii. Pests and Insects Control

Snails, grasshopper, crickets-- Handpick if they are few. Spray insecticides to control if they are many.

Nursery Diseases – are ***freckle and anthraxnose.*** Spray for the first 3 weeks after transplanting against anthraxnose at weekly intervals.

Freckle – This is caused Cercospora Elasidis. It may be controlled by spraying with fungicides at 14 day intervals throughout the nursery season and spraying starts when spraying against anthraxinose stops.

3.4.4. Polythene Nursery

The use of polythene bags that are specifically designed (big size) has become the norm in recent years. The bags are filled with good rich humus top soil. The filling is done to ¾ level of the bag. The bags are then allowed to rest for a couple of days and are then arranged in rows as described in unit 2. Oil palm sprouts are planted directly into the bags. The bags are then heavily wetted after the planting. All operations that are performed on the regular nursery also performed on the polythene nursery beds –

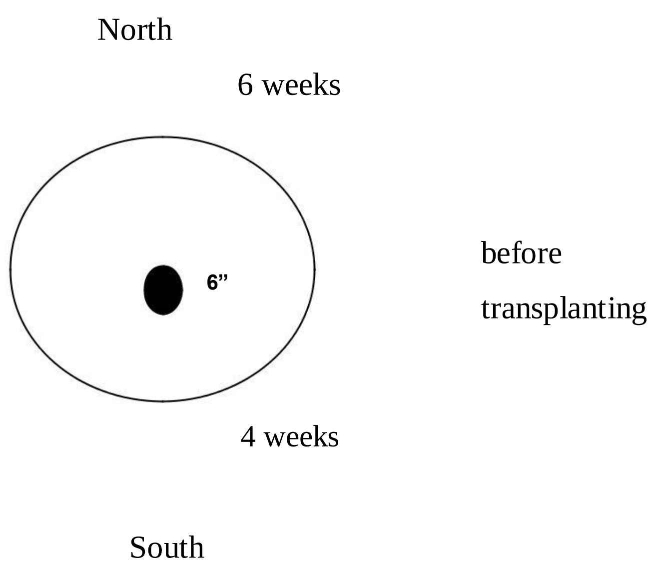
supplying, pests and disease control, water and shade management manure application and fertilization,

3.4.5. Pre Field -Transplanting Operations

The main pre-transplanting operations that should be done in the nursery are:

(1) Heavy watering during the seedlings last ten days in the nursery;
(2) Root pruning. The technique of root-prunning is described below:

Cut the north part/half of the circumference of the seedling at a radius of 15cm (6 inches) six weeks before transplanting time, and the southern half 4 weeks before transplanting. The cutting is done with a spade driven vertically into the soil until the cutting of the roots is distinctly felt. Press the soil to re-establish contact between the roots and the surrounding soil.



Dry Season Nursery

This should be planted in mid-October with seedling planted in the pre-nursery in June with the same planting technique as was adopted in the wet season nursery. As mentioned earlier, there is no basic difference between the techniques of wet and dry season nurseries, but the whole process of growing dry season seedlings has to be more intensive with greater attention being paid to details. Seedlings to be planted into the nursery remain in the pre-nursery during heavy rains in May – July which cause soil leaching. Sulphate of Ammonia at 56gm/18litres (2 oz / 4 gallons) of water / 400 seedlings should be applied fortnightly starting at the 2 leaf stage in the pre-nursery.

i. Shading management – The dry season nursery should be shaded. Thin out the shade progressively as from December until all is removed by the end of January.

iiFertilizer Application – Apply 28gm (1 oz) of a 1:1:1:2 N.P.K.mg mixture per seedling / month after transplanting.

iiiWatering – heavy watering needed at the rate of 4.55 litres (1 gallon) of water per seedling per week and more if need be.

Mulching, weeding, disease and pests control as well as removal and burning of dead and diseased fronds must be carried out in the usual way. The pre-transplanting operations described for the wet season nursery are also a necessity here.

Student Self-Assessment Exercise 1

1. Distinguish the African palm from the other palms
2. Using fruit qualities , distinguish between the types of African palm
3. Describe the process of sprouting seeds for large plantations
4. Describe the edaphic and climatic requirements for production of palms

3.5. Field Operations

3.5.1.Field Establishment

Planting of oil palm seedlings should be done in May; as such the field planting must be prepared earlier.

3.5.2. Land Preparation – Clear the bush, fell the trees, and burn the refuse to facilitate the lining out of the farm.

3.5.3. Spacing – The normal spacing for oil palm is 29ft triangular (Δ). This gives a total of 59 palms per acre or 143 palms per hectare at a spacing of 9m x9m

3.5.4. Holing – Dig holes of the size that will conveniently take the seedling and the ball of earth or cross-shaped hole if planting naked root seedlings. Other methods of land preparation include:

- The felling of the huge trees and cutting traces area. Holes are then dug after determining the spacing on the traces and the seedlings planted.
- In other cases, planting may be done amidst food crops.

The best method however is the one described under land preparation above.

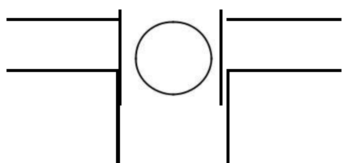
3.5.5. Field Planting – Two methods have been involved for the planting of oil palm seedlings into the field --Ball of earth and Naked Root System

i. Ball of Earth Planting

In planting with the ball of earth, the seedlings are lifted with a whole ball of earth in the nursery with a Wascot cylinder or spade. Care should be taken to maintain the ball of earth intact. These are transported in head pans to the field and placed in the already dug holes. As deep or shallow planting may lead to failure, it is very much important that the correct depth of planting must be observed. Do not bury any green portion of the base. Fill the gap between ball of earth and surrounding soil with good top soil and firmly pressed down.

ii. Naked Root System

Before lifting the seedlings from the nursery, cut off half of every leaf except the pruning may be less severe. The planting hole for naked root seedling should be cross-shaped with a little elevation at the centre upon which the base of the seedling will sit. Immediately the seedlings are lifted in the nursery, the exposed roots should be dipped in clay slurry. This will prevent the drying off of the roots before and after planting. The seedlings are then placed in the cross-shaped holes, the base sitting on the core of earth at the centre and the roots evenly distributed in the four arms of the hold. Fill the hole with good top soil and press down firmly.



Student Self Assessment Exercise 2

1. Distinguish the African palm from the other palms.
2. Descibe the types of African palm using the fruit qualities.
3. Describe the process of sprouting palm seeds for large nursery operations
4. Describe the climatic and edaphic factors required for the production of African palm.

3.5.6. Plantation Maintenance

i) Seedlings should be protected immediately after transplanting with wire-net acting as collar of about 18” high to keep away rodents. Do not remove the wire netting collar until 2 – 3 years after planting depending on the rate of development of the palm.

ii) The newly planted seedlings should be mulched as the dry season approaches. Do not allow the mulching materials to touch the base of the palm to prevent termites attack.

iii) Cover crops like centrosema, pueraria etc. should be planted to prevent erosion, weed growth and to preserve soil moisture.

iv) Ring weeding to a diameter of 1-1.5m (4 – 6 feet) is very essential to surpass weeds as well as to check the vines of the cover – crops from climbing the palms.

v) Food crops may be planted through the plantation during the first two years of establishment.

vi) Dead and diseased fronts must be pruned regularly.

vii) Diseases and pests / insects should be regularly controlled by the use of fungicides and insecticides respectively, especially during the first two years of establishment and as necessary afterwards.

viii) Supply vacancies up to a maximum of two years after planting.

ix) Fertilizer application in the form of wood ash or potash will enable the palm to develop healthy forms and restore yield. A general application of a mixture of 1 – 1 – 1 – 2 of sulphate of ammonia, sulphate of potash and magnesium sulphate at 700gm, 1400gm and2800gm (1½ lb, 3 lb and 6 lb) per palm. Apply during the first three years respectively will be of immense advantage.

x) Present competition between palms and weeds.

Mature palm plantation .

Young oilpalm mulched

i.Diseases of Oil Palms – could be broadly classified under two headings, namely-- Parasitic diseases and Deficiency diseases.

a.. Deficiency Diseases

Although the oil palm tolerates acid conditions and grows well on soils of low fertility, yet it is highly susceptible to deficiencies of K & Mg which in most cases lead to reduction in and in very serious cases reduce in yield.

i. **Symptoms of the Potassium Defficiency**

(a) Most general – mid crown yellowing and premature withering of old leaves. Leaves in the centre of crown become uniformly pale yellow in colour, another condition termed "Mbawsi Disease" in which orange lesions develop as broad bands on each side of the mid-rib with narrow strips of leave on both sides of the mid-rib and at the leaf edge remaining green has been associated with Potassium deficiency.

(b) Another symptom is that of orange spots of irregular shape on medium aged leaves followed by either edge or tip burn called “Confluent orange spotting”. Although the real cause of this condition is not yet clear, yet the symptom has disappeared on the application of Potassium Fertilizer.

Treatment on Young Palms – Apply 225gm, 450gm , 900gm aqnd 1500gm (½ lb, 1 lb, 2 lb and 3 lb) per palm six weeks, 1 year, 2 years, and 3 years respectively after planting. Apply sulphate or muriate of potash. Thereafter apply 2.25Kg (5 lb) per palm every third year.

Treatment on Matured Palms – If these had never been manured, apply 2.25Kg (5 lb) of potash every third year.

Method of Application – Apply before or after the rains but never at the height of the rains. Broadcast to the limit of leaf spread of old palm. But on young palms, apply in a circle of 6.6 feet diameter around young palms.

ii. .**Symptoms of Magnesium Deficiency**

Fronds show a yellow discoloration which spreads along the leaflet turning a deep orange as the disease progresses. Leaves become infected by fungi with the tips turning purplish and finally drying out from the leaf top downwards.

Treatment – Apply 225gm, 450gm , 900gm and 1500gm (½ lb, 1 lb, 2 lb, 3 – 4 lb) of Magnesium Sulphate per palm in the four years following planting. Later, apply 2.75Kg (6 lb) every third year.

iii. Symptoms of Nitrogen Deficiency

Leaves assume pale green colour. The leaflets are narrow and often rolled under thus giving the frond a fealthery appearance. There is basal swelling with the rachis and the mid-rib burning brighter yellow.

Treatment – Apply 225gm, 450gm & 900gm (½ lb, 1 lb, and 2 lb) of Sulphate of ammonia per palm at 6 weeks, 1 year and 2 years after planting respectively.

NOTE – Application of sulphate of ammonia on young palms increases freckle attack. Apply 225gm, 450gm & 900gm (½ lb, 1 lb and 2 lb) of sulphate or muriate of potassium 6 weeks, 1 year, and 2 years respectively after planting making sure if magnesium deficiency is likely to occur to apply the same rates of magnesium sulphate at the same period.

If a soil is naturally rich in potassium or potash leads to K/Mg, Potassium / Magnessium inbalance which may cause severe magnesium deficiency. It is therefore always necessary to balance the two (2) at every application.

b. Parasitic Diseases

- Anthracnose
- Freckle
- Blast
- Trunk Rot
- Vascular Wilt

i. Trunk Rot

This is caused caused by the fungus called Ganoderma lucidium which attacks roots of old palms of about 13.5m (45 feet) in height but rarely shorter palms.
It is caused by the fungus called Ganoderma lucidium which attacks roots of old palms of about 45 feet in height but rarely shorter palms.

Symptoms (a) leaves wilt and hang down, (b) old palms gradually disintegrate.

Control – Rehabilitate.

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ii. Vascular Wilt

This is caused by the fungus fusarium oxysporum which attacks the vascular bundles (the phloem and the xylem vessels) that are responsible for translocation of food, water ad minerals) makes them rotten and finally causes the causes oozing out of the content of the bundles. The leaves eventually wilt, break, hear their bases and hang down inside the trunk. The palm eventually disintegrates.

Treatment – (1) Attack the pathogen with fungicides

(2) Breed resistant varieties of oil palm

(3) Modify the environment by crop rotation, move especially at the nursery state and crop sanitation on the field.

iii. Bassal Decay

This is a localized disease. It attracts young palms mainly. Its control is not yet established.

Student Self-Assessment Exercise 3

1. Describe the stage at which you can easily traasnsfer seedlings to the permanent site.
2. What are the advantages of polybags in oilpalm nursery operations?

3.6. Soil Nutrient Uptake and Oilpalm Plantation Management

Nutrient demand is highly variable, depending mainly on the yield potential determined by the genetic make-up of the planting material and on the yield limit set by climatic factors (water, effective sunshine, temperature). Yield and nutrient uptake are much higher, for example, in Malaysia than in Nigeria (see table). More important, however, is the fact that the efficiency of nutrient use (uptake/ton FFB) is much higher in Malaysia, the main reason being the heavy climatic stress in Nigeria (a long dry season, and limited hours of sunshine during the wet season). The response to most stress factors is a reduction in fruit output, while vegetative growth is little affected.

Nutrient uptake is low during the first year (transplanting shock!), but increases steeply between year one and year three (when harvesting commences) and stabilizes around years five to six.

Recognition of this fact has resulted in increased early applications of fertilizer, which combined with improved other agronomic practices (better planting material, higher nursery standards, more rigid culling etc.) has led to a dramatic increase in early yields (in third to sixth years from planting). In regions without any serious climatic constraint yields of over 25 t/ha FFB have been achieved in the second year of harvesting, largely as a result of higher early rates of fertilizer application.

i. Plant analysis data

Producing, as it does, leaves (and fruit) throughout the year at a relatively uniform rate, the oil palm is better suited to leaf analysis than most other crops. The reference tissue for adult palms is the centre part of the pinnae (without midrib) from the seventeenth frond..

ii. Nutrient deficiencies

N deficiency is usually associated with conditions of water-logging, heavy weed infestation and topsoil erosion. Symptoms are a general paling and stiffening of the pinnae which lose their glossy lustre. Extended deficiency will reduce the number of effective fruit bunches produced as well as the bunch size.

P deficient leaves do not show specific symptoms but frond length, bunch size and trunk diameter are all reduced. Most soils on which oil palms are grown are very low in P, but it appears to be very efficient in utilizing soil and fertilizer P.

K deficiency is very common and is the major yield constraint in sandy or peaty soils. The most frequent symptom is "confluent orange spotting". Pale green spots appear on the pinnae of older leaves; as the deficiency intensifies, the spots turn orange or reddish-orange and desiccation sets in, starting from the tips and outer margins of the pinnae. Other symptoms are "orange blotch" and "mid-crown yellowing". In soils having a low water holding capacity (sands and peats) K deficiency can lead to a rapid, premature desiccation of fronds.

Mg deficiency is a frequent problem in light textured soils and in acid soils where the topsoil has been eroded. Symptoms are a yellowing of leaflets of older fronds, with leaflets exposed to sunlight showing more severe yellowing than do shaded leaflets.

S deficiency has not (yet) reached levels of significance in any of the major growing areas. Current sources of N (Ammonium Sulphate) and Mg (Kieserite) appear to be sufficient to meet the S needs of the crop.

Outright Ca deficiency is rare and the largest benefit from applied Ca (lime or dolomite) is probably due to better growth of legume covers and improved P availability.

Although Cl is a micronutrient for most crops, oil palm (and coconut palms), for optimum growth and yield, require Cl in concentrations that bring it well into the range of a secondary nutrient. No clear deficiency symptoms have been observed so far, other than pronounced signs of water stress during dry spells.

B is so far the only micronutrient of general significance. Deficiency first appears as retarded growth of young tissues. Deficient leaves are misshapen, wrinkled, brittle, and dark green in color. Specific to oil palms are: "frond shortening", "blind leaf", "crinkle leaf", "hook leaf" and "fishbone leaf".

Cu deficiency is a common problem on peat soils and on highly leached sandy soils in high rainfall areas. Symptoms are severely stunted growth, chlorosis (starting from the tips or upper part of the youngest pinnae), shortening of internodes and dessication.

Only isolated cases of Fe, Zn and Mn. deficiency have been detected.

iii. Fertilizer recommendations

Fertilizer recommendations must take into account environmental (soil and climate) and economic (fertilizer price and produce price) constraints. Actual fertilizer use should be further modified by the level of agronomic management. Responses tend to be most vigorous from the first to the sixth year in the field.

iv. General Nursery Programme. Healthy, well selected seedlings are a pre-condition for early and sustained high yield. In most cases granular multinutrient compound fertilizers (NPK Mg + micronutrients) are the preferred nutrient source for seedlings in the nursery. Where sub-soil is used to fill the polybags, extra dressings of Kieserite may be required (10-15 g every 6 to 8 weeks). Where compound fertilizers are not available, equivalent quantities of straight materials should be used.

v. Field Programme

Nitrogen rates range from 1.5-8 kg/palm of ammonium sulphate (AS) or its equivalent, depending on the yield potential as affected primarily by the total rainfall and its distribution and the intensity of solar radiation.

P rates range from 0.5-2 kg/palm/year of triple superphosphate (TSP) or its equivalent.

K rates range from 1 to 5 kg/palm of KCl, depending on soil and yield potential. To maintain good fertilizer response and high yields in older palms (selective) thinning is often necessary where interpalm competition has become a problem as a result of initial high density planting in combination with a high fertility regime and good rainfall.

Recent pioneering work on maximum exploitation of genetic yield potentials (MEGYP) in Malaysia (Ng et al. 1990) has demonstrated that through a combination of good overall agronomic husbandry and intensive and well balanced use of fertilizer, productivity of oil palms can be enhanced by as much as 30 to 40 %.

With good management and proper fertilizer use, differences between soils of widely different inherent fertility largely disappear, so long as moisture deficit does not become a limiting factor.

vi. Preferred nutrient forms and methods of applications

N: the preferred source is ammonium sulphate (AS), but urea is expected to become a dominant source. To avoid N losses due to volatilization, urea must be applied at times of assured rainfall.

Other N sources include ammonium chloride (AC) and ammonium nitrate (AN).

With young palms N should be evenly distributed over the weeded circle; in older palms inter-row application is also possible if there is no competition from a ground cover. In no case should N be applied in a narrow band around the base of the palms, as this will increase losses and may cause severe root damage. High N rates should be split into several dressings. In areas with an extended dry period, the last N application should be at least 3-4 months before the beginning of the dry season (high N levels in leaves result in more water consumption).

P: water-soluble sources (TSP, DAP and NPK compounds) are prefered during the immature phase. Thereafter phosphate rocks (preferably of high reactivity) can be used, applied up to year 4 in the circle, and thereafter alternating between circle and inter-row or inter-row only (where surface erosion is a problem).

K: potassium chloride (KCl) is the sole K source of significance. Potassium chloride has the added benefit of supplying chloride - an element found to be often deficient in oil palms. With young palms (up to year 4) it should be spread evenly over the circle; with mature palms it should be broadcast in the inter-row.

Mg: Kieserite ($MgSO_4 . H_2O$) is the main Mg source for oil palms. Other sources include sulphate of potash magnesia and dolomite (suitable for acid soils only).

Kieserite should be spread over the circle while dolomite should be applied to the inter-rows.

Cl: potassium chloride is the main Cl source. In high K soils ammonium chloride can be used as an efficient alternative Cl source.

B: Sources are mainly various forms of sodium borate ($Na_2B_4O_7.10H_2O$, $Na_2B_4O_7.5H_2O$).

Placement of B should be into the weeded circle. Axillary application, though effective, is not advisable as it may result in uneven B distribution in the palm and cause B toxicity.

Cu: a one time soil application of 50 g/palm of copper sulphate is usually sufficient to correct Cu deficiency. On some peat soils repeated applications may be required.

3.7.0 Harvesting

The bunch of the oil palm is ready for harvesting when the fruits are ripe. This is usually 5 – 6 months after successful fertilization. This period is usually longer in the dry season and shorter in the rainy season.

In plantations, harvesting is done every two weeks with harvesting hooks and cutlasses. The fronts are first removed before the bunches-base can be accessed. The bunches are then cut at the base with the aid of hook or cutlass..

Fruit of oil palm tree

Student Self-Assessment

Exercise 4

- Describe the process of harvesting oilpalm fruits from the trees.

3.8.0. Processing and grading of palm products

Palm bunches are harvested every processed. There are three major methods of processing:

- Hand processing
- Hydraulic processing
- Mill processing

1. Hydraulic Processing

The palm bunches are harvested and later quartered into spikelets.
The spikelets are sprinkled with water and heaped together and then covered with polythene to prevent vapour loss for 24 hours.

i. The fruits are then picked.
ii. Meanwhile, water is poured into the sterilizer and brought into boiling.
iii. The fruits are then poured into the sterilizer covered with sacs to conserve heat.

iv. Immediately steam appears on top of the sacs, the boiling is timed and prolonged for another one hour.
v. After this, the fruits are collected into mortars and pounded with pestles.
vi. From here, the pounded fruits are sent into the stork press and pressed as follows:

(a) Fill the perforated baskets or cans of the press with pounded or mashed fruits.
(b) Push the can centrally under the rain.
(c) Shut the valve for flow of dumous oil to the head of the ram during cranking.
(d) Fix the cranking handle and crank.
(e) When the cranking becomes stiff, change to high pressure plunges and continue cranking until it is stiff again. This cranking takes about seven (7) minutes. During this process, crude sludgy oil would have started oozing out from the perforations in the can unto the platform. The oil flows through a gutter into a container.
(f) At the end of this period, open the hydraulic valve and the ram rises.
(g) Pull out the basket and knock out the fibre.

vii. Examine the pressed for nuts and fibre mixture for oil by squeezing between your palms. If it is still oily, it shows that either you have not pressed long enough or that the fruits were not well pounded or that it was getting cold before pressing or that it contained too few nuts. If the latter is the case, reduce the content of the nuts or add more as the case may be.

viii. The oil thus collected is thick and contains a lot of fibre. The oil should therefore be refined by a system called clarification which simply means the separation of oil from fibre, diet, and water. This is done as follows:

(a) Two clarification drums are required and these should be mounted over an open drum fire.

(b) A clarification drum contains 2 drums in one – an outer and inner smaller one. Pour 40 litres (10 gallons) of water into each of the outer drums.

(c) Bring the water to the boil.

(d) Pour the thin oil on top into drum number 1.and continue to heat but *taking care not to heat to boiling point* in order to prevent oil/ water emulsion which can be very difficult to separate.

(e) Oil being higher than water flows through the water deposits, the (sluggy) sludge and diet and the thin oil flows on top. Rake away foams till no more appear. Add more thin oil to raise the level until the fine oil overflows into the inner drum.

(f) Meanwhile, the sludgy oil is pounded into drum no. 2 and the thin oil collected sent to drum number 1 for further clarification.

(g) If the sludgy oil in drum no. 2 refuses to yield oil, give it a vigorous boiling and allow it to rest overnight in order to collect more oil from it.

ix. Collect clean fine oil from the inner drum through a tap leading outside the outer drum.

x. Simmer the clean thin oil over a low fire (to remove all traces of water).

xi. Weigh or measure in gallons, drums and send to the store for disposal.

Diagrammatic Flow –Chart of Hydraulic Processing

Disposal

Store

Drum

Simmer ……. The oil collected are placed on a low fire to remove the remaining water in the oil

Clarification Drum

Press

Pounding Reheating Drums

Sterilizer

Chop and pick fruits

Harvest ⟶ Processing shed

↑

Field

ii. The Pioneer Oil Mill

This is an advanced processing mechanism working strictly on automatism (mechanical routine) or on a system of automation. The pioneer oil mill is set up to meet all precautions necessary to reduce the F.F.A. content of palm oil. It is therefore designed to produce high rating oil.

WORKING OF THE MILL

On arrival, palm-bunches are packed into ladder like ***cranes*** which when revolving deposits them into ***Sterilizer*** cages where they are boiled.

From here, the bunches pass into the ***Thresher*** where the fruits are dislodged / separated from the bunches. The bunch refuse goes one way to the outside while the fruits pass on in another way into the ***Digester*** where they are marshed and sent to the ***Press*** or Centrifuge where pressing is done by centrifugal force.

The oil drains through a screen which separates any accompanying fibre and nut into the ***crude oil tank*** while the fibre and nuts go another way into the ***fibre and nuts separator***.

The oil is now pumped from the crude oil tank into the ***settling tank where clarification takes place***. From here, the oil goes to a chamber where it is to be turned over and over again in order to separate pure oil from other admixing waste products by another centrifugal force and finally drains into the ***storage tank*** from where it is collected in drums and disposed off.

The nuts are separated from the fibre and the dry fibre sent to the ***boiler***. The nuts go through a grading screen into the ***nut cracker*** where the nuts are cracked. Shell and kernel pass on to the ***clay berth*** for separation. The shells pass on to the boiler while the kernels are collected, graded and bagged for disposal.

3.9.0 Grading of palm oil-- Hard and Soft Oils

The percentage of F.F.A. (Free Fatty Acids) contained in any quantity of palm oil determines its hardness or softness.

Palm oil is a fat which is a compound of glycerine and Palmitic acid . When the cells of a fruit are injured either by cutting or bruising or piercing, the enzymes residing inside the living protoplasm of the cells become liberated, begin to act on the palmitic acid and so split it up into its components – Free Fatty Acid (F.F.A). and glycerine through rapid decomposition. It is therefore the amount of F.F.A. released during this decomposition that determines whether the oil is hard or soft. If the oil contains 5 percent or less of F.F.A; it is regarded as soft oil while any that contains more than 5 percent F.F.A is down graded as hard oil.

Advantages of Soft Oil

i. It fetches a higher price than hard oil
ii. It is soft oil that is mostly used in the manufacture of edible fats
iii. Only soft oil is used as fuel in internal combustion engines
iv. It is the one used as flux and protective coating in tin-planting.

Since soft oil is more commercially useful than hard oil, the ***following precaution must be taken to reduce the F.F.A content of our palm oil:***

a. Avoid bruising or injuring fruits when cutting off the bunches as well as during transportation and separation of fruits from the bunches
b. Do not depulp the fruits until they had been thoroughly boiled
c. Avoid any cause that prevents the fruits from being processed immediately after harvesting or which necessitates the storing of fruits and bunches in heaps.
d. Process loose and bruised fruits immediately after harvesting
e. Avoid processing over ripe and fermented fruits
f. Use only clean materials and equipment during processing
g. See that no water remains in processed and boiled oil.

3.10. Storage of palm products

i. Inspection and Grading of palmoil

The standard prescribed for exportable palm oil is quality No. 1 which means that palm oil should contain only 2 percent or less of H20 and other extraneous substances and free from adulterants. Grades specified are as follows:

(1) Special Grade "A" – exportable palm oil that contains not more than 3.5 percent F.F.A
(2) Special Grade "B" – exportable palm oil containing not more than 4.5 percent F.F.A.
(3) Grade I – exportable palm oil containing not more than 90 percent F.F.A.
(4) Grade II – exportable palm oil – not more than 18 percent F.F.A.
(5) Grade III – exportable palm oil – not more than 30 percent F.F.A.

ii. Palm Kernels

The standard prescribed for exportable palm kernel is quantity No. 1 which means palm kernel contains by weight, less than 4 percent shell, fibre, rotten and decayed kernel and other extraneous matters. The nuts are thoroughly dry and hard.

3.11.0. Uses of palm oil and other palm products

1. Palm oil

Palm oil is a form of edible vegetable oil obtained from the fruit of the oil palm tree. Previously the second-most widely produced edible oil, after soybean oil, it may have now surpassed soybean oil as the most widely produced vegetable oil in the world.

The palm fruit is the source of both palm oil (extracted from palm fruit) and **palm kernel oil** (extracted from the fruit seeds). Babassu oil is extracted from the kernels of the Babassu palm.

Palm oil itself is reddish because it contains a high amount of betacarotene. It is used as cooking oil, to make margarine and is a component of many processed foods. Boiling it a few minutes destroys the carotenoids and the oil becomes white.

Palm oil is one of the few vegetable oils relatively high in saturated fats (such as coconut oil) and thus semi-solid at room temperature.

i. Chemical composition

The palm oil and palm kernel oil are composed of fatty acids, esterified with glycerol just like any ordinary fat. Both are high in saturated fatty acids, about 50% and 80%, respectively. The oil palm gives its name to the 16 carbon saturated fatty acid palmitic acid found in palm oil; monounsaturated oleic acid is also a constituent of palm oil while palm kernel oil contains mainly lauric acid. Palm oil is the largest natural source of tocotrienol, part of the vitamin E family. Palm oil is also high in vitamin K and dietary magnesium.

Napalm derives its name from naphthenic acid, palmitic acid and pyrotechnics or simply from a recipe using naphtha and palm oil.

The approximate concentration of fatty acids (FAs) in palm oil is as follows:

Fatty acid content of palm oil

Type of fatty acid	pct
Palmitic C16*	44.3%
Stearic C18*	4.6%
Myristic C14*	1.0%
Oleic C18**	38.7%
Linoleic C18***	10.5%
Other/Unknown	0.9%

* =: Saturated; ** =: Mono unsaturated; *** = Poly unsaturated

Fatty acid content of palm kernel oil

Type of fatty acid	pct
Lauric C12*	48.2%
Myristic C14*	16.2%
Palmitic C16*	8.4%
Capric C10*	3.4%
Caprylic C8*	3.3%
Stearic C18*	2.5%
Oleic C18**	15.3%
Linoleic C18***	2.3%
Other/Unknown	0.4%

* = Saturated; ** =: Mono unsaturated; *** = Poly unsaturated

Demand for palm oil is rising and is expected to climb further, particularly for use in **biodiesel**. Biodiesel is promoted as a form of **renewable energy** that greatly reduces net emissions of **carbon dioxide** into the atmosphere, and therefore its use is being touted as a way to decrease the impact of the **greenhouse effect** and also the possibility of **peak oil**

ii. Palm Oil as Biodiesel

The Malaysian government is refocusing the use of palm oil to the production of ***biodiesel*** to cater to the huge demand from European countries; it has encouraged the building of biodiesel plants. This is due to the higher prices of fuel and increasing demand for alternative sources of energy in the Western world.

The plants will start operating middle of 2007 and produce 100,000 tonnes of biodiesel annually. Strong demand for biodiesel from Europe as well as Colombia, India, South Korea and Turkey has fueled the industry's growth as more countries seek to reduce their reliance on fossil fuels.

Malaysia has already begun preparations to change from diesel to bio-fuels by 2008, including drafting legislation that will make the switch mandatory. From 2007, all diesel sold in Malaysia must contain 5% palm oil. Being the world's largest producer of crude palm oil, Malaysia intends to take advantage of the rush to find cleaner fuels.

With the growing emphasis on biodiesels presenting a sustainable alternative to ***fossil fuels*** it is important to recognise that these benefits are partly negated when forest is cleared to make room for biodiesel crops such as oil palm.

On 23 Nov 2006 Australia's first palm oil based ***biodiesel*** plant was opened in Darwin. When fully operational in 2007 this plant should produce 140 million litres of biodiesel annually.

Crude palm oil is considered the richest natural source of carotenoids (about 15 times more than in carrots). Carotenoids are a group of more than 700 compounds (e.g. alphacarotene, beta-carotene) that produce the red, yellow, and orange colours found in many fruits and vegetables. The human body uses carotenoids as Vitamin A which enhances eye health. Carotenoids also play an important potential role by acting as biological antioxidants, protecting cells and tissues from the damaging effect of ***free radicals,*** which could cause cancer. Studies also suggest that carotenoids enhance immune function by a variety of mechanisms, and improve cardiovascular health. Red palm oil is a form of processed palm oil (deacidified and deodorised) which retains 80% of the original carotenoids, making it a remarkable source of Vitamin A.

- High in ***tocotrienols,*** an ***antioxidant*** with other possible health benefits

Natural vitamin E exists in eight different forms or isomers, four tocopherols and four tocotrienols. Natural palm oil contains alpha, beta, gamma, and delta-tocopherols and alpha, beta, gamma, and delta-tocotrienols. No other natural source contains this much vitamin E. Tocotrienols in Vitamin E have been found to have many beneficial properties, among them antioxidant and anti-cancer activities. Probably the most important finding in recent research on tocotrienol was its role in inhibiting human breast cancer cells. Tocotrienols have also been demonstrated to lower blood cholesterol levels, by reacting with certain enzymes in the liver which produces cholesterol. Its antioxidant properties bring many benefits to the human body, such as preventing skin aging, preventing fat oxidation, reducing blood pressure and many more.

- Other minor nutrients

Palm oil contained about 10% linoleic acid, which is an unsaturated ***omega-6*** fatty acid. Linoleic acid is one of the two essential fatty acids that humans require. Palm oil also contains small amounts of squalene (possible cholesterol lowering and anti-cancer properties) and ubiquinone (energy booster).

Reasons for choosing palm oil:

- Red palm oil is rich in *co-enzyme Q10*
- Palm oil is an excellent dietary energy source.
- Palm oil is a very rich source of Vitamin A and E.
- Palm oil is a stable oil in high temperatures (good for frying).
- Palm oil is a cheap vegetable oil (due to the oil palm's high productivity).

Reasons to not choose palm oil:

- Palm oil has a high ***saturated fat*** content, which may lead to cardiovascular disease.

iii. Palm oil and blood cholesterol controversy

For many years now, it has been established that the primary cholesterol-elevating fatty acids are the saturated fatty acids with 12 ***(lauric acid***), 14 (***myristic acid***) and 16 (***palmitic acid***) carbon atoms with a concomitant increase in the risk of coronary heart disease. Monounsaturated fatty acids such as ***oleic acid*** is as effective in reducing serum total and low-density lipoprotein (LDL) cholesterol levels as polyunsaturated fatty acids such as ***alpha-linoleic acid***. The **World Health Organization** in its report states there is convincing evidence that palmitic oil consumption contributes to an increased risk of developing of cardiovascular diseases.

A study by a group of researchers in China comparing palm, soybean, peanut oils and lard showed that palm oil actually increased the levels of good cholesterol and reduced the levels of bad cholesterol in the blood (Zhang, et al, 1995, 1997 cited by Koh, 2006).

A study by Hornstra in 1990 also showed similar results.**The controversy may be resolved by a study showing palmitic acid to have a no hypercholesterolaemic if intake of** *linoleic acid* **was greater than 4.5% of energy, but that if the diet contained trans fatty acids the health effects were unfavorable -- LDL cholesterol increased and HDL cholesterol decreased.**

iv. Ceremonial Importance of Palms

The palm branch was a symbol of triumph and victory in pre-Christian times. The ***Romans*** rewarded champions of the games and celebrated military successes with palm branches. Early ***Christians*** used the palm branch to symbolize the victory of the faithful over enemies of the soul, as in the ***Palm Sunday*** festival celebrating the triumphal entry of ***Jesus*** into ***Jerusalem***. In ***Judaism***, the palm represents peace and plenty. The palm may also symbolize the **Tree of Life.**

v. Other Uses

Arecaceae has great economic importance includijng coconut products, oils, dates, ivory nuts, carnauba wax, rattan cane, raffia, etc..

The type member of Arecaceae is the Areca palm, the fruit of which, the betel nut, is chewed with the betel leaf for intoxicating effects. Also belonging to the family of the Arecaceae are the Date Palm, harvested for its edible fruit; Rattans, whose stems are used extensively in furniture and baskets; and the Coconut. Palm oil is an edible vegetable oil produced by the oil palms in the genus *Elaeis*. Several species are harvested for heart of palm, a vegetable eaten in salads. Palm sap is sometimes fermented to produce palm wine or toddy, an alcoholic beverage common in parts of Africa, India, and the Philippines. The Palm Sunday festival uses palm leaves, usually from the Date Palm, hence the name. Dragon's blood, a red resin used traditionally in medicine, varnish, and dyes, may be obtained from the fruit of *Daemonorops* species. Coir is a coarse water-resistant fiber extracted from the outer shell of coconuts, used in doormats, brushes, mattresses, and ropes. Some indigenous groups living in palm-rich areas use palms to make many of their necessary items and food. Sago, for example, a starch made from the pith of the trunk of the Sago Palm *Metroxylon sagu*, is a major staple food for lowland peoples of New Guinea and the Moluccas. Palm leaves are also valuable to some peoples as a material for thatching or clothing.palms are valuable as ornamental plants and are often grown along streets in tropical and subtropical cities, and also along the Mediterranean coast in Europe. Farther north, palms are a common feature in botanical gardens or as indoor plants. An indication of the importance of Palms is that they are mentioned more than 30 times in the ***Bible,*** and at least 22 times in the ***Quran***.

Student Self-Assessment Exercise 4

- What are the major producte got from
  - oilpalm
  - coconut?

3.12.0. Other palms

The vast majority of palms grow in the tropics. They are abundant throughout the tropical regions around the world, and are present in almost every type of habitat in the tropics. Diversity is highest in wet, lowland tropical forests, especially in ecological "hotspots" such as Madagascar, which has more palms than the entire continental Africa. Colombia may have the highest number of palm species in one country.

It is estimated that only 130 palm species grow naturally beyond the tropics, most of which grow in the subtropics. The northernmost palm is *Chamaerops humilis,* which reaches 44°N latitude in southern France, where the local Mediterranean climate is milder than other places ascompared with far north. The southernmost palm is the *Rhopalostylis sapida,* which reaches 44°S on the Chatham Islands where an oceanic climate has a similar warming effect.

The followings are a few of the types of palms (genera) that are available in the tropics.

- *Areca* – Betel palm
- *Bactris* – Pupunha
- *Borassus* – Palmyra palm
- *Calamus* – Rattan palm
- *Copernicia* – Carnauba wax *palm*

- *Euterpe* – Cabbage Heart palm, Açaí palm
- *Jubaea* – Chilean Wine palm, Coquito palm
- *Metroxylon* – Sago palm
- *Sabal* – Palmettos
- *Salacca* – Salak
- *Trachycarpus* – Windmill palm, *Kumaon* palm

a*. *Phoenix – **Date palm**. Date Palms may also grow in grasslands and scrublands, usually associated with low water supply, and in desert oases . Fruit of the Date Palm

Phoenix dactylifera is widely consumed as a beverage/snack in the Middle East including the people of North Africa.

Human use of palms is as old as or older than human civilization itself, starting with the cultivation of the Date Palm by Mesopotamians and other Middle Eastern peoples 5000 years or more ago.Date wood, pits for storing dates, and other remains of the Date Palm have been found in Mesopotamian sites.The Date Palm had a tremendous effect on the history of the Middle East. W.H. Barreveld wrote:

Phoenix dactylifera

"One could go as far as to say that, had the date palm not existed, the expansion of the human race into the hot and barren parts of the "old" world would have been much more restricted. The date palm not only provided a concentrated energy food, which could be easily stored and carried along on long journeys across the deserts, it also created a more amenable habitat for the people to live in by

providing shade and protection from the desert winds. In addition, the date palm also yielded a variety of products for use in agricultural production and for domestic utensils, and practically all parts of the palm had a useful purpose." The "edible" or true Date Palm is a spectacular palm for landscaping large areas. The Palm reaches heights of 18m (60feet).

Canary Island Date Palms are massive, tough and durable. The leaf scar pattern on the trunk adds to the impressive look.

(Phoenix canariensis)

b *.**Raphia*** – **Raffia palm**. This species forms pure stands in areas with poor drainage or regular flooding which is common in coastal freshwater swamps in West Africa**. Raffia palms** (*Raphia* spp.), with leaves up to 25 meters long and 3 meters wide, have the largest eaves of any plant.

v *Raphia* spp.

c.Roystonea **– Royal palm**. This is otherwise called '**ornamental palm' as** it is often used as decorative plant in landscape engineering. Tall and graceful with leafy fronds, this palm gives landscapes a tropical look. They are very showy, especially when clumped.

d.Cocos – Coconut

Coconut is not of commercial importance in Nigeria. It is one of the most important sources of vegetable oils. The copra obtained from coconut contains 65% oil.

i. Yield

An acre of coconut yields about 800 to 2,200 lbs oil. From an acre of coconut palm, you can get 2 tons of oil. Like the oil palm, every part of the coconut is useful to us. Nuts are obtained from the fruits; the inflorescence (spatha) can be tapped to obtain the coconut wine (TODDY). The toddy can be further processed to produce alcoholic drinks and also sugar called faggery.

ii. Vinegar

This is also obtained in the alcoholic part. The endosperm is eaten or oil is extracted from it and the residual is used for livestock feed. The oil is used in making soaps of all kinds, margarine.

iii. Coir

From the coir, foot mats, brushes, ropes, and household decorations materials can be made.

iv. Shell

The shell can be used as fuel, charcoal, wood tar, comb, bottons, cups, beads, etc.

v. Trunk

Timbers and building poles can be got.

vi. Leaves

Thatch, fencing materials, hats, brooms etc.

vi. Young Growing Ones

The apical point of young coconut can be obtained to make the millionaires cabbage, though this may lead to its death.

coconut

vii. Oil

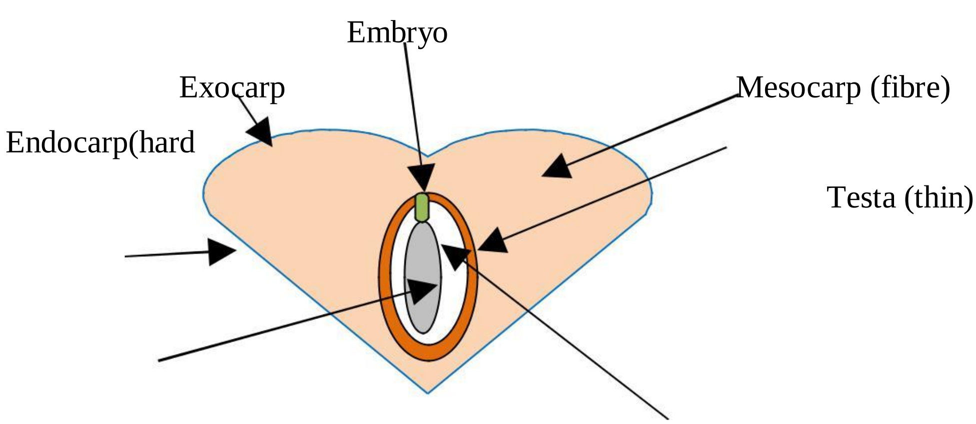
From the oils, one can get coco tearing, out of which candles can be made. After making or obtaining the oils, residue is used in making confectionaries e.g. coconut cake. Inside the coconut is found some milk like water which helps in the germination of planted seeds. It is also useful in preventing the livestock smell when practicing Artificial Insemination (A.I.), hence every part is useful to man.

viii.Production

On the world basis, there are not more than 10 million acres of coconuts out of which about 2 million acres are in production. Chief producers are Philippines, Islands, Indonesia, Ceylon, Malaysia, all these put together produce about 90% of the world output. Some quantity could be obtained along the coast of East Africa, also some are obtained in East Indies e.g. Trinidad & Tobbago, India, Burma and Thailand. They produce only for their home consumption.

ix. Ecology

Though many plantations are often found near oceans or seas, yet they are not salt loving – HALOPHITES. They can grow successfully well 200 miles away from the sea. All they need is well drained aerated and fertile soil with good supply of an under-current of water. They will tolerate a good amount of salt. Water logging conditions don't encourage a good health and good production of fruits. They require not too hot or too cold climate with high rainfall. With a very few exceptions, the growth of coconut palm is within a limit of 20ºN & S of the Equator. Generally, they grow well at a height of 1000 feet above sea level. They require 60 inches or more of rainfall annually and a temperature of 27º-34ºC.



Juice Water

White Endosperm

T.S. COCONUT FRUIT

x.Germination

The embryo develops into two parts when it germinates i.e. the plumule and the radicle. Both force themselves out from one of the eyes on the shell. It takes 4 – 6 months for them to emerge from the mesocarp. Total germination takes 4 – 6 months.

xi. Nursery Technique

In the nursery, plant either upright or by flat on soil on the flat side. Plant in rows 22.5-30cm (9 – 12inches) apart along the rows and 30-60cm (1 – 2feet) between the rows. The seedlings are left in the nursery for 6 – 8 months before transplanting. The period between germination and the formation of 3 – 4 leaves takes 6 – 8 months.

xii. Types

Ther are two types viz:

(1) Dwarf

(2) Tall

xiii. Spacing

The spacing is 9m x 9m (25 – 30 ft square or 29ft triangular). Ring weed the seedlings regularly. Clear/weed the orchard about 2 – 3 times yearly. Mechanized weeding can be adopted. Inter-planting with banana could be done to save cost of weeding at early stage, but when fully grown, the inter crops should be removed. livestock can be introduced into the plantation mainly because:

(1) The plantation provides shaded grading for the livestocks

(2) The plantation is manured by the droppings of the livestock

(3) Weed growth reduced by grazing.

xiv. Use of Fertilizers

The most important minerals needed by coconut are N & K. Phosphate being less important. About 3 – 5 lbs of a mixture of N & K with little phosphate can be applied for tree per annum.

xv. Yield

80 nuts per tree per annum is good enough for the coconut grown around the compound but for crop grown in plantations of 60 trees per acre, 30 – 40 nuts per tree per annum is economical enough. Age of fruiting is 5 – 7 years after transplanting but may be earlier in the dwarf type.

xvi. Production of Copra

In order to keep for longer time, the copra has to be dried until a moisture content of 6 – 7 percent is obtained and an F.P.A. of 1 percent.

Picking

Get the best nuts for copra but don't select the dropped ones as they might be germinating. Collecting the dropped ones should be regular and packed in with heaps.

Processing

It is done by family labour while men are chopping the fruits, the women remove the endosperm with knifes. The endosperm is then sent to the oven or sun for drying.

Drying: there are three (3) methods of drying:

i. By the sun – putting in the sun continuously will complete drying in 40 hours but it is quite impossible in the wet tropics because of the heavy rains. Therefore drying takes 12 – 14 days.

ii. Hot air or smoking – produces copra of lower grades.

iii. Oven drying – produces copra of high grade. It could be done by a natural draft of air or by a force producing hot air.

xvii. Cultural Operations

This depends on soil type. On heavy soils, you have to plough the sub-soils using the sub-soiler to allow in fresh air into the soil and also introduce the supply of potash. In light soils, cover crops may be used to prevent soil erosion, weed growth, to add organic matter to the soil, to preserve soil moisture and encourage aeration and to improve soil structure.

Student Self-Assessment Exercise 4

- Name four types of palms and mention three products got from each type

4.0. Conclusion

Palms are perennials with generic life of over 200 years, but the economic life is 20-25 years, (nursery 11-16 months, first harvest 32-38 months from planting, peak yield 5-10 years from planting).

Most widely used planting material consists of Dura x Tenera hybrids. Clonal palms are expected to come into commercial use soonest.

Harvested part: Fruit (Fruit bunch). Oil is obtained from fleshy mesocarp of fruit (45-55 % oil) and from kernels (50 % oil). Oil extraction rate (from mature fresh fruit bunches FFB) = 20-24 %.

Highest yield attained to-date (1990) 46 t/FFB = 10.6 t/ha crude palm oil/ha.

Planting density: 128-148 palms/ha, depending on planting material, soil and climate. Most common spacing 9m x 9 m triangular (= 143 palms/ha).

Grown in lowlands of the humid tropics, 15° N - 15° S with evenly distributed rainfall of 1 800-5 000 mm/year. Palms are adapted to a wide range of soils and to low pH, but sensitive to high pH (above 7.5) and to stagnant water.

African oil palm (*Elaeis guineensis*)

The fruit is reddis about the size of a large plum and grows in large h bunches. A bunch of fruits can weigh between 10 to 40 kilograms each. Each fruit contains a single seed (the palm kernel) surrounded by a soft oily pulp. Oil is extracted from both the pulp of the fruit (palm oil, edible oil) and the kernel (palm kernel oil, used mainly for soap manufacture).

For every 100 kilograms of fruit bunches, typically 22 kilograms of palm oil and 1.6 kilograms of palm kernel oil can be extracted.

The high productivity of the oil palm at producing oil (as high as 7,250 liters per hectare per year) has made it the prime source of vegetable oil for many tropical countries. It is also likely to be used for producing the necessary vegetable oil for biodiesel, an example being a planned refinery Darwin, Australia which will import the palm oil from Indonesia and Malaysia.

The oil palm originated in West Africa but has since been planted successfully in tropical regions within 20 degrees of the equator.

The world's largest producer and exporter of palm oil today is Malaysia, producing about 47% of the world's supply of palm oil. Indonesia is the second largest world producer of palm oil producing approximately 36% of world palm oil volume. Both nations are expanding their palm oil production capacity and the market continues to grow.

Worldwide palm oil production during the 2005-2006 growing season was 39.8 million **metric tons**, of which 4.3 million tons was in the form of palm kernel oil. It is thus by far the most widely-produced tropical oil, and constitutes thirty-four percent of total edible oil production worldwide.

5.0 Summary

In this unit, we have treated palms as a family of plants in general and then zerod on the cultivated palms in particular. The oil palm was –*Elaeis guineensis* – was treated into details. The requirements for its growth and cultivation were discussed. Agronomic operations as: extra nursery, pre-nursery, nursery and field were discussed intensively. Harveting and processing of palm produce, grading and storage of the produce were equally given attention. The uses of palm oil were treated while its chemical composition was not left out. Finally, other useful palms as: Date, Raffia, Royal and Coconut were discussed. Pictoral illustrations of these palms were given. This was done so you can identify and describe the differences between these palms.

6.0. TMA

1. Describe the germination process in oilpalm nuts

2 Describe the pre-nursert and nursery operations in oilpalm.

3 Briefly describe the mill processing of palm fruits.

4. Diferentiate between ‘hard’ and ‘soft’ palmoil.

5. What are the uses of palms and palmoil?

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MODULE 4: JUICE/BEVERAGE CROPS

UNIT 7: CITRUS

Contents

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UNIT 5: CITRUS

1.0. INTRODUCTION

Citrus is a common term used for oranges a plant of the *genus* and family *Rutaceae*. The crop originated in tropical and subtropical southeast Asia. The plants are large shrubs or small trees, reaching 5–15 m tall, with spiny shoots and alternately arranged evergreen leaves with an entire margin. The flowers are solitary or in small corymbs, each flower is 2–4 cm in diameter, with five (rarely four) white petals and numerous stamens; they are often very strongly scented. The fruit is a *hesperidium*, a specialised berry, globose to elongated, 4–30 cm long and 4–20 cm diameter, with a leathery rind surrounding segments or "liths" filled with pulp vesicles. The genus is commercially important as many species are cultivated for their fruit, which is eaten fresh or pressed for juice.

Citrus fruits are notable for their fragrance, partly due to flavonoids and limonoids (which in turn are terpenes) contained in the rind, and most are juice-laden. The juice contains a high quantity of citric acid giving them their characteristic sharp flavour. They are also good sources of vitamin C and flavonoids.

The taxonomy of the genus is complex and the precise number of natural species is unclear, as many of the named species are clonally-propagated hybrids, and there is genetic evidence that even the wild, true-breeding species are of hybrid origin. Cultivated *Citrus* may be derived from as few as four ancestral species. Numerous natural and cultivated original hybrids include commercially important fruit such as the *orange*, *grapefruit*, *lemon*, some *limes*, and some *tangerines* . This unit treates the crop called citrus (oranges) into details.The unit starts with the history and the origin of citrus, its' spread into various parts of the world, through it's botany to harvesting, processing and finally, it's uses.

2.0. UNIT OBJECTIVES

At the end of this unit you are expected to:

- Identify the origin and spread of the plant/crop called citrus.
- Enumerate the original types that exist and their characteristics.
- Identify the various breeds and varieties that exist in your area.
- Enumerate the different types of nursery operations that are required in citrus cultivation.
- Enumerate the field operations needed in citrus production.
- Enumerate the uses of citrus bearing in mind, the various breeds and species.

3.0. SUBJECT –MATTER

3.1. History

While the origin of citrus fruits cannot be precisely identified, researchers believe they began to appear in Southeast Asia around 4000BC. From there, they slowly spread to northern Africa mainly through migration and trade. During the period of the Roman Empire, demand by higher ranking members of society and increased trade allowed the fruits to spread to southern Europe. Citrus spread throughout Europe during the Middle Ages and were then brought to the Americas by Spanish explorers. Worldwide trade of citrus fruits didn't appear until the 1800s and trade in orange juice developed as late as 1940.

Prior to human cultivation, the genus *Citrus* consisted of just a few species:

- *Citrus maxima*, the pummelo, from the Malay archipelago
- *Citrus medica*, the citron, from India
- *Citrus aurantifolia*, the key lime, from India
- *Citrus reticulata*, the mandarin and similar, from China

Citrus halimii, a more recent discovery, from Thailand and Malaya

3.2 Botany of Citrus

Citrus fruits constitute several species of the genus Citrus of the subfamily Aurantiodeae of the plant family Rutaceae. The Aurantiodeae has a total of thirty-three mostly subtropical and tropical genera, a few of which have economic importance. The citrus fruits proper are characterized by their distinctive fruit, the hesperidium, which is a berry with the internal fleshy parts divided into segments (typically 10 to 16) and surrounded by a separable skin. The name, citrus, is derived from classical mythology, referring to the "golden apples" grown in the garden of the Hesperides (the daughters of Hesperus, the evening star), located in the far west, in Paradise. When grown naturally, citrus plants are generally small to large trees, with glossy alternate leaves having oil glands. The attractive and fragrant flowers have an annular disk.

The genus Citrus is divided into two subgenera, Citrus and Papeda. The former contains "edible" citrus fruits (including some less palatable varieties), while the latter consists of the papedas. These are a distinctive group, the fruits of which have high concentrations of droplets of acrid oil in the pulp vesicles, rendering them inedible due to the bitter, unpleasant flavour. The leaves are also distinctive as compared to those of the subgenus Citrus, having large, prominent petioles.

Lemon fruits

Citrus reticulata

flower and fruits

The taxonomy of Citrus, as a genus, is unclear. So, for that matter, is the taxonomy of the other thirty-two genera in the subfamily. Different authorities have recognized anywhere from 3 to 170 species of Citrus. Obviously, this large a difference is due to more than mere hair-splitting. The most commonly used systems that of W. T. Swingle or its modifications recognize about sixteen species.

Most of the difficulties in Citrus taxonomy arise due the free hybridization that can occur between different varieties and even between different species of Citrus. In fact, many of the other Aurantiodeae genera are capable of free hybridization with Citrus. The result is that many types of citrus arose from these hybridization events at some time in the past. A strict interpretation of the “species” concept would result in fewer types being awarded species rank, whereas a looser interpretation would result in a higher number of species. This problem is compounded by the numerous controlled hybridizations and selections made by humans with the goal of producing a more desirable fruit.

Currently, the generally accepted concept is that there are ***four primordial or fundamental Citrus species*****: Citrus medica (citrons), Citrus grandis (grapes), Citrus aurantifolia (lime) and Citrus reticulata (mandarins).** All other types of citrus currently existing arose from single or sequential hybridization events between these species or their offspring. This concept is supported by various types of studies: classical taxonomy, chemotaxonomy, and molecular analysis.

3.2.1. The four (4) *original wild species of CTRUS* from which the main hybrid species are derived

***1. Citrus medica* (Citron)**
Citron is thought to be native to India and then to have spread prehistorically, through cultivation, to the Near East and China. By 300 BC it was known in Greece, and by 20 BC it was being cultivated in Italy. Fruit are yellow, ovoid-oblong and can be large, measuring up to 30 cm long. They have a very thick rind and sour juicy parts. The rind is used in making candied confectionery but Citron is used predominantly for medicinal and ritual purposes rather than for food. It is also used as a scent. From a ritual point of view, Citron is used in Budhist ceremonies, and since about 100 BC, Citron has played an important part in the Jewish Feast of the Tabernacles.

***2. Citrus grandis* (Pummelo, Pamplemousse, Shaddock)**
Thought to have originated in Southeast Asia. Varieties differ in fruit sweetness, size, shape, colour, seediness and amount and kinds of essential oils. By 300 BC, *Citrus grandis* was being grown commercially in China. It is important in Chinese medicine and trees are grown also for their beauty and fragrance. Before 1200 AD, cultivation of Pummelo had spread westward to India, North Africa and Spain. *Citrus grandis* is not grown commercially these days but is still grown as a garden tree.

***3. Citrus reticulata* (Mandarin, Satsuma and Tangerine) Naartjie [Afrikaans]**
The Mandarin was probably domesticated in tropical Southeast Asia. By 500 BC it was known in China and by 300 BC it was being grown commercially in central China. By 400 AD, grafting methods were being used to clone favourable varieties. They were also using tree-nesting Taylor Ants (*Oecophylla smaragdina*) to defend trees [CHECK SCI AM]. It appears that the Mandarin has and still is the most important citrus species in China, both commercially and in people's gardens. It was introduced to Japan at an early stage, where it also became the most favoured of the citrus species, and it was here that the Satsuma variety was developed. Despite its popularity in Asia, it was only in the 1800's that *Citrus reticulata* was established in Europe, North Africa, West Indies, North and South America, and Australia.

***4. Citrus aurantifolia* (Lime)**
Originates from tropical Southeast Asia, where it can still be found wild. Cultivars have been developed based on sweetness (usually sour), size, shape (round or oblong) and colour (yellow or green). All varieties have relatively thin skins. Lime fruit are used for preserves, garnishes and juices. Citral oil is extracted for use in perfumes.

3.2.2. RELATED Hybrid species

***i. Citrus aurantium* (Seville, Bergamot or Sour Orange)**
Hybrid between Pummelo (*Citrus grandis)* and Mandarin (*Citrus reticulata)*.
Bergamot is sometimes placed in a separate species *Citrus bergamia*, but is otherwise considered to be a variety of *Citrus aurantium* . *Citrus aurantium* orginated in China and seems to have entered the written record there by 300 BC. It is recorded from Japan by about 100 AD. By about 100 BC, Sour Orange seeds appear to have reached Rome. In China and Japan, Sour Orange is not usually eaten raw but used for: (1) making

marmalade and candied peel; (2) producing essential oils for use in soaps and perfume; and (3) scenting tea using the flower buds. Bergamot yields **neroli oil** from the flowers which is used in perfumery (e.g. in Eau de Cologne), and **Bergamot oil** which is the substance added to **Earl Grey tea** to give it that distinctive flavour

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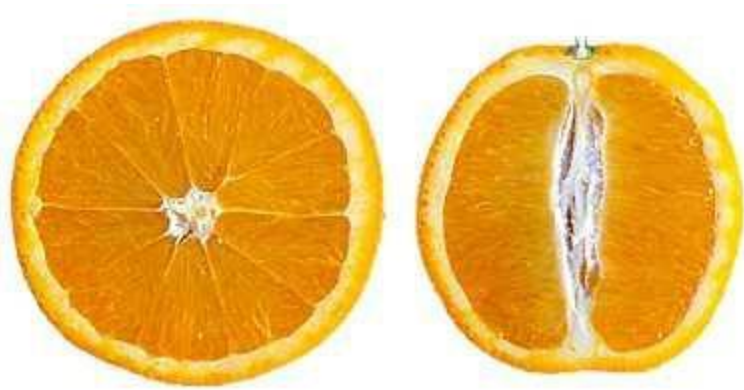
ii. Citrus sinensis



(Edible, Sweet, Valencia, Navel Orange)

Hybrid between Pummelo (*Citrus grandis)* and Mandarin (*Citrus reticulata)*.

Although originating from the same parent species as *Citrus aurantium*, the actual parents were different varieties to those of *Citrus aurantium.* There are clear records of *Citrus sinensis* in China only by the 1100's and in India by the 1300's. By the 1400's it had spread to the Mediterranean. From the mid 1600's onwards, European colonists spread it around the world's tropical regions. The Navel variety originated in Bahia, Brazil in the 1800's.

iii. Citrus limon (Lemon)

Hybrid between Citron *Citrus medica* and Lime *Citrus aurantifolia.*

The place and date of origin of the Lemon is uncertain but it probably came from China. Lemon is used for making lemonade, it is used in drinks, and for flavouring a wide variety of foods. The essential oil from Lemon is known as cedro oil, and is used as a flavouring in the food industry and is also used in soaps, detergents and perfumes

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Lemon citrus flower.

iv .Citrus limonia (Canton Lemon or Rangpur Lime)

Hybrid between Mandarin (*Citrus reticulate)* and Lime (*Citrus aurantifolia).*

Thought to have originated in Southeast Asia and spread to China and India and by 1000 AD it was cultivated in southern China. This species is evidently grown widely as a garden tree in subtropical regions.

v.s. citrus fruit ***l.s. citrus fruit***

v. Citrus paradisii (Grapefruit)

Hybrid between Pummelo (*Citrus grandis)* and Sweet Orange (*Citrus sinensis)*.
This hybrid species is thought to have originated on the island of Barbados in about 1750. Further varieties of Grapefruit were developed mainly in Florida and Texas, USA.

3.2.3. Edible citrus

Edible citrus is generally divided into: ***sweet oranges, sour oranges, mandarins, grapefruit, pummelos, lemons, limes, and citrons.*** Within each of these types there are various subtypes, as well as types that arose from free or controlled hybridization. Depending on the taxonomic system used, these subtypes and hybrids may or may not be accorded species status. Oroblanco is actually a hybrid of a pummelo and a grapefruit, but it is generally marketed as a grapefruit; Meyer is probably a low-acid natural hybrid of a lemon and a sweet orange, but it is usually marketed as a lemon; Mediterranean Sweet is probably more accurately referred to as a "limetta" rather than a sweet lemon. However, the idea is to present the reader with some general information on fruits that might be encountered and eaten. Some types (low-acid sweet oranges, sour oranges, citrons) are not of much importance commercially, while others (sweet lemons, sweet limes) are important in some regions of the world but not in others.

Sweet oranges.

1. ***The navel oranges*** possess a small, secondary fruit in the stylar end of the main fruit. This is the navel. Since navel oranges were introduced to California from Brazil in 1873, they have assumed a primary importance throughout the world as a sweet orange for fresh consumption. Like the navel oranges, common sweet oranges mature during the winter. Because of the popularity of the navel as a fresh fruit, common oranges are generally grown mostly for processing, although they can be important locally as fresh fruits

.2. ***Blood oranges*** have a pigment called anthocyanin in the rind and juice, producing a reddish blush that becomes more pronounced with cooler night temperatures in the fall. The blood oranges have a distinctive taste compared to other sweet oranges.

3. ***Valencia oranges*** mature later than the other sweet oranges and are generally harvested in the late spring or summer. Low-acid oranges have about the same levels of sugars as regular sweet oranges, but much lower levels of acid, resulting in a rather bland flavor.

4. ***Mandarins*** are often referred to somewhat incorrectly as tangerines. The word "tangerine" was used in the nineteenth century to designate Mediterranean types of mandarins, and referred to the city of Tangier. This term later became associated with other types of mandarins. Mandarins are of ancient cultivation in China, their probable

area of origin, and other parts of Asia. The common mandarins include such important varieties as Ponkan, which is widely grown in Asia under different names. The Satsumas are a distinctive, seedless, early maturing group apparently originating in Japan relatively recently as compared to the common mandarins. The Clementines are another distinctive group that apparently originated in Algeria as recently as the 1890s. There are now many different selections of Satsumas and Clementines. The hybrids of tangelo (crossed with pummelo or grapefruit) and tangor (crossed with sweet orange) are included here as types of mandarins since they are generally thought of by the public as being more like mandarins than the other parent.

Sour oranges are not often eaten as fresh fruit or used for processing. However, the fruit is used to produce marmalade, and the flowers of certain types are used in the production of perfume. The Bergamot, a sour orange hybrid, has distinctively scented oil that is used in s well as perfume. Sour oranges often make attractive ornamentals.

3.2.4. Summary of the Botany of Citrus.

Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Rosidae
Order: Sapindales
Family: Rutaceae
Genus: ***Citrus*** L.

Species
Citrus aurantifolia—Key lime
Citrus grandis—Grapefruit
Citrus medica—Citron
Citrus reticulata—Mandarin & Tangerine

Major hybrids
Citrus ×sinensis—Sweet Orange
Citrus ×aurantium—Bitter Orange
Citrus ×paradisi—Grapefruit
Citrus ×limon—Lemon
Citrus ×limonia—Rangpur lime
Citrus ×latifolia—Persian lime

Other hybrids

- Alemow, Colo, *C. ×macrophylla*
- Amanatsu
- Bergamot orange *C. ×bergamia*
- Bitter orange, Seville Orange

- Blood orange
- Buddha's hand, *C. medica*
- Calamondin (Calamansi)
- Citron *Citrus medica*
- Clementine
- Daidai, Seville, Sour Orange, *Citrus aurantium*
- Dekopon- hybrid between ChungGyun mandarins and Ponkan
- Desert Lime, *Citrus glauca* (syn. *Eremocitrus glauca*)
- Djeruk limau, *C. ×amblycarpa*, Indonesia
- Finger Lime, *Citrus australasica*, (syn. *Microcitrus australasica*)
- Gajanimma, Carabao lime, *C. ×pennivesiculata*
- Grapefruit, *C. ×paradisi*
- Ichang Lemon *Citrus ×ichangensis*
- Imperial lemon *Citrus limon* × *Citrus ×paradisi*
- Iyokan
- Kabosu *Citrus sphaerocarpa*
- Kaffir lime *Citrus ×hystrix*
- Key lime *Citrus aurantifolia*
- Kinnow
- Khasi pepeda, *C. ×latipes*
- Kumquat - in the related genus *Fortunella*, not *Citrus*; forms hybrids with *Citrus* (see *Citrofortunella*)
- Lemon *Citrus ×limon*
- Lime *Citrus aurantifolia*
- limetta, Sweet Lemon *C. ×limetta*
- Limequat *Citrus ×Fortunella* hybrids
- Mandarin Lime *C. ×limonia*
- Mandarin Orange, Dancy
- Meyer Lemon
- Mikan
- Natsumikan, Japan, *C. ×natsudaidai*
- Orange *Citrus sinensis*
- Orangelo: Chironja
- Orangequat
- Oroblanco
- Persian lime, Tahiti lime *Citrus ×latifolia*
- Pomelo, Pummelo, Shaddock, *Citrus grandis*
- Ponderosa lemon
- Ponkan
- Rangpur, Lemanderin *Citrus ×limonia*
- Rough Lemon *C. ×jambhiri*
- Satsuma
- Shekwasha, Taiwan tangerine, Hirami lemon, *C. ×depressa*
- Sudachi
- Sunki, Suenkat, *C. ×sunki*
- Sweetie

- Sweet Lime, Sweet Lime, Central America, *C. ×limettioides*
- Tachibana Orange
- Tangelo: Minneola tangelo Ugli
- Tangerine *Citrus reticulata*
- Tangor *C. ×nobilis*
- Ugli fruit
- Yuzu *C. ×junos*

Student Self Assessment Exercise 1

1. Distinguish between the four major/original species of citrus.
2. Explain why there are very many types of citrus in the world.

3.3.Agro-Climatic Requirements

The trees do best in a consistently sunny, humid environment with fertile soil and adequate rainfall or irrigation. Any age Citrus grows well with infrequent irrigation in partial/understory shade, but the fruit crop is smaller. Though broadleaved, they are evergreen and do not drop leaves except when stressed.
Citrus trees are not generally frost hardy. *Citrus reticulata* tends to be the hardiest of the common Citrus species and can withstand short periods down to as cold as −10 °C, but realistically temperatures not falling below −2 °C are required for successful cultivation. A few hardy hybrids can withstand temperatures well below freezing, but do not produce quality fruit. A related plant, the Trifoliate orange (*Poncirus trifoliata*) can survive below −20 °C; its fruit are astringent and inedible unless cooked.

3.4 Edaphic factors and .Areas of Citrus Production

Major commercial citrus growing areas include southern China, the Mediterranean Basin (including Southern Spain), South Africa, rain forest zone of Nigeria, Australia, the southernmost United States, and parts of South America. In the U.S., Florida, Texas, and California are major producers, while smaller plantings are present in other Sun Belt states.

Some modern hobbyists still grow dwarf citrus in containers or greenhouses in areas where it is too cold to grow it outdoors. Consistent climate, sufficient sunlight, and proper watering are crucial if the trees are to thrive and produce fruit. Compared to many "normal green" shrubs, citrus better-tolerates poor container care. For cooler winter areas, lime and lemon should not be grown, since they are more sensitive to winter cold than other citrus fruits. Lemons are commercially grown in cooler-summer/moderate-winter coastal Southern California, because sweetness is neither attained nor expected in retail lemon fruit. Tangerines, tangors and yuzu can be grown outside even in regions with sub-zero winters, although this may affect fruit quality. Hybrids with kumquats (citrofortunella) have good cold resistance.

3.4.1. Countries involved in Citrus production

Citrus fruits are produced all over the world. According to UNCTAD, in 2004 there were 140 citrus producing countries. Around 70% of the world's total citrus production is grown in the northern Hemisphere, in particular, countries around the Mediterranean

In the United States, citrus fruits for consumption as fresh fruit are mainly grown in California, Arizona and Texas, while most orange juice and grapefruit is produced in Florida.

China could be a major player in the orange juice and processed citrus markets, except for high tariffs on citrus that make domestic sale more profitable.

Though citrus originated in southeast Asia, current citrus production is low due to lower than average yields, high production and marketing costs and problems with disease.

Citrus production in most of Europe continues to decline, although the clementines produced by Spain are increasing in popularity among consumers.

Nigeria produces large quantities of citrus but for home consumption only.

PRODUCTION

Sweet Oranges

World (2002 FAO) - 64,128,523 MT or 141 billion pounds. Oranges are produced commercially in 114 countries worldwide, on about 9 million acres. Worldwide average yields are just over 15,000 lbs/acre.

Top 10 Countries
(% of world production)

1. Brazil (29%)	6. Spain (4%)
2. USA (18%)	7. Italy (3%)
3. Mexico (6%)	8. Iran (3%)
4. China (6%)	9. Egypt (3%)
5. India (5%)	10. Pakistan (2%)

United States (2002 USDA) - 11,403,136 MT or 25 billion pounds. Production has increased 1.5% per year in last decade. The industry value is $1.8 billion. Leading states:

1. Florida (82%)	587,000 acres
2. California (16%)	194,000 acres
3. Arizona (<1%)	6,200 acres

4. Texas (<1%) 9,100 acres

Prices received by growers are among the lowest of any fruit crop in the USA: 5-15 ¢/lb, with fresh fruit receiving 10-15 ¢/lb, and processed about 5-6 ¢/lb.

Grapefruit

World (2002 FAO) - 4,979,781 MT or 10.9 billion pounds. FAO statistics include pummelo with grapefruit, so a small fraction of this amount is actually not grapefruit. Produced commercially in 74 countries worldwide, on about 653,000 acres. Yields average 16,700 lbs/acre.

Top 10 Countries

(% of world production)

1. USA (44%)	6. Israel (5%)
2. China (7%)	7. Argentina (3%)
3. South Africa (6%)	8. Turkey (3%)
4. Cuba (6%)	9. India (3%)
5. Mexico (5%)	10. Tunisia (1%)

United States (2002 USDA) - 2,206,464 MT or 4.8 billion pounds. The industry value is $285 million. Yields range from about 8000 lbs/acre in Arizona to 38,000 lbs/acre in Florida. Prices received by growers are extremely low, about 5 ¢/lb. Leading states:

1. Florida (83%)	101,000 acres
2. Texas (10%)	20,000 acres
3. California (8%)	15,000 acres
4. Arizona (<1%)	2,000 acres

Tangerines & Hybrids [hybrids include tangelos and tangors. FAO statistics may place some hybrids in an alternate category, "Citrus NES", so these data may be a slight underestimate]

World (2002 FAO) - 18,792,909 MT or 41.3 billion pounds. Produced commercially in 60 countries worldwide, on about 4.2 million acres. Worldwide average yields are 10,600 lbs/acre.

Top 10 Countries

(% of world production)

1. China (38%)	6. Iran (4%)
2. Spain (10%)	7. Thailand (3%)
3. Japan (7%)	8. Italy (3%)
4. Brazil (5%)	9. USA (3%)
5. South Korea (4%)	10. Pakistan (3%)

United States (2002 USDA) - 627,660 MT or 1.1 billion pounds. Value = $168 million. Yields range from 9000 lbs per acre in Arizona to 25,000 lbs/acre in Florida. Leading states: FL, CA, AZ (in order). The USA average price paid to growers is about 13-14 ¢/lb.

Lemons & Limes

World - (2002 FAO) - 11,227,173 MT or 24.7 billion pounds. Lemons and limes, as we know them in the USA, are not distinguished by the FAO. Thus, the following data are totals of lemon- and lime- like fruits. In Mediterranean climates (like Spain, Italy, and California), production of lemons dominates; in tropical and subtropical regions (like Mexico, Brazil, and Florida) lime production dominates.

Lemons and limes are produced commercially in 94 countries worldwide, on about 1.9 million acres. Yields average 13,500 lbs/acre.

Top 10 Countries
(% of world production)

1. Mexico (15%)	6. USA (7%)
2. India (12%)	7. Brazil (5%)
3. Argentina (11%)	8. Italy (5%)
4. Iran (9%)	9. Turkey (4%)
5. Spain (8%)	10. China (3%)

United States (2002 USDA):

Lemon. 1,095,160 MT or 2 billion pounds. Value = $341 million. California 86%, Arizona 14%. Yields are about 16,000 lbs/acre in Arizona and 32,000 lbs/acre in California. Prices are 12-15 ¢/lb.

Lime. 6360 MT or 14 million pounds. Value = $1.7 million. Florida produced 100% of the limes in the USA, but hurricane and disease damage has all but eliminated the Florida industry. Acreage estimates showed 1000 acres in 2002, and less than 400 in 2003.

3.5. Cultivation of Citrus

Propagation

Although citrus seedlings will produce fruit identical to the parent tree due to nucellar embryony, trees are generally budded onto various rootstocks to avoid the long juvenile period for seedlings. Budding can be performed during most of the year, when pencil-sized, round budsticks are available, and bark slips on rootstocks. Bud unions on citrus are generally higher than many other tree fruits (8-12" above soil line) to avoid any contact of the scion to the ground.

Rootstocks

Rootstock	Yield / tree	Fruit size	Tree Vigor	Tolerance to Freeze damage to tree
Rough Lemon	high	large	high	poor
Sour Orange	mid	mid	mid	good
Cleopatra mandarin	low	small	high	good
Trifolate orange	low	small	low	good
Carrizo citrange	high	mid	high	fair
Troyer citrange	mid	mid	mid	good
Swingle citrumelo	high	mid	high	fair

Planting Design, Training, Pruning

Planting Design - rectangular arrangements which eventually become tall hedgerows

Spacings are typically 20 x 25 for grapefruit and vigorous trees, 15 x 20 for oranges and tangerines, and 12-15 x 18-20 for limes and smaller cultivars.

Tree densities are now about 100-110 trees/acre for grapefruit, and 130-140 for sweet orange.

Training and Pruning - very little training is needed. Young trees may be headed at 30 inches to induce branching, and stripped of trunk sprouts and suckers for the first 2 years. They may be defruited for a year or two to induce vegetative growth. At maturity, trees are mechanically hedged and topped to form hedges about 12 ft tall and wide. Almost no hand pruning is done.

3.5.1. Nursery Operations

Citrus can be grown from seed; however, there are some disadvantages. In some cases, seedlings are not true-to-type with the mother tree as citrus trees hybridise very readily (e.g., seeds grown from Persian limes can produce fruit similar to grapefruit). Due to juvenility factors, seedling trees do not usually bear fruit until they are nearly a decade old; and they are vulnerable to unfavorable soil conditions, diseases, and so forth. For these reasons, most citrus produced throughout the world utilizes budded (grafted) trees. A budded tree consists of two parts: the scion, which is the fruit variety, and the rootstock, which supports the scion in the soil environment. Rootstocks are chosen based on a number of factors, including compatibility with the scion, resistance to diseases or pests, adaptation to soil conditions, effect on fruit quality. Citrus root-stocks can be grown from seed, since the commonly used rootstocks are apomictic (and hence true-to-

type), and there are no confirmed seed-transmitted systemic diseases of citrus. Production from seed is easier than from cuttings, the common method of production for root-stocks for most other tree crops.
The rootstock is usually of an appropriate size for budding about nine months to a year after germination, when it is about the diameter of a wood pencil . The scion variety is budded onto the rootstock by making an incision into the bark of the rootstock, inserting a bud removed from the scion variety, and wrapping it with tape. A callus should form between the rootstock and scion tissues in two to four weeks. With appropriate training, the young tree is ready for planting in the field in about another year.

Sudent Self Assessment exercise 2

1. Why is budding a very important operation in citrus production?
2. What are the guidelines for selecting :
   a. parent stock?
   b. budding stock?

3.6. FIELD OPERATIONS

i. Soil Considerations

Citrus trees will grow on a wide variety of soils if they have good surface and sub-surface drainage. Well-drained soils are essential, and good drainage can be accomplished by planting trees on high beds or ridged rows. Deep ditches criss-crossing a grove can carry off excess water or drop the water table. In many areas of south Louisiana, drainage ditches should be at 250-foot intervals to drop the water table. In addition, excess water from runoff or a high water table must be disposed of in a timely manner.

Coastal prairie soils of southwest Louisiana are underlaid with an impervious clay pan. In this area, drainage ditches may need to be spaced 100 feet apart with high beds constructed for trees. Coastal prairie soils, because of the presence of a clay pan, promote a shallow root system.

ii. Other Considerations

i. A site near a body of fresh water makes supplemental irrigation possible in dry years.
ii. Some land close to urban areas may be too valuable for citrus or taxed at too high a rate. Citrus is a high value crop, but at current land prices near some industrial or urban locations, production cannot be expected to offset excessively high prices.
iii. Access roads should be available to remove citrus regardless of weather conditions.
iv. Do not locate citrus orchards out of recommended zones.

iii. Land Preparation

Where land is not level, it should be disked and dragged to fill in depressions. If more extensive grading or leveling is required, an experienced operator may be needed. In leveling land, the object is to remove as little of the topsoil as possible. A widely used leveling practice in rice growing regions of southwest Louisiana is "water-leveling." The water level in a rectangular block of land is dropped gradually, and high spots are removed with a blade.

Where a high water table exists, it may be necessary to have a grid system of drainage ditches spaced as close as 250 feet with pumping facilities to carry off excess water. Ridged rows with one row of trees are best for Louisiana. Ridges are easily formed with moldboard plows. Grader blades can be used for final shaping. A quick growing sod, such as rye, is desirable for row middles to stabilize the soil initially and prevent ruts later.

Planting systems in Louisiana are usually rectangular. Trees are set at intersections of lines perpendicular to each other. The number of trees per acre can be varied by decreasing the distance between trees in the row. Distance between rows is less flexible because of the need to move equipment in the grove.

iv Spacing

Planting distances for citrus have been subject to considerable study.
Important considerations are:

1. ***High Density Spacing:*** (Trial plantings only) For maximum early production to offset high costs (and where land is limited), consider a spacing of 22 feet between rows and 11 feet within a row for Washington navels. For maximum early production of satsumas, a spacing of 20 feet by 10 feet may be desirable. In about 15 years, remove alternate trees within a row to eliminate crowding or shading out of adjacent rows. The common problem with high density spacings is the reluctance of producers to remove trees when crowding occurs. Hence, yields drop off with time.
2. ***Conventional Spacing:*** Spacings of 25 feet by 20 feet or 22 feet by 22 feet for Washington afford maximum production after the 15th year. For optimum yield before the 15th year, space trees 20 feet by 20 feet or 20 feet by 15 feet. Orange color develops first and is more intense at wider spacings. In some high density plantings, fruit colorings may be delayed 45 days. Wider spacings also favor earlier development of a higher sugar/acids ratio at legal maturity.

Variety or Type	Spacing	Trees/Acre
Kumquats	10' x 15'	290 - 294
Grapefruit & Round Oranges	15' x 30'	96 - 98

Satsumas	15' x 20'	87- 116
Navels	20' x 25'	87- 90

v. Timing of Planting

The best time to plant Louisiana citrus trees is between late February and early April, after the danger of severe frost. Plant trees before an active growth flush have begun. Trees planted at this time have a long growing season in which to become established. Summer-planted trees experience severe shock at high temperatures and require frequent irrigation. Trees planted in the coldest months may need cold protection.

vi. Planting

Citrus trees are taken from the nursery in two forms:

- *Bare-rooted trees:* Care must be taken at all times to prevent roots from drying out. Polyvinyl bags with moist peat inside are one way to maintain moisture. Tops should be cut back 40 percent to compensate for root loss during transplanting. The leaves may even be stripped from the trees for additional precaution.
- *Containerized trees*: Generally, containerized nursery trees are dug with mechanical cutters that cut around the root system and sever the tap root. Trees are then placed in long, narrow containers (7 to 8 inches in diameter) for holding until sale. Such trees often lack sufficient feeder roots after digging and may not hold up. A wider 10-inch container is preferred to the 7-inch size for field-dug trees. A small quantity of nursery trees are grown and budded while in containers (usually 3 to 5 gallons). Container-grown trees are less likely to suffer transplant shock and have better survival rates than field trees. Most trees are grown in containers.

Dig a hole only as large as necessary to accommodate the root system. Prune any damaged roots back beyond the damaged area. If container-grown trees have a tap root curled in the bottom of a container, cut this root off at the point where it begins to curl. The tap root will re-grow. Separate and trim the roots of container trees that may be root-bound.

Place the tree in the hole at the same depth it was growing previously. If holes are dug too deeply, and loose soil is placed at the bottom, trees may settle after watering. Trees set too deeply may die. Container trees should have the top of the soil ball flush with the top of the hole. Bare-rooted trees should have soil placed underneath them in a manner to allow the spreading of the roots in a natural position with no bending or crimping.

Back-fill with the same soil that was removed from the hole. Never back-fill with an amended soil mix of a lighter texture. Such a practice will create drainage problems and cause tree roots to suffocate during periods of excessive moisture.

Before completion of back-filling, add water to settle the soil and eliminate air pockets around the roots. After watering, fill the hole to completion and, if necessary, construct a basin (ridges of soil around the complete circumference of the tree) to hold water during subsequent irrigations. With trickle irrigation, this practice may not be necessary. Basins are not needed during excessive rains.

A soil drench containing Ridomil (at recommended rates) may be considered at this time to prevent root rot problems caused by *Phytophera* sp.

3.6b. Bringing Trees into Production

Citrus is produced in slightly different ways in different areas. Commercial production is more uniform throughout the world than is local or personal production, but there are some differences here as well. Many of the differences are in the nature of farming inputs rather than the production of trees. For instance, fertilization and irrigation are necessary in most areas. However, a more industrialized producer in an exporting country may utilize drip irrigation with inorganic fertilizers injected through the drip system, while a producer for the local market in a poor country or area may use manure and flood irrigation. . Lemons grow vigorously upright and require more frequent topping. Irrigation and fertilization are necessary. Certain production problems or challenges in citrus have been successfully managed with the application of plant growth regulators

Once planted, it is usually about two to three years before the tree begins to produce fruit. Full production is usually achieved at about ten years of age. Under appropriate conditions, citrus trees may live a long and productive life and achieve a fairly tall height. This was common in many older citrus-producing areas. Since about the 1970s, citrus production has become more cyclical, like that of other tree crops, and the life of an orchard may be no more than twenty to thirty years.

During the first two or three years, the objective of the grower is not to obtain the earliest possible production, but to develop a sturdy tree of good size. Little or no formal training is given citrus trees, other than topping them at planting and minimal pruning to assure development of low heads. It is advisable to allow the tree to grow its branches at a minimum height of two to three feet so herbicide and spray equipment can easily move underneath the lowest limb. Since citrus trees naturally form strong crotches, and the wood is tough, a sturdy framework of scaffold branches is obtained easily. The grower needs only to encourage growth by supplying favorable conditions for development. With no crop to consider, all attention can be devoted to promoting vegetative growth. Sometimes growers tend to give limited attention to young trees because they have yet to produce fruit, and therefore are not returning an income. This is a mistake and can delay production.

i. Watering Young Trees

Watering young trees may be more important than fertilizing. Seldom will a tree die due to lack of fertilizer. Conversely, trees will die if adequate moisture is not supplied. Young trees have a limited root system, and water should be applied frequently. Trickle irrigation (drip) is the most practical means of irrigating citrus. Regardless of the method used, the fact remains some consideration should be made to bring water to trees.

As a general rule, if two weeks pass without at least an inch of rainfall on recent transplants, trees should be irrigated. A convenient way to hold water around a young tree is to build a basin at its base. The basin is simply a shallow wall of soil with a radius of about 18 inches built around the complete circumference of the tree. To the basin, add 8 to 10 gallons of water each time the trees are watered. This allows water to penetrate slowly and ensures that the deepest roots receive water. The basin is retained as long as irrigation is needed. In some seasons, rainfall may make irrigation unnecessary, but be prepared to deal with the possibility of a drought situation.

Young trees seldom need watering in the fall. Tree roots have penetrated the soil for some distance, so they have access to a much larger reserve of water than they had during the first spring of growth. Also, falling temperatures reduce the rate of water loss from the tree. Except in cases of extreme drought, it is better to encourage early winter dormancy by allowing the soil moisture to become low in the fall.

Even though watering may be needed for several years, watering is most critical during the first year of grove life. By the second growing season, the trees are better able to take care of their needs for water, but they are still not self-sufficient.

ii. Fertilization

Unfortunately, no one fertilization recommendation can be made for every situation. Every grove requires special attention. This sometimes takes the form of amended applications of fertilizers.

Soil should be tested every two years. Soil tests will help determine the nutritional changes, if any, taking place. A soil test will indicate if needed levels of nutrients for good production are being maintained. If not, additional amounts may be added. A soil test will also measure the soil reaction (pH) and indicate a need for liming. Soils for citrus trees should be maintained at a pH of 6.5 - 7.5.

At this level, soil nutrients, particularly phosphorous, are most readily available.

Generally, only two types of commercial fertilizers are required: a balanced fertilizer (8-8-8, 13-13-13), and a nitrogen fertilizer such as ammonium nitrate (33-0-0), or ammonium sulfate (21-0-0). The balanced or complete fertilizer contains nitrogen, phosphorous, and potassium, the elements needed in the largest amounts by citrus trees. The nitrogen fertilizer stimulates vegetative growth later in the year.

Newly set trees should not be fertilized until they show signs of growth, usually six weeks after they are set in the spring. The first application should be light, not more than one-half of a pound of 8-8-8 or one-third of a pound of 13-13-13 per tree. Each succeeding application made at six-week intervals may be increased slightly until the tree receives about three-fourths of a pound of 8-8-8 or one-half of a pound of 13-13-13. Do not fertilize later than the last week of June or when soil is dry. If fertilized too late, trees may exhibit a late flush of growth exposing them to possible winter injury.

Average Recommendations per Tree*

Age	Early February	Mid March	Early May	Early June
Year of Transplanting		1/2 lb. 8-8-8 or 1/3 lb. 13-13-13	3/4 lb. 8-8-8 or 1/2 lb.13-13-13	1 lb. 8-8-8 or 3/4 lb. 13-13-13
Second Year	11/4 lb. 8-8-8 or 1 lb. 13-13-13	11/4 lb. 8-8-8 or 1 lb. 13-13-13	3/4 lb. 21-0-0 or 2/3 lb. 33-0-0	3/4 lb. 21-0-0 or 2/3 lb. 33-0-0
Third Year	11/4 lb. 8-8-8 or 1 lb. 13-13-13	11/4 lb. 8-8-8 or 1 lb. 13-13-13	3/4 lb. 21-0-0 or 2/3 lb. 33-0-0	3/4 lb. 21-0-0 or 2/3 lb. 33-0-0
Fourth Year & Bearing Age	2 lb. 8-8-8 or 13/4 lb. 13-13-13 up to 12 years			1/3 lb. 21-0-0 or 1/4 lb. 33-0-0 up to 12 years

*These are only average recommendations. Have your soil tested every 2

years. **iii. Protecting the Trees**

Young citrus trees may require protection form sunburn, cold or rabbits and grasscutters. Various wraps of aluminum foil, wire gauze, plastic, Styrofoam, rope and other materials have been used successfully to protect the trunk. Soil banking is not recommended for commercial orchards because of the possibility of foot rot. Before using wraps, spray a fungicide on the trunk to control *Phytophthora.*

iv. Spraying

For the first four years in the life of a citrus grove, little, if any, spraying is required. Insect problems may need attention, however. Caterpillars, scale and mites may cause serious defoliation. Because leaves are involved in food manufacturing, any damage can result in a tree that is stunted and is less cold hardy. Inspect trees regularly for insect and disease infestations before the pests have built up to serious levels.

Aside from citrus scab, fungal diseases are not much of a concern in young groves. This disease causes distortion and malformation of foliage and tender shoots (as well as fruit) of grapefruit, temples, satsumas and lemons. However, round oranges or tangerines are not attacked.

v. Weed Control

During the early years of a citrus grove, weed competition affects tree growth more than any other pest. Weeds compete much more seriously with young trees than they do with older trees. Older trees have a deeper and more extensive root system and quite often shade out much of the competing vegetation. Young trees, however, have a poorly defined root system, and weeds compete heavily for moisture and nutrients. Tree growth can be reduced by an estimated 50 to 60 percent by competing vegetation in a young orchard.

Weed control is an integral part of citrus, and its neglect can be costly. It is the one cultural practice most often neglected by producers. Producers should have good working knowledge of the science of weed control to achieve consistently satisfactory results.

vi. Pruning

Pruning is not a major task in young orchards. Sprouts on the trunks should be removed before they are large enough to compete with larger limbs. During the first year, the young grove should be walked every two to three months for sprout removal. Later, the intervals between inspections may be lengthened. In the fourth year, a single inspection will suffice.

Developing permanent scaffold limbs on young citrus trees is the most important phase of pruning. Scaffold branches should be developed 2 1/2 to 3 feet from the ground to allow herbicide applications or mowing. This selected height also increases air circulation in the orchard, thereby reducing the incidence of disease problems.

Allowing scaffold branches to grow at this height for the first three years requires no special pruning techniques other than heading the tree at that height and selecting permanent branches at that level. The citrus grower need not be concerned with special training of these scaffold branches for the first three years.

In the fourth year, just before the bearing period, examine the trees for weak limbs. Also look for limbs that may lie across and rub against others. Remove these branches to strengthen the bearing framework. The objective is to construct a well-shaped head with evenly spaced scaffold limbs and space for branches to develop properly without excessive competition from other branches.

Small pruning wounds do not need special treatment. However, any limb larger than 2 1/2 inches in diameter should be painted with commercial wound dressing or paint. All limbs should be cut flush with adjacent trunks to eliminate stubs.

3.6c.Care of Bearing Trees

1. Fertility and fertilization

i. Nitrogen

Nitrogen has the greatest effect on citrus yield. Nitrogen deficiency can be recognized by the uniform loss of chlorophyll and a yellowing of the leaves. Unlike other yellowing related deficiencies, nitrogen deficiency is characterized by the loss of green color and the uniform yellowing of the leaves. It is most clearly marked on the fruit-bearing twigs. Fruits are generally small and have a thick, leathery skin.

Heavily producing trees can tolerate large quantities of nitrogen without suffering any injurious effects if they are also supplied with phosphorus and potassium. Nitrogen is particularly important during blossom time. Within certain limits, the number of flowers formed is directly related to the nitrogen status of the tree. During flowering there is a large translocation of nitrogen from the leaves to the flowers.

If leaves are damaged or nutritionally weak, fruit production is usually affected. The most common form of nitrogenous fertilizer used is ammonium sulfate. Ammonium nitrate is also used and has some advantages. It involves less loss of nitrogen associated with the acid effect of ammonium sulfate. Furthermore, by increasing nitrate and decreasing ammonium forms of nitrogen, the concentration of potash, calcium, and magnesium is increased in the leaves. The amount of nitrogen applied during the year varies according to age and productivity of the tree.

ii. Phosphorus

Phosphorus is also critical to maintaining citrus production. Phosphate deficiency is indicated by small, blue-green, lusterless leaves. Under conditions of acute deficiency, leaves show blue- green to bronze-brown discolorations and irregular necrotic spots. The formation of new shoots is restricted. The leaves are easily shed, and portions of the twigs may die.

Phosphate excess seldom occurs on heavy soils because of their high powers of fixation. Superphosphate (0-20-0) is the fertilizer most often used when phosphorus is needed.

iii. Potassium

Potassium levels are usually maintained by adding a complete fertilizer, but murate (potassium chloride) of potash may be used.

In contrast to most other nutrient deficiencies, initial potassium deficiency is indicated by the fruits remaining small while the leaves show no external symptoms. The advanced stage of potassium deficiency is denoted by a thickening and puckering of the leaves, the disappearance of chlorophyll in the inner vein areas, and the appearance of necrotic spots. Premature leaf fall and shoot die-back occur with severe deficiencies.

iv. Trace Elements

Frequently observed symptoms of trace element deficiencies in citrus varieties have led to the conclusion that fertilizer formulae should contain trace elements. Generally, in the case of trace elements, it is advisable to wait until the deficiency of the element is established by visual symptoms or by leaf analysis before treating.

In some instances and in some soils, young citrus trees may show deficiency symptoms as a result of trace element deficiencies. In such instances, the leaves should be diagnosed by an appropriate expert and the proper recommendation made. Applying trace elements to correct minor element deficiencies requires special expertise.

v. Timing of Fertilizer Application

The timing of fertilizer applications must be adjusted, as far as possible, to the growth rhythm of the trees. In most cases, an application is made in late winter (February) before the blossoming and in summer (June) when the summer shoots are formed. For best results, fertilizers are applied 20 to 40 days before the onset of the first growth in late March or early April.

2. Irrigation and Soil Moisture maintenance

Drip or trickle irrigation allows the precise application of water in the immediate vicinity of plant roots. In addition, it simplifies procedures, reduces labor requirements, and minimizes distribution and evaporative loss. Less of the total soil area is fully wetted than with sprinkler and furrow systems. This reduces significantly the amount of water required. Automatic control of the irrigation system using time clocks or moisture sensors and automatic valves is simple and relatively inexpensive.

Water is carried to individual trees through a carefully planned pipeline system. Each line should be planned for a specific orchard considering size, shape, slope, and tree spacing. Plan the system to provide reasonably uniform pressure at all emitters, to require minimum material, and to achieve maximum operating convenience.

The heart of any irrigation system is the pump. A main pipeline carries water from the pump to the plant rows. A filter, or system of filters, must be installed on the main lines. One option may involve the installation of a fertilizer injector upstream from the filter. If a fertilizer unit is used, an antisiphon unit consisting of a check valve and vacuum breaker will prevent backflow of water and fertilizer material back into the well.

A lateral pipeline containing the emitters is placed along each row of trees. In larger systems, the orchard may be divided into blocks of 10 to 20 acres. The laterals for each block are connected to a header pipeline or manifold. A globe-type valve with pressure gauge installed on the manifold side of the valve allows precise control of pressure in all blocks. Laterals should be on the contour, or perpendicular to the slope, when the slope is too steep to maintain a more uniform pressure at the emitters.

Water is released by drip emitters attached to laterals and located near each tree. Numerous emitters are on the market. Usually each emitter applies one or two gallons each hour, but the rate should never exceed the percolation and infiltration rate of the soil. Some drip emitters can be installed underground, but it is easier to adjust and clean clogged emitters when they are on the surface. Emitter selection is important since satisfactory performance is essential to the success of every drip irrigation system.

Mature citrus trees may not need irrigating frequently in Louisiana. A critical period for irrigation is during fruit maturity. A water shortage can mean severe losses of fruit caused by splitting and premature fruit shedding. The expense involved in installing a drip irrigation system in citrus can often be reclaimed in one season by increased yields.

3.6d. Insect Pests Management

1. MITES

Citrus rust mite, (*Phyllicoptruta oleivora*)

The citrus rust mite is small (about .01 in. long) and cannot be recognized with the unaided eye. Under 10x magnification, they appear as lemon-yellow, wedged-shaped objects, but distinct features cannot be seen. Rust mites can be seen more easily on green leaves and fruits than on ripe fruits. A heavily-infested leaf appears to be fuzzy or dusty. Eggs of whiteflies are often mistaken for rust mites. The life cycle requires only about a week in summer, which accounts for the rapid build-up often noted.

Rust mites infest leaves, fruit and tender green shoots, causing rusty-colored fruit. Heavily-infested leaves lose their gloss and dark-green color and may drop prematurely. Heavy infestations may develop on the leaves just before bloom and cause severe injury to young fruits soon after they are set. Rust mites seem to prefer exposed locations and are numerous in the tops of trees. They are more numerous on fruit from spring until late summer. Inspect the fruits and underside of leaves with a magnifying glass.

Melanose, a fungus, causes blemishes on citrus often confused with rust mite injury. Lesions caused by melanose are darker, more rounded, and raised with a sandpapery feel. Scab, another fungus, causes spots that are usually rougher, larger, more irregular and lighter in color than rust mite injury.

Six-spotted mite, (*Eotetronychus sexmaculatus)*

The six-spotted mite is about 0.02 in. long, pale grayish-yellow in color, and lays a round, yellowish-white egg. It usually has four or six dark spots arranged in two rows on the body. With 10x magnification, the spots are barely visible on the adult mites, and few or none can be seen on the young. Mites and eggs are found in colonies, often covered with webbing, and located only on the upper surface of the leaf. Feeding causes yellow or chlorotic areas, usually along the veins, and results in leaf drop. These mites are usually most numerous March through May, but may build up in January and February after a cold December. Although grapefruit varieties are preferred, they can be found on other types of citrus.

Texas citrus mite, (*Eutetranychus banksi*)

The adult female of the Texas citrus mite is about 0.02 in. long and has a shiny body with conspicuous hairs. The color varies from tan to brownish-green with dark brown to greenish spots or bars near the lateral margins. The adult male, which has longer legs than the female, also has a smaller triangular-shaped body. The female lays flat, disc-shaped eggs along the midrib and near the lateral margins of the leaves. The eggs vary in color from light yellow when laid to tan and green as they mature, turning to reddish brown just before hatching. Newly-hatched mites are light yellow to tan with pale legs. Populations are usually heavier on the upper leaf surface. Injury to leaves is caused by the mites sucking out the juices giving foliage the classic mottled appearance. Injury may cause leaf drop. Mites are most numerous May through July, but most injurious October through February due to dry weather.

Citrus red mite, (*Panonychus citri*)

The adult female of the citrus red mite is about 0.02 in. long, rose to deep purple in color with prominent light-colored hairs. Eggs are round and reddish in color. Both eggs and mites are usually found on the upper surface of leaves, but often occur on the under surface and on green twigs. Eggs laid on leaves are most abundant along the midrib and petiole. The life cycle is short, and there may be 12 to 15 generations per year. The mites are most numerous May through July, but most injurious October through February because of dry weather. Leaf injury is similar to that of the Texas citrus mite.

2. SCALES

Florida red scale, (*Chrysomphalus aonidum*)

The adult female Florida red scale is circular, less than 1/10 in., and dark reddish-brown in color with a conspicuous lighter colored center. She lays bright yellow eggs under her armor that produce bright, lemon-yellow, oval-shaped crawlers. There are usually four generations per year. These insects feed on leaves and fruits, preferring exposed surfaces. Their feeding results in yellow areas on leaves and fruit which may often be followed by heavy leaf and fruit drop. The denuded braches may be killed the following fall and winter. Make sure to inspect groves at regular intervals from May through October.

Yellow scale, (*Aoniiella citrina*)

Yellow scale can be distinguished from Florida red scale by the lighter color of its armor and the shape of the body. The adult female is circular, yellow to light orange in color, and noticeably flatter than other armored scales on citrus in Florida. The body, which can be seen through the semi-transparent armor, is lemon-yellow and kidney-shaped. No eggs are found, as the females give birth to living young. Feeding damage is very similar to Florida red scale.

Glover scale, (*Lepidosaphes gloverii*)

Purple scale, (*Lepidosaphes beckii*)

Glover scale and purple scale are very similar in appearance and habits, but Glover scale is longer and narrower. These scales feed on leaves, fruit, and wood, and are often overlooked because they are found primarily on the inside of the tree and on the wood. They like shady areas such as the under surface of leaves and collect especially at the midrib and base. Yellow, chlorotic areas on the leaf result in defoliation and subsequent twig death. Infestations on the fruit near the stem end cause fruit loss, as well as green spots, which cannot be removed in the coloring room. Grove inspections should be made prior to post-bloom and summer spray periods.

The female purple scale lays grayish-colored eggs in a sac-like enclosure under her armor, while Glover scale eggs are pink and found in two rows. Crawlers of both scales are oval and have an off-white color with a posterior brown tip. Peaks of young stages occur in March-April, June-July, and September-October.

Black scale, (*Sassetia spp.*)

The adult female black scale is nearly circular, hemispherical, and dark- brown to almost black, with two lateral ridges and a longitudinal ridge forming a pattern on the back resembling the letter "H". She lays approximately 2000 eggs in a cavity under her body. The eggs are oval and pink in color changing to reddish-orange before hatching. The light brown, flat, oval, crawlers travel about considerably before settling on twigs or leaves and to some extent on fruit. Later the young move from leaves or fruit to small twigs, particularly stems that hold fruit. There are usually two or three generations a year. Black scales excrete large quantities of honeydew.

Brown soft scale, (*Coccus hesperidum*)

Brown soft scale is oval and flat, and light brown in color. No eggs are laid as pale yellow crawlers are born alive. Young female and male scales are similar in shape and color, but smaller than adult females. These scales infest young twigs and often gather along the midrib of the leaf. They are highly parasitized by tiny wasp-like insects and rarely become abundant except on young trees, either in newly-planted groves or in a nursery, where ants feed on honeydew and drive away the parasites. Like black scales, brown scales excrete large amounts of honeydew.

Cottony cushion scale, (*Icerya purchasi*)

The body of the female cottony cushion scale is bright orange, red, yellow, or brown, but its most distinguishing feature is the elongated, fluted, white cottony egg sac that is attached to its body. The female usually occurs on twigs, and the egg sac contains from 600 to 800 red eggs. It may become two to three times as long as the body of the female, resulting in an overall length of almost 1/2 inch. Eggs hatch in a few days during warm weather, but take up to 2 months to hatch in winter. Crawlers are red with black legs and antennae. Second-instar nymphs settle on twigs and leaves, usually along leaf veins. The third instar moves to branches and trunks. All three instars are covered with a thick, whitish, cottony secretion, which disappears after the insect molts. The minute, red, winged male is rarely seen; the loose cottony cocoons from which males emerge, however, may be detected in secluded places on the tree or ground. Cottony cushion scale usually has three generations a year; unlike most other scales, it retains its legs and its mobility throughout its life.

Feeding can result in defoliation and dieback of twigs and small branches when infestations are extremely heavy. Feeding also reduces the yield of citrus trees. Like soft scales, cotton cushion scale excretes honeydew, which is often accompanied by sooty mold growth and ants.

Chaff scale, (*Parlatoria pergandii*)

Chaff scale forms a light brown nearly round armor, which is slightly smaller than that of a mature female Florida red scale. The eggs and crawlers are purple. This scale infests leaves, wood, and fruit causing green spots, which lower the grade. Tangerines and early varieties of oranges must be de-greened due to Chaff scale damage. Heavy infestations are most likely to develop during late summer and through the winter.

Citrus snow scale, (*Unaspis citri*)

Citrus snow scale gets its name from the white color of male scales. Female scales are brown to blackish with a lengthwise roof-like ridge. They are very difficult to see against the tree bark. Scales are largely confined to the trunk, limbs, and twigs.

Florida wax scale, (*Ceroplastes floridensis*)

Florida wax scale is a soft scale that appears white to pinkish-white when not stained by sooty mold or other foreign matter. The adult female is 1/8 inch or less in length, oval in general outline but presenting an angular appearance due to dome-shaped masses of wax on the back. The pale-brown crawlers collect on the lower leaf surface along the midrib. Young larvae are star-shaped. This scale is highly parasitized.

3. **APHIDS**

Green peach aphid, (*Myzus persiae*)

Spirea aphid, (*Aphis spiraecola*)

Cotton or melon aphid, (*Aphis gossypii*)

Black citrus aphid, (*Toxoptera aurantii*)

Aphid infestations are usually found on new growth flushes. Aphids suck sap from leaves and stems, resulting in curled, distorted leaves which can retard tree growth and cause fruit and blossom shed. In addition, aphids produce large amounts of honeydew that promote growth of sooty mold, which may reduce photosynthesis. Aphids are also associated with the transmission of plant diseases. Low to moderate infestations of aphids can be considered beneficial to the citrus ecosystem by providing food early in the season for natural enemies, such as lacewings and ladybeetles.

Three aphid species, the spirea aphid, the green peach aphid, and the cotton or melon aphid are the most common aphids on citrus in Louisiana. The black citrus aphid may also be found occasionally.
Aphids reproduce asexually with females giving birth to young nymphs. Within a week of their birth, the females mature sexually and are themselves capable of producing offspring. This rapid rate of reproduction can result in large infestations developing in a very short time. Many generations per year can occur on citrus before the winged aphids migrate to their alternate hosts during the winter. Fortunately, natural mortality factors, especially predators and parasites, are usually highly effective in limiting aphid populations.

4. **WHITE FLY**

Cloudy-winged white fly, (*Dialeurodes citrifolia*)

Adult cloudy-winged whiteflies differ from other whiteflies by the darkened area in the middle of each wing, which gives the wings a cloudy appearance, and by the fact that the wings are held in a flatter position than those of the citrus whitefly. Fresh-laid eggs of the cloudy-winged whitefly are yellow, but soon turn black and have a network of ridges. Eggs are commonly laid on young leaves. Nymphs and pupae are very similar to those of the citrus whitefly. Populations of this whitefly are often mixed with the citrus whitefly within an orchard.

Citrus white fly, (*Dialeurodes citri*)

The citrus whitefly lays smooth, shiny pale-yellow eggs. Eggs usually hatch in one to three weeks and the crawlers move about for several hours before settling. The larvae are oval, thin and translucent, which makes them difficult to see on green leaves. The nymphs require three to four weeks before pupating and another two to four weeks before emerging as adults. Pupae are similar to nymphs but are thicker and have distinct eyespots.
Adults live an average of two weeks during which time the female lays an average of 150 eggs. Citrus whiteflies have been observed to develop high populations during growth flush periods, but generally occur in low numbers.

Wooly white fly, (*Aleurothrixus floccusus*)

Adults are yellowish-white and seldom fly. Woolly whitefly eggs are laid in a circle on the underside of mature leaves, with the female at rest in the center. The eggs are brown and sausage-shaped. The first instars are light green; subsequent instars are brown. Pupae are covered with waxy white filaments, giving a woolly appearance. Copious amounts of honeydew often are associated with colonies of this species.

5. **OTHER INSECTS**

Citrus mealybug, (*Planococcus citri*)

The adult female citrus mealybug is wingless and appears to have been rolled in flour (hence the name). It grows to 1/10 in. long and 0.06 in. wide. A fringe of small waxy filaments protrudes from the periphery. The adult male is small, but with its wings and tail filaments, it appears to be 2/10 in. long.

Eggs are oblong, yellow, and are enmeshed in a dense, fluffy, white ovisac.

The tiny crawler is oval and yellow, with red eyes. The antennae are rather distinct. Female nymphs resemble the larger adult females. Male nymphs are narrower and often occur in a loose cocoon.

Citrus mealybugs are often confused with cottony- cushion scale. They also excrete large amounts of honeydew in which sooty mold fungus develops. They may get into crevices in the bark on the limbs and trunk and in such sheltered places as the angle between the petiole of the leaf and stem. Mealybugs often collect around the stem end and under the calyx of the fruit and cause fruit drop. Another favorite place for mealybugs is the sheltered area formed by clusters of two or more fruits, particularly grapefruit. Controls should be applied before mealybugs have settled under the fruit calyx.

Orange dog caterpillar, (*Papillio cresphontes*)

The orange dog caterpillar is often a pest of citrus trees. Two or three may defoliate a young tree in a few days. They are most important on young trees and nursery stock. The caterpillar is dark brown with light yellow patches, growing to a length of up to 2 inches. The front part of the body is enlarged and when not feeding, the caterpillar pulls the head back into these large segments and causes the whole front of the body to resemble the head of a dog – hence the name. The orange dog can push out a fold of skin at the back of the head, which forms two long, red, horn-like projections. This organ gives off a strong odor, which repels natural enemies. The adult is a large, yellow and black butterfly.

Broad-winged katydid, (*Microcentrum rhombifolium*)

The broad-winged katydid lays its eggs along the margin of the leaf and there are several generations a year. Other kinds of katydids occur in citrus groves, but only the broad-winged katydid is of any economic importance. They sometimes feed on the rind of growing oranges, causing large, smooth sunken areas to develop on the fruit. Occasionally they cause severe defoliation of young trees.

Eastern lubber grasshopper, (*Romalea microptera*)

The eastern lubber grasshopper can cause injury to citrus fruit and foliage. Eggs are laid in the ground. After hatching, young nymphs may migrate to the cover crop and trees in the grove. Injury is most important on young trees. In some instances they have completely defoliated newly set trees. There is only one generation per year, and they can be seen during spring and summer near low, marshy land.

Fullers rose beetle, (*Pantomorus cervinus*)

Citrus root weevil, (*Pachnaeus litus*)

The Fuller's rose beetle is gray-brown and 1/4 to 1/3 in. long. The citrus root weevil is blue-green and 1/2 to 3/4 in. long. Both can occur in sufficient numbers to cause severe injury to both roots and foliage of citrus varieties. Injury from these pests has been noted most commonly along the Florida east coast. Growers should become familiar with both the larval and adult stages of these insects.

Injury by the larval stage is by far more serious than injury by the adult stage. The legless white larvae of both species eat canal-like channels in the roots. This injury is usually more prevalent on the underside of lateral roots although primary roots may be girdled near the main trunk root. Adult injury to leaves typically appears as notches cut out along the leaf margin. Adults may also be seen on small fruits.

Pink scavenger caterpillar, (*Sathrobrota rileyi*)

The pink scavenger caterpillar is a small caterpillar with a deep wine-red abdomen, brownish head and black mouth parts. It has a dark brown area just behind the head. Its diet consists mainly of dead insects and decayed areas of fruit. However, it has been known to feed on the rind of sound fruit causing a reduction in grade. Several may be present during heavy infestations of mealybugs or scale.

Insect Spray Schedule*			
Time	**Crops**	**Formulation/100 gal and % of citrus acres receiving at least one application/season**	**Comments**
Pre-bloom Jan.15 - Feb. 15	Satsuma Grapefruit Temple Valencia Round Oranges	Ethion 4 M at 1 pt. REI is 48 hr. 50% Kelthane MF at 1 pt. REI is 12 hr. 25% Vendex 50 WP at 4-8 oz. +	For control of spider mites and rust mites. Do not mix copper with other pesticides. Follow label directions carefully. Do not use more than 4 times per season. Do not use on tangerines, tangelos, Reed grapefruit, or Webb red blush grapefruit. Do not repeat

		Latron CS7 at 1 qt. REI is 48 hr. 90%	applications of Ethion within 90 days. Do not use on navel oranges. Pre-harvest intervals may vary due to rate – consult labels.
Post-Bloom Satsumas when 75% petals have fallen, other oranges when pea size.	All citrus	Malathion 57 EC at 1.75 pt. REI is 12 hr. 100% Diazinon 50 WP at 0.5-1.0 lb. REI is 24 hr. 75% Lorsban 4 E at 0.5-1.0 pt. REI is 24 hr. 20% Supracide 2 E at 0.5-2.0 pt. REI is 48 hr. 10% Kelthane MF at 1 pt. 25% Vendex 50 WP at 4-8 oz. + Latron CS7 at 1 qt. 90% Sevin 4 F at 3-5 qt./A REI is 12 hr. 25% SpinTor 2 SC at 4-10 oz. REI is 4 hr. <5%	For control of scale, thrips, mealybugs, mites, aphids, and whiteflies. Nutritional mixtures should not be used with Malathion. PHI of 14 days on Supracide PHI of 21 days on Diazinon, Lorsban. 2 application limit per season on Lorsban. No application above 95° F. Do not use where shrimp or crawfish would be affected. Use another miticide in conjunction with Sevin as spider mite numbers increase following. PHI of 5 days on SpinTor.
Post-Bloom 80% petal fall	All citrus	Agri-mek 0.15 EC at 0.5-2 oz. or 10-20 oz./A in 150 gal/A carrier. 60%	For mite, leafminer, and thrips control. PHI of 7 days. Do not apply within 30 days of last application. Always use horticultural spray oil. Do not apply more than 40 oz./A.
April	All citrus	Extinguish IGR at 1.0-1.5 lb./A or 3-5 Tbs./mound. 10%	Broadcast control for Fire ants when ants are actively foraging.
June 15 - July 15	All citrus	Malathion 57 EC at 1.75 pt. 100% Agri-mek 0.15 EC at 0.5-2 oz. or 10-20 oz./A in 150 gal/A carrier. 60% Supracide 2 E at 0.5-2.0 pt. 10% Diazinon 50 WP at 0.5-1.0 lb. 75% Lorsban 4 E at 0.5-1.0 75%	For control of scale, thrips, mealybugs, mites, aphids, and whiteflies. See comments above.
Aug. 14 - Sept. 15	All citrus	Ultra Fine Oil at 1.5 gal 80% Malathion 57 EC at 1.75 pt. 100%	For control of scale, thrips, mealybugs, mites, aphids, and whiteflies. See comments above.

		Supracide 2 E at 0.5-2.0 pt. 10% Diazinon 50 WP at 0.5-1.0 lb. 75% Lorsban 4 E at 0.5-1.0 pt. 30% Kelthane MF at 1 pt. 25% Vendex 50 WP at 4-8 oz. + Latron CS7 at 1 qt. 90%	
Oct. 15 - Nov. 15	All citrus	Vendex 50 WP at 4-8 oz. + Latron CS7 at 1 qt. 90% Agri-mek 0.15 EC at 0.5-2 oz. or 10-20 oz./A in 150 gal/A carrier. 60% Extinguish IGR at 1.0-1.5 lb./A or 3-5 Tbs./mound. 10% SpinTor 2 SC at 4-10 oz. <5%	For mite, leafminer, and fire ant control.

* Follow label directions carefully

3.6e. Diseases Control and Management in Citrus

i.Citrus canker. Citrus production is often cut short in many areas by outbreaks of bacteria known as *Xanthomonas axonopodis*, or **Citrus canker**, which cause unsightly lesions on all parts of the plant, affecting tree vitality and early drop of fruit. While not harmful to human consumption, the fruit becomes too unsightly to be sold, and entire orchards are often destroyed to protect the outbreak from spreading.

Citrus canker affects all varieties of citrus trees, and recent outbreaks in **Australia**, **Brazil** and the **United States** have slowed citrus production in parts of those countries.

ii **Melancose** has become the major disease problem the last several years. Several applications of copper are employed to control this disease. The first application is made before bloom with another one made after bloom when fruit are pea size. Only 20% of the growers used copper to control this disease this past year.

iii. **Melanose (*Diaporthe citri*.)**

Symptoms: Melanose affects the leaves, shoots and fruit. It forms numerous, dark brown dots or spots on the leaves, young shoots and fruit. These spots are at first sunken, but later become raised so that the russeted area has a rough, sandpaper feel. The spots may be irregularly scattered on the surface of the fruit or they can run in streaks (tear stains). Like scab, melanose infection occurs only on the young, tender growth. The fruit becomes progressively resistant with age. However, the same fungus that causes melanose can infect the ripe fruit after harvest. It is one of the two most common causes of the very destructive fruit decay known as stem-end rot. Control of melanose, therefore, helps to reduce the losses from stem-end rot. Prune and burn the dead wood. This practice eliminates much of the source of infection.

iv. **Scab** (*Sphaceloma fawcettii*.)

Symptoms: Scab is primarily a disease of satsuma, orange, tangerine, grapefruit, lemon, sour orange and trifoliata orange root stock. It does not affect the sweet orange. Scab affects fruit leaves and young shoots, causing irregular, raised, corky, scabby, wart-like outgrowths. Severely scabbed leaves and fruits become misshapen and distorted. The rind of scabbed fruit is thick and puffy.

v.. **Sooty Mold** (*Capnodium citri*.)

Symptoms: The sooty mold fungus (*Capnodium citri*) is not a parasitic organism. It does not penetrate the tissue of the plant but grows superficially on the honeydew excretions of white flies, aphids, mealy bugs and scale insects. Sooty mold causes a certain degree of injury, when its growth is very thick, by preventing the sunlight from reaching the leaf and by making the fruit black and unattractive. Fruit covered with sooty mold is smaller and does not color well.

vi.. **Green Mold, Blue Mold** (*Penicillium* sp.)

Symptoms: The fungus enters the fruit through injuries to the skin. Decay appears as a softened water-soaked area that is easily punctured by pressure. Later white mycelium appears on the surface and soon a mass of powdery olive-green (green mold) or blue spores (blue mold).

vii.. **Sour Rot** (*Geotrichum citri*)

Symptoms: Lesions appear as soft water-soaked spots on fruit at points where injury has occurred and may increase to involve the entire fruit. White fungal growth develops on the surface of the infected fruit. A strong sour odor is present.

viii. **Foot Rot** (*Phytophora parasitica)*

Symptoms: Foot rot is the most frequently encountered disease on the trunks of citrus trees in Louisiana. Members of this genus also cause brown rot on the fruit.

Foot rot produces motile spores which usually invade the trunk at the bud union. Wet conditions during the spring of the year favor fruit rot development. Initial symptoms include water soaking of bark that appears as a dark spot on the trunk. At first the bark may appear firm, but with age it becomes cracked and may eventually shred. Gumming often accompanies advanced stages of foot rot. Maintaining adequate drainage in orchards helps to reduce disease incidence.

Disease Spray Schedule*			
Time	**Crops**	**Formulation and amount/100 gal.**	**Comments**
Pre-bloom	Satsuma Grapefruit Temple	Fixed copper. Follow label directions.	For control of Scab and Melanose. Do not mix copper with other pesticides. Do not use more than 4 times per season. Do not use within 7 days of harvest. Do not use on tangerine, tangelos, Red grapefruit or Red Blush grapefruit. 80% of citrus acres receive at least one application during the season.
Bloom	All citrus	Topsin M 70WP. Follow label directions	With Benlate no longer available, Topsin was granted Section 18 by EPA. Do not use copper during bloom. 20% of citrus acres receive at least one application during the season.
Post-Bloom	All citrus	Fixed copper. Follow label directions. Abound at 0.2-0.25 lb./A Follow label directions.	For control of Scab and Melanose. Do not mix copper with other pesticides. Do not use in full bloom or where shrimp or crawfish may be affected. Make first application at pea-size fruit, and the second 14 - 21 days later. Time applications to follow rain, if possible. May require 200 - 300 gallons per acre for large trees. Abound can be sprayed up to day of harvest. 20% of citrus acres receive at least one application during the season.
June 15 – July 15	All citrus	Fixed copper. Follow label directions	For control of Scab and Melanose. Do not mix copper with other pesticides. 80% of citrus acres receive at least one application during the season.
Oct. 15 – Nov. 15	All citrus	Aliette at 5 lb.	For control of Brown rot, apply Aliette as foliar spray when disease conditions develop. REI for Aliette is 12 hr. 15% of citrus acres receive at least one application during the season.
Soil Treatment	All citrus,	Ridomil 5G at 40 - 80 lb./A.	Apply Ridomil to control Phytophthora

	including new plantings and nursery stock	Follow label directions. Aliette at 5 lb./A	foot rot no more than 3 times a year. Rate depends on tree size. REI is 48 hr. 20% of citrus acres receive at least one application during the season. Alliette will also control Phytophthora foot rot. Do not exceed 4 applications per year. Do not apply within 30 days of harvest. 15% of citrus acres receive at least one application during the season.

- Follow label directions carefully

3.6f. Weeds and Weeds Management in Citrus.

i. **Cultural**

Cultural methods include: 1) exclusion and sanitation practices to minimize species introduction, establishment, and spread, 2) modification of other grove practices which may promote the establishment and spread of vegetation, i.e., off-target irrigation and fertilizer applications, 3) early shading of grove floor surface by tree canopies, and 4) leguminous cover crops which can supply nitrogen and require less maintenance after establishment.

ii. **Mechanical**

Cultivation in row middles kills annual weeds efficiently and economically by severing the stems from the roots. Each crop of weeds must be killed in order to prevent competition with the trees and production of seeds. Each cultivation also brings seeds to the soil surface, where they can germinate and the number of cultivations required should be determined by the number of flushes of weed emergence. Cultivation at proper time intervals can theoretically be used to ultimately kill deep-rooted perennial weeds by exhaustion of their underground food reserves. Although infrequent cultivation provides temporary control, it spreads and invigorates perennials by increasing the number of buried seeds and by widely distributing rhizome and stolon cuttings, tubers, and bulbs. The result of infrequent tillage is the establishment of solid stands of resistant species which can greatly impact tree growth. Constant cultivation also results in the destruction of citrus fibrous roots which normally would grow in the undisturbed portion of the soil.

iii. Chemical

Generally speaking, all weed species listed as susceptible on the herbicide product label will be controlled by that herbicide at the appropriate rate, time of application and stage of growth. Environmental and plant conditions before, during and following the application are also important including moisture in the form of rainfall and/or irrigation. Poor control can sometimes be expected from post-emergence applications to weeds under stress conditions due to poor uptake and translocation of applied herbicides. Assuming that the appropriate herbicide or herbicide mixtures are selected for the weed species present, failures in the program will usually be due to one of the above factors or to the actual application including calibration and/or equipment design and operation.

Herbicides may be classified as foliar or soil-applied. Foliar applied materials may have systemic or contact activity. Soil applied pre-emergence herbicides are absorbed through weed root systems, being most effective during germination and early seedling growth stages. Systemic herbicides are those that are absorbed by either roots or above-ground plant parts and are translocated throughout the plant. Contact herbicides act as desiccants, damaging or killing all plant parts actually sprayed with little if any translocation. For the control of well-established perennial weeds, a post-emergence herbicide with systemic metabolic activity should be used with pre-emergence soil residual products.

Timing and frequency of application are the keys to good vegetation management. Increased application frequency of lower rates of soil residual herbicides is more effective in young groves where vegetation presence is greater due to more exposure of the grove floor to sunlight and where a greater herbicide safety factor is required.

Weed Spray Schedule – Pre-emergence*			
Trade Name	**Chemical**	**Rate/acre**	**Comments**
Goal 1.6 E	oxyfluorfen	2.5-10 pt.	**Nonbearing only.** Do not use until growth flush has hardened. Post-emergent activity at the higher rates. REI is 24 hr. 15% of citrus acres receive at least one application during the season.
Hyvar L	bromacil	2-8 qt.	Rate depends on tree age and soil type, 8 qt. Maximum/year. Some post-emergent activity. Hyvar X also labeled. REI is 12 hr. 10% of citrus acres receive at least one application during the season.
Krovar I DF	bromacil + diuron (1:1)	2-8 lb.	Rate depends upon tree age and soil type. 16-lb maximum per year on bearing trees. Some post-emergent activity. REI is 12 hr. 50% of citrus acres receive at least one application during the season.
Princep Caliber 90	simazine	4.4-5.3 lb.	Do not use for 1 year after freeze damage. Princep 4L also labeled. REI is 12 hr. 25% of citrus acres receive at least one application during the season.
Post-emergence			
Finale	glufosinate	2-6 qt.	Can be tank-mixed. Avoid contact with green bark. Do not use within one year of

			transplanting. REI is 12 hr. 30% of citrus acres receive at least one application during the season.
Gramoxone Extra	paraquat	2-3 pt.	Crop oil concentrate or non-ionic surfactant required. Avoid all tree contact. REI is 12 hr. 80% of citrus acres receive at least one application during the season.
Poast	sethoxydim	1.5-2.5 pt.	Spot treatment at 1-1.5%. Crop oil concentrate or Dash® required for activity. Grass control only. REI is 12 hr. 25% of citrus acres receive at least one application during the season.
Roundup	glyphosate	1-5 qt.	Spot treatment at 0.75-1.5%. REI is 4 hr. 90% of citrus acres receive at least one application during the season.
Touchdown	sulfosate	up to 4.8 pt.	**Nonbearing use only.** Not for use within 1 year of harvest. Spot treatment at 0.25-5%. REI is 12 hr. 50% of citrus acres receive at least one application during the season.

- Follow label directions carefully

iv. Biological

Biological control of economically important species in groves is not widely observed except in Texas for milkweed vine, *Morrenia odorata*, for which the commercial mycoherbicide DeVine was developed. However, where species are being stressed by native insects or pathogens in groves, such events should be noted and if possible exploited. Soil applications of fungicides for the control of *Phytophthora* should be scheduled not to coincide with DeVine applications as they may affect its efficacy.

v. Integrated weeds management Programme

Establishing a weed management program involves a consideration of plant species growing as weeds and competing in the rooting zone of trees. Indigenous or introduced ground cover species in row middles, while also competitive, can play a positive role in grove management. Inputs into management decisions include:

- the identification of native and introduced species,
- a knowledge of their relative level of competitiveness/ interference with trees and other cultural practices,
- an understanding of their impact on pest and disease management strategies, and
- an informed selection of efficacious, cost-effective, and environmentally compatible management options.

Integrated Weed/Vegetation Management (IVM) stresses the integration of control/suppression methods with other grove practices. It involves the selection, integration, and implementation of effective vegetation management strategies in light of economic, ecological, and environmental consequences. The adoption of practices consistent with IVM will reduce seed reservoirs and vegetatively produced plant parts substantially, making management programs more efficient and cost-effective over time.

All vegetation species are not equally competitive with citrus trees. Grasses, especially sod-forming species are more aggressive competitors than most broadleaf species. Vines in tree canopies can become very competitive for sunlight. Mowed grass can be very competitive due to the moisture demands of vigorous re-growth. Relatively sparse weed growth on poor sandy soils may be more harmful than that on heavier soils with greater moisture and nutrient reserves to be shared between trees and weeds. Large numbers of seeds representing numerous vegetation species reside in the surface soil layers in which tree roots are established. From these seed reservoirs, each species has periods of emergence ensuring weed cover for most of the citrus growing season. With time and appropriate sanitary and suppression methods, weed reservoirs can be greatly reduced. However, one season or year of reduced weed management can all but eliminate benefits accrued over time. From a practical and economical standpoint, the total elimination of weed seed and plant parts is neither economically practical nor desirable.

Vegetation species are considered economic pests if they reduce the growth, health and survival of young trees, or the time to come into bearing and ultimately fruit production. Eventually, trees are deprived of whatever portion of resources that vegetation utilizes. The more competitive the vegetation, the more adversely it alters tree physiology, growth, fruit yield and quality. The attainment of early crop production requires controlling the growth of weed competitors. Weeds alter economic status by competing with trees, particularly young trees, for water, nutrients and even light in the case of climbing vines, which can easily cover trees if left uncontrolled. Weeds also have various effects on tree performance, referred to as interference, including reduced efficacy of low volume irrigation systems, interception of soil-applied pesticides, lowered grove temperatures during freeze conditions and some yet to be clearly defined effects on insect and mite populations, disease incidence, and mammal activity.

3.6g. Pollination and ripening of citrus Fruits

Fragrant white flowers are borne on one-year-old wood from December to February. Warmth and humidity encourage good flowering. Flowers are bisexual, sweet-scented (fragrance can felt between 2 and 20 metres away from the plant) and self-pollinating, so don't require artificial pollination. Fruits take almost a year to develop fully. As the fruits ripen, it develops increasing sweatness. The younger plants produce smaller fruits. Some cultivars of tangerines ripen by winter. Some, such as the grapefruit, may take up to eighteen months to ripen. When the environment factors change citrus crops react as follow:

- ***Flowers fall before fruits- set*** *is caused by* dry roots or very low humidity.

- ***Poor flower formation/failure*** *is caused by* poor light, poor nutrition, erratic watering or cold.
- ***Leaf yellowing*** *is by caused* **excessively** wet or dry roots, draughts, cold or poor nutrition.
- ***Leaf fall*** *is caused by* cold, draughts, high winter temperatures or over-watering.

The color of citrus fruits only develops in climates with a (diurnal) cool winter. In tropical regions with no winter, citrus fruits remain green until maturity, hence the name “tropical green orange". Many citrus fruits are picked while still green, and ripened while in transit to supermarkets. Ethylene gas build up within the packaged fruits in transit and assist in the ripenning process.

The lime plant in particular is extremely sensitive to cool conditions, thus it is usually never exposed to cool enough conditions to develop a colour. If they are left in a cool place the fruits will actually change to a yellow color

3.7. HARVESTING and POSTHARVEST HANDLING OF

CITRUS ***Maturity***

All citrus are non-climacteric fruit, meaning that they ripen gradually over weeks or months and are slow to abscise from the tree. External color changes during ripening, but is a function of climate more than ripeness, and a poor indicator of maturity. The best indices of maturity for citrus are internal: oBrix (sugar), acid content, and the oBrix/acid ratio.

Harvesting of Citrus

Citrus is harvested by hand. At this point, there have not been any widely accepted methods of mechanical harvest. The time of harvest is dictated by the market or in some cases by legal maturity standards. Citrus is more forgiving than some other crops in that harvesting can be delayed somewhat and fruit quality is not decreased too much by the extra time on the tree. This varies with variety. However, if fruit are left on the tree too long, quality deteriorates as acid levels decrease and the taste becomes insipid. Other fruit quality problems can also occur. After harvest, citrus can be stored at low (refrigerated) temperatures for several months. This has had important implications in the development of the industry since the beginning of the twentieth century.
After harvest, commercial citrus is transported to a packing house. There, the fruit is washed, sorted and graded, treated with fungicides and waxes, and packed. In some cases, ethylene gas treatment is used for degreening. Citrus packing today is highly automated in some ways, with various sensors and other devices routing and sorting the fruit through a complexly routed pathway of conveyor belts, and bins. However, there is still a substantial amount of hand labour necessary for sorting, grading, and movement.

After citrus is packed, it is transported away from the packing house and enters wholesale and retail market channels.
In addition to commercial production, citrus is widely grown for personal use in back-yard orchards, roadsides, and in small subsistence plots. Growing citrus for this use is extremely variable. Trees may be grown from seed, grafted by the grower, purchased from commercial sources, and so forth. Varietal selection is based on personal preference rather than economic factors. Citrus is also prized for its ornamental value and often serves a decorative purpose as well. There are some cultivars that are grown strictly as ornamentals, such as some variegated types and the Buddha's Hand citron.

Citrus is hand harvested, whether processed or marketed fresh. Mechanical harvesters have been used for processed fruit in Florida and are increasing in popularity due to high labor costs and lack of labor availability.

Postharvest Handling

For fresh fruit, standard packing line operations are used (in order): dumping, culling, washing, brushing, waxing, drying, grading (human), sizing, and boxing. For processed fruit, growers are paid for "lbs -solids" or sugar content, based on juice analysis. Harvested fruits are culled for rot, and remaining fruit is washed prior to juicing. Juice is extracted by inserting a cylindrical strainer in the center of the fruit and compressing the fruit hydraulically. Extracted juice contains some pulp and oils, which are separated from the juice by centrifugation and screening. Juice is pooled into lots of various colors and sugar levels; some mixing is done to produce uniform product. Sales of frozen concentrate have been outpaced by single-strength juice products in recent years, due to the superior flavor of the latter.

Storage

Citrus may be stored for periods of up to 1-2 months at low temperatures (32-40°F). Chilling injury is common in grapefruit, lemons, and limes when stored below 50°F, but rare in oranges and tangerines. A unique aspect of citrus is the ability to store fruit on the tree. Fruit may reach minimum maturity standards in early winter, but since they are nonclimacteric, they ripen slowly and will not soften or abscise for periods up to several months.

Student Self Assessment Exercise3

1. Why is pest and disease control very essential in Citrus management?
2. What is the best method of harvesting oranges and at what stage should the fruits be harvested?
3. How do you effect uniform ripening in citrus?

3.8. **Marketing**

There is perhaps no better illustration of the influence of climate on fruit quality than in citrus. Internal and external quality differs greatly between humid subtropical and Mediterranean climates. Temperature and humidity are the main environmental factors controlling quality. The following changes are easily seen:

- Peels become thicker and have more pebbly or rough texture in Mediterranean climates than in subtropical climates.
- Peel color is best in Mediterranean climates due to cool winters enhancing chlorophyll destruction and fewer pests that blemish the peel.
- Juice content is higher in subtropical than Mediterranean climates.
- Acid content is higher and sugar content generally lower in Mediterranean than subtropical climates, due to warmer temperatures during ripening. Acids break down faster with warm nights, and warmer day temperatures allow greater photosynthesis. Hence, the sugar:acid ratio is higher in Florida, and fruit is said to be richer in flavor.
- Within arid climates, rate of maturation is faster in hot, desert areas of California and Arizona than in cool, coastal areas.
- On-tree storage is generally better in Mediterranean than subtropical climates. ‘Valencia' oranges maintain color and quality well into the summer if left on trees in California, but will regreen if the same is done in Florida.

Total production and consumption of citrus fruit has grown strongly since the 1980s. Current annual worldwide citrus production is estimated at over 105 million tons, with more than half of this being oranges. According to the United Nations Conference on Trade and Development (UNCTAD), the rise in citrus production is mainly due to the increase in cultivation areas, improvements in transportation and packaging, rising incomes and consumer preference for healthy foods.

This trend is projected to change from 2000 to 2010 since the high production levels have slowed the rate of new plantings.

Citrus fruits are the highest value fruit crop in terms of international trade. There are two main markets for citrus fruit:

- the fresh fruit market
- the processed citrus fruits market (mainly orange juice)

. After fruit enter the plant, they are washed, juiced with a press or extractor, and strained to remove peel and rag. The juice then goes to the finisher, where excess pulp and essential oils are removed from the juice. It is then concentrated by an evaporator. The bulk concentrate is stored in tank farms and transported in refrigerated trucks, train cars, or ships. The bulk concentrate is packaged into consumer-or industrial-sized containers. Frozen concentrate orange juice is sometimes reconstituted into "single strength orange juice." This is also produced directly without first being concentrated. Processing has little effect on the nutritional value of orange juice, but there is generally a loss of palatability. Grapefruit juice and to a lesser extent lemons, limes, and mandarins are processed similarly. These products are sometimes used to blend with other types of fruit juice or for the production of frozen confections. By-products of processing include essential oils and pulp. The latter is used for cattle feed. Other processed products of citrus include canned segments, segments in juice, pectin, jellies, and jams. Peel products are used for animal feed, marmalade, and shaved peel.

Most citrus production is accounted for by oranges, but significant quantities of grapefruits, pomeloes, lemons and limes are also grown.

3.9. Uses

3.9.1. Oranges and orange juice

About a third of citrus fruit production goes for processing: more than 80% of this is for orange juice production. Demand for fresh and processed oranges continues to rise in excess of production, especially in developed countries.

The two main players are Florida in the United States and São Paulo in Brazil. Production of orange juice between these two makes up roughly 85 percent of the world market. Brazil exports 99 percent of its production, 90 percent of Florida’s production is consumed in the US while 100 percent of Nigeria production is consumed internally..

Orange juice is traded internationally in the form of frozen concentrated orange juice to reduce the volume used, so that storage and transportation costs are lower.

i. Culinary

Many citrus fruits, such as oranges, tangerines, grapefruits, and clementines, are generally eaten fresh. They are typically peeled and can be easily split into segments. Grapefruit is more commonly halved and eaten out of the skin with a utensil. Orange and grapefruit juices are also very popular breakfast beverages. More astringent citrus, such as lemons and limes are generally not eaten on their own. Though 'Meyer' "Lemon" can be eaten 'out of hand', it is both sweet and sour. Lemonade or limeade are popular beverages prepared by diluting the juices of these fruits and adding sugar. Lemons and limes are also used as garnishes or in cooked dishes. Their juice is used as an ingredient in a variety of dishes, it can commonly be found in salad dressings and squeezed over cooked meat or vegetables. A variety of flavours can be derived from different parts and treatments of citrus fruits. The rind and oil of the fruit is generally very bitter, especially when cooked. The fruit pulp can vary from sweet and tart to extremely sour. Marmalade, a condiment derived from cooked orange and lemon, can be especially bitter. Lemon or lime is commonly used as a garnish for water, soft drinks, or cocktails. Citrus juices, rinds, or slices are used in a variety of mixed drinks. The skin of some citrus fruits, known as zest, is used as a spice in cooking. The zest of a citrus fruit, preferably lemon or an orange, can also be soaked in water in a coffee filter, and taken as drink.

ii. Medical

Citrus juice also has medical uses - the lemon juice is used to relieve the pain of bee stings. The orange is also used in Vitamin C pills, which prevents scurvy. Scurvy is caused by Vitamin C deficiency, and can be prevented by having 10 milligrams of Vitamin C a day. An early sign of scurvy is fatigue. If ignored, later symptoms are bleeding and bruising easily.

Table 1.. Nutritive value of citrus fruits and raw juices

Fruit	Grapefruit	Grapefruit juice	Lemon	Lemon juice	Lime juice	Orange	Orange juice	Tangerine
Serving	½ grapefruit, raw, without peel, membrane, and seeds (3.75 in. diam., 1 lb. 1 oz., whole, with refuse)	Raw, 1 cup	1 lemon, raw, without peel and seeds (about 4 per lb. with peel and seeds)	Raw, 1 cup	Raw, 1 cup	1 orange, whole, raw, without peel and seeds (2.625 in. diam., about 2.5 per lb., with peel and seeds)	Raw, 1 cup	1 tangerine, raw, without peel and seeds (2.375 in. diam., about 4 per lb. with peel and seeds)
Grams	120	247	58	244	246	131	248	84
Water, %	91	90	89	91	90	87	88	88
Food energy, kcal	40	95	15	60	65	60	110	35
Carbohydrate, g	10	23	5	21	22	15	26	9
Protein, g	1	1	1	1	1	1	2	1
Fat, g	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Fatty acids, saturated, g	Tr	Tr	Tr	Tr	Tr	Tr	0.1	Tr
Fatty acids, mono-unsaturated, g	Tr	Tr	Tr	Tr	Tr	Tr	0.1	Tr
Fatty acids, poly-unsaturated, g	Tr	0.1	0.1	Tr	0.1	Tr	0.1	Tr
Cholesterol, mg	0	0	0	0	0	0	0	0
Calcium, mg	14	22	15	17	22	52	27	12
Phosphorus, mg	10	37	9	15	17	18	42	8
Iron, mg	0.1	0.5	0.3	0.1	0.1	0.1	0.5	0.1
Potassium, mg	167	400	80	303	268	237	496	132

Fruit	Grapefruit	Grapefruit juice	Lemon	Lemon juice	Lime juice	Orange	Orange juice	Tangerine
Sodium, mg	Tr	2	1	2	2	Tr	2	1
Vitamin A, IU	10	20	20	50	20	270	500	770
Thiamin, mg	0.04	0.10	0.02	0.07	0.05	0.11	0.22	0.09
Riboflavin, mg	0.02	0.05	0.01	0.02	0.02	0.05	0.07	0.02
Niacin, mg	0.3	0.5	0.1	0.2	0.2	0.4	1.0	0.1
Ascorbic acid, mg	41	94	31	112	72	70	124	26

SOURCE:Gebhardt and Matthews, pp. 20–26.

In addition to processing for juice and its associated by-products, there are minor industrial uses of citrus. Although essential oils are extracted as part of juice processing, in some instances trees are grown specifically for the production of these oils. The center of this industry is Calabria, Italy, and the main variety used is Bergamot, of which there are various selections. Citrus is also used to produce pesticides, cleaning products, and hair care products.

iii. Health Benefits and Traditional Usage

In addition to the nutritional value and vitamin content of citrus, there are certain health benefits associated with some of the secondary products. For instance, various limonoid compounds, particularly D-limonene, have been shown to reduce tumorgenesis under experimental conditions. Carotenoids, such as lycopene, have been associated with decreased risks of heart attacks as well as general antioxidant activity. The high pectin content of some types of citrus contributes to soluble fiber consumption, which has been linked to increased cardiovascular health and reduced risk of certain types of cancer. As might be expected with a crop utilized by humans for a number of millennia, these health benefits are reflected in the traditional use of citrus by indigenous people. Many of these uses are focused around the center of origin in China and India. However, health-related use of citrus has also been reported from traditional peoples in such areas as Fiji, Guatemala, and Chile. Citrus has been reported to be used for treatment of various illnesses, to reduce vomiting or diarrhea, and for regulating fertility. The sour orange has been reported to be used in voodoo ceremonies in Haiti.
Many of these uses are also associated with other plants in the subfamily Aurantiodeae. The kumquats have been mentioned already as being edible, but some other types of fruits are sometimes eaten by traditional peoples. Of particular note are the use of the leaves of Murraya koenigii as condiments and in the preparation of curry (the common name for this tree is curry leaf) and the use of Aegle marmelos ("Bael") for the preparation of teas. Other traditional uses reflect some of the properties suggested by the industrial use of citrus: insecticides and shampoos. As more insight into ethnopharmacology and secondary plant products is gained, it is possible that industrial

use of citrus may increase, and probably some of these uses will reflect traditional uses of these plants.

Stuednt Self Assessment Execise 4

1. What are the uses of citrus?
2. Compare and contrast the nutritive value of raw juice and fresh citrus fruits.

4.0. CONCLUSION

Citrus is a common term and genus of flowering plants in the family Rutaceae, originating in tropical and subtropical southeast Asia. The plants are large shrubs or small trees , reaching 5–15 m tall, with spiny shoots and alternately arranged evergreen leaves with an entire margin. The flowers are solitary or in small corymbs, each flower 2–4 cm diameter, with five (rarely four) white petals and numerous stamens; they are often very strongly scented. The fruit is a hesperidium, a specialised berry, globose to elongated, 4– 30 cm long and 4–20 cm diameter, with a leathery rind surrounding segments or "liths" filled with pulp vesicles.

The World Citrus Industry

Citrus is grown throughout the world in the "Citrus Belt" between approximately 40°N and 40°S latitude. Within this belt there are tropical, semitropical, and subtropical climates, and it is possible to grow citrus in all three. Although there is some influence of scion and rootstock in cold susceptibility, frost is the main climatic limitation to citrus production. At the northern and southern margins of production (Corsica, Japan, New Zealand), the mildness and shortness of the summers is a secondary constraint. In areas that have a Mediterranean climate, which has a long, dry summer, supplemental irrigation is necessary.

The majority of commercial production is in the subtropical regions between 20o and 40o northern and southern latitudes. In the tropics, flowering is often erratic , and fruit may mature throughout the year. Although fruit size is generally large in the tropics, fruit quality is usually lower. Fruit color is generally less intense and acids may be too low for good eating quality. Yellow-fleshed and high-acid types (lemons and limes) are not as affected by these factors and are widely grown in the tropics, as are pummelos. Although there is less large-scale commercial production in the tropics, citrus is important locally and when grown for personal consumption.

In the subtropical areas, the yearly cycle of flowering and fruit development, as well as vegetative growth, is more tightly regulated by climatic conditions. This results in a crop that matures at the same time and has higher fruit quality. Semitropical conditions are intermediate between tropical and subtropical conditions. These areas, which include such major production areas as Brazil and Florida, produce high yields of citrus that is of acceptable quality. Fruit quality for fresh consumption is lower than in subtropical climates such as California and Spain, but most fruit produced in Brazil and Florida is grown for processing, which has slightly lower-quality standards.

Within these climatic types, there are some variations in types of citrus successfully produced. For example, varieties that are colored by lycopene, such as the pigmented grapefruits, do well in these semitropical climates, while those colored by anthocyanins (blood oranges) do better in areas with lower winter temperatures. In marginal areas such as Japan and New Zealand, early maturing varieties such as Satsumas are grown.

Brazil has been the largest producer of citrus for some time, followed by the United States. Other important producing countries include China, India, Spain, Morocco, Argentina, Italy, South Africa, Australia, Mexico, and Egypt. The relative ranking of these countries varies from year to year. Recently, there has been much interest in large-scale production in countries such as China and India, where the climate is suitable and labor and infrastructure inexpensive. There are many niches within the world citrus production. For instance, in the United States, Florida produces a large proportion of the sweet oranges, the majority of which are used in processing. California produces a higher quality sweet orange, with emphasis on navel varieties, which is eaten fresh and largely exported. Countries such as Spain and Morocco produce large quantities of mandarins for export to the United Kingdom and northern Europe. Some of the Southern Hemisphere countries export to major Northern Hemisphere producers during the off-season.

As with any industry, there have been changes over the years. In the last decades of the twentieth century, the trend has been toward increased global trade and yearlong availability in most major markets. Processed products have grown in importance. In fresh fruit, the trend has been toward easy-peeling, seedless mandarins and sweet oranges. In grapefruit, the pigmented varieties are becoming predominant.

Production. Citrus is produced in slightly different ways in different areas. Commercial production is more uniform throughout the world than is local or personal production, but there are some differences here as well. Many of the differences are in the nature of farming inputs rather than the production of trees

Citrus requires relatively little cultural manipulation compared to crops such as grapes and deciduous trees, which require pruning and extensive training. In some areas, however, such as the Mediterranean basin, mandarins and sweet orange may receive somewhat more manipulation than in areas such as California. Lemons grow vigorously upright and require more frequent topping. Irrigation and fertilization are necessary.

Uses of Citrus Fruits

Citrus is consumed fresh, juiced, and processed. The most nutritious ways of serving citrus are as fresh fruit or fresh-squeezed juice. Citrus fruits are well known for their vitamin C content, but are also good sources of vitamin A, folic acid, and dietary fiber. Fresh citrus fruits can be stored for several days at room temperature or for several weeks in the refrigerator. Fresh-squeezed juice should be stored in the refrigerator and is stable at refrigerator temperatures for several weeks from a nutritional standpoint. However, there is often a loss of quality when fresh-squeezed juice is stored. This is especially true of navel orange juice.

Processing is an important part of the citrus market worldwide. Where production is oriented toward producing citrus for processing, different varieties and to some extent different cultural practices are employed than when grown for fresh market. Criteria for harvest and quality standards are also different. Internal quality is paramount for processing citrus, whereas external appearance counts for more in fresh market fruit. The most important use of citrus for processing is the production of frozen concentrated orange juice. The bulk concentrate is stored in farm tanks and transported in refrigerated trucks, train cars, or ships. The bulk concentrate is packaged into consumer-or industrial-sized containers. Processing has little effect on the nutritional value of orange juice, but there is generally a loss of palatability.

Citrus fruits are high in vitamin C, flavonoids, acids and volatile oils. They contain coumarins such as bergapten which make the skin sensitive to sunlight. Many citrus species and varieties are not cultivated for producing fresh edible fruit but are sour and used for other purposes: oil is extracted from freshly open flowers (e.g. neroli oil from Bergamot) and used in perfumes. Leaves are used for flavouring foods and for medicinal infusions. Essential oils are extracted from leaves and unripe or ripe fruit and used in flavourings and for scenting toiletry products. The skin of fruit is used for making marmalade.

5.0. SUMMARY

In this unit, history, origin and spread of citrus was treated. Thereafter, the botany of citrus and related species were discussed. Because of the polyembronic nature and the ease of intercrossing among the citrus species, the four (4) ancestral species from which the various very commonly found market available species of today derived, were described .Agroclimatic and edaphic requirements for the cultivation and production of citrus were treated. Nursery and field operations in the production and management of citrus plantations/orchards were carefully treated into details. Harvesting and processing of citrus were also treated. Storage, trade and usage of citrus and its bye-products were equally discussed.

5.0. TUTOR MARKED ASSIGNMENT

1. What are the agroclimatic and edaphic requirements for the cultivation of citrus?
2. Enumerate and discuss the nursery and field operations in the management of citrus plantation.
3. Discuss pest control measures and disease control measures in citrus orchards.
4. Discuss the harvesting of citrus fruits in relation to the marketing of the fruits.

5. Identify some of the uses of citrus and its bye products.

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MODULE 4: JUICE/BEVERAGE CROPS

Unit 8: CASHEW

Contents

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Unit 8: CASHEW

8.0 .INTRODUCTION

The **Cashew** (*Anacardium occidentale*; syn. *Anacardium curatellifolium* A.St.-Hil.) is a tree in the flowering plant family Anacardiaceae. The plant is native to northeastern Brazil, where it is called by its Portuguese name *Caju* (the fruit) or *Cajueiro* (the tree). It is now widely grown in tropical climates for its cashew "nuts" (see below) and cashew apples.

It is a small evergreen tree growing to 10-12 m tall, with a short, often irregularly-shaped trunk. The leaves are spirally arranged, leathery textured, elliptic to obovate, 4 to 22 cm long and 2 to 15 cm broad, with a smooth margin. The flowers are produced in a panicle or corymb up to 26 cm long, each flower small, pale green at first then turning reddish, with five slender, acute petals 7 to 15 mm long.

What appears to be the fruit of the cashew tree is an oval or pear-shaped accessory fruit or false fruit that develops from the receptacle of the cashew flower. Called the **cashew**

apple, better known in Central America as "**marañón**", it ripens into a yellow and/or red structure about 5–11 cm long.

The true fruit of the cashew tree is a kidney or boxing-glove shaped drupe that grows at the end of the pseudofruit. Actually, the drupe develops first on the tree, and then the peduncle expands into the pseudofruit. Within the true fruit is a single seed, the **cashew nut**. Although a nut in the culinary sense, in the botanical sense the fruit of the cashew is a seed. However, the true fruit is classified as a nut by some botanists. The seed is surrounded by a double shell containing a caustic phenolic resin, urushiol, a potent skin irritant toxin (also found in the related poison-ivy). Some people are allergic to cashews, but cashews are a less frequent allergen than some other nuts.

Other vernacular names include cajueiro, cashu, casho, acajuiba, caju, acajou, acaju, acajaiba, alcayoiba, anacarde, anacardier, anacardo, cacajuil, cajou, gajus, jocote maranon, maranon, merey, noix d'acajou, pomme cajou, pomme, jambu, jambu golok, jambu mete, jambu monyet, jambu terong, kasoy. In the Antilles, specifically Puerto Rico, it is known as pajuil and the pseudofruit is the main used part as raw fruit. In this unit, you will study the Cashew as an economic crop cultivated in plantations.

9.0 UNIT OBJECTIVES

At the end of the unit, you are expected to:

- Identify and describe cashew as a crop.
- Enumerate the agronomic requirements for cashew cultivation.
- Describe nursery and field operations in the management of cashew production
- Describe the harvesting and processing of cashew nuts and fruits.
- Enumerate some of the uses of cashew fruits, nuts and tree.

10.0.COURSE CONTENT

3.1. Origin and Spread of Cashew

The first western people who sighted the cashew tree was by the Portuguese. They invaded Brazil in the 1500's. Portuguese seamen brought the seeds of the cashew nut tree from Brazil to be planted by the early settlers along the east coast of Africa. The trees took root and thrived. It was not long before cashew trees were growing wild along the entire coast of Mozambique. They spread to Kenya and Tanzania.

Uncared for and uncultivated, the ripe nuts were primarily harvested by the African natives. Later, they were sold to the Portuguese traders who in turn disposed of them to merchants who then shipped the nuts to India where they were shelled.

Eventually, India grew their own cashew tree and the Kerala State (India) Cashew Association is now the largest exporter of cashews in the world. Forteleza, Brazil, ships the second largest quantity of cashews and the two areas represent over 80 percent of the world supply which is around 4 million cases (50 pounds per case). Africa is a distant third. The India crop harvests in May and the Brazilian crop harvests in October.

3.2. Taxonomy of the Cashew Tree

Kingdom: *Plantae*
Division: *Magnoliophyta*
Class: *Magnoliopsida*
Order: *Sapindales*
Family: *Anacardiaceae*
Genus: *Anacardium*
Species: ***A. occidentale***

The Cashew tree, known by the Latin name *Anacardium occidentale*, is a member of the Anacardiaceae floral family, which includes the mango tree, pistachio tree, poison ivy and poison oak. The Anacardiaceae family contains 73 genera and 600 species. *Anacardium* contains eight species which are all native to South America.

The cashew tree is a small to medium tree, generally single-trunked and spreading in habit, up to 40feet in height but generally 10-20feet in cultivation. In older trees, spread may be greater than height, with lower limbs bending to touch the ground. Leaves are thick, prominently veined, and oval to spatulate in shape, with blunt tips and entire margins. New foliage contains reddish pigment.

Flowering for the cashew tree is similar to the close relative mango tree: both male and perfect flowers are born in the same inflorescence (polygamous). Individual flowers are 1/4" across, with crimson petals, often striped longitudinally and reflexed. They are borne terminally on panicles, generally at the beginning of the dry season. Flowering may occur over several weeks, and it is not uncommon to have ripening fruit and flowers on the tree at the same time.

Trees are at least partially self- fruitful, as lone trees can bear many fruit. One study of pollination biology showed no difference in pollen tube growth between self and cross pollinated flowers, yet final yield was higher when cross pollinated. In practice, cashews are often grown from seed, and cross pollination in orchards must occur to a high degree. Another study showed no indication of self-incompatibility, but a low percentage of fruit set (1-18%). Fruit set is highest in flowers that open first, and suggests some type of apical dominance with respect to fruit set, as found in the close relative the pistachio. Fruit set is similar for female and perfect flowers. Various insects, even flies and ants provide pollination.

The true botanical fruit is a nut, about 1" long, shaped like a small boxing glove, hanging below a fleshy, swollen peduncle called the cashew apple or pseudo-fruit. The cashew apple resembles a pear in shape and size, is juicy, fibrous, and astringent tasting. It has thin skin of either yellow or light red color, but yellow flesh. Fruit are borne singly or in small clusters, and mature in 60-90 days. The nut develops first, followed by the rapid swelling of the cashew apple in the last few weeks.

3.3. Agro-Climatic and Edaphic Requirements for Cashew Trees

3.3.1. Climate

It requires a warm humid climate, with a minimum of 600mm rainfall, but well distributed rainfall is more important. Cashew thrives under a wide range of temperatures from 15º to 40º degrees Celsious. Cashew does not grow well in areas subject to frost and cold waves. It is also drought resistant.

3.3.2. Soil requirements

The cashew is a strong plant that is renowned for growing in soils, especially sandy soils that are generally unsuitable for other fruit trees. For the best production, deep well-drained sandy or sandy-loam soil is recommended. Cashew trees will not grow in poorly-drained soils. . Hilly slopes up to an elevation of 700 m above mean scale level can also be utilized for cashew cultivation.

Student Self Assessment Exercise 1

1. Distinguish between the types of cashew grown in Nigeria
2. Describe the climatic requirements for cashew production.

3.4. Nursery Management in Cashew

3.4.1. Selecting and Planting Cashew seeds

Fresh seeds that sink in water are planted in an upright position in a planting bag containing a loose, sterilised soil mixture. Three to four seeds can be planted directly in the planting hole. The weakest ones are thinned out later and the strongest left to develop further. The seedlings are very susceptible to Phytophthora root rot. The plant bags should be 350 to 400 mm deep, as the tap-root grows very fast and bends around as soon as it touches the bottom.

3.4.2. Seedlings

Cashew seedlings are grown under shade (45 %) and hardened off before planting in the orchard. It is very important not to disturb the root system during planting. Young trees should be supported for the first 2 to 3 years so that wind will not blow the plants over.

3.4.3. Establishment through asexual Methods

Until recently, cashew was propagated only through seeds. Cashew being a cross pollinated crop, there is a wide variation in nut and apple characteristics as well as yield in seedling progenies. It also takes about 5-6 years for first bearing when propagated through seeds and hence should be discouraged. Vegetatively propagated planting material is necessary to obtain higher and early yield. Many techniques of vegetative propagation like grafting, budding and layering have been tried in cashew with varied degrees of success. Amongst different vegetative methods of propogation tried so far, soft wood grafting has been found suitable giving 60 % success.

Soft wood grafting

Following steps should be followed to obtain better success with soft wood grafting in cashew.

(a) **Raising seedlings for rootstock**: Collect uniform cashew seednuts during the peak period of harvest i.e. February to April, preferably from high yielding uniform cashew trees.Select the seeds with high specific gravity (1.025 to 1.05) to get quick germination and to obtain vigorous seedlings with healthy shoots. In order to identify the weighty seed nuts, immerse the seed nuts in 10% saline solution, reject the floating nuts and select the nuts which are settling at the bottom for sowing.

Prepare polythene bags of 30 cm x 20 cm size of 300 gauge thickness and punch 15-20 holes on the bag. Fill the bag with potting mixture 2:1:1 (soil: sand: compost) upto the brim leaving I" of gap at top. Add 5 g of Mussorie Phosphate per bag, which can be mixed with the soil mixture at the time of preparation.

Sow the seed nuts, stalk end up, 2 to 2.5 cm deep in the centre of the filled polythene bag. To hasten the process of germination, the seed nuts can be soaked overnight in water before sowing. Water the bag immediately after sowing and everyday in the morning. Seednuts usually germinate within 15-20 days after sowing. The seedlings will be ready for soft wood grafting in about 30-40 -days after germination. Select healthy vigorous seedlings having tender flush, for grafting (with four developed leaves). Spray insecticides like Nuvacron, Rogor, Endosulfan and Malathion at the rate of 1.5 ml/litre of water to control leaf damaging insects.

(b) **Selection of scion**: Scion should be selected from high yielding mother trees preferably from the trees of proven performance. The selected scion shoot should be 8-10 cm long, straight, round, of pencil thickness and brown coloured having dormant plumpy terminal bud. The selected scion should be precured by clipping off leaf blades, leaving behind petiole stubs, about a week prior to its detachment from mother plant for grafting.

(c) **Grafting procedure**: Remove the leaves from the top portion of the seedlings, keeping one or two mature leaves at the bottom. Give the transverse cut at the top of the seedling and remove the terminal shoot and make a cleft of 3-4 cm deep in the middle of the decapited stem of the' seedling by giving a longitudinal vertical cut, on the soft portion of stem.

Mend the scion into a wedge shape of 3-5 cm long by chopping off the bark and little wood from two opposite sides, taking care to retain some bark on remaining two sides. Insert the wedge of the scion into the cleft of the stock seedling, taking care that the cambium layers of the stock and scion come in perfect contact with each other. Cambium is a thin layer of cells in between the bark and the wood seen as a line on close observation. Tie the graft joint firmly with 1.5 cm wide and 30cm long polythene strip of 100 gauge thickness.

After-care of the graft

Keep the newly grafted plants under shade and humid conditions. Sprouting of the terminal bud will be seen after about 15-20 days. Water the grafts as and when required depending upon the season and weather conditions. Any sprouts observed on the rootstock portion below the graft joint should be removed at frequent intervals. Remove the polythene strip from the graft joint about 3 months after grafting, to avoid girdling. Shift the grafts from one place to another or just lift the grafts and keep at the same place once in amonth, to prevent them from striking roots into the ground. Inorder to avoid this shifting work, grafts may be kept on polythene sheet (I m wide,1000 gauge). Protect the grafts from pests and diseases as and when they are noticed. Spray endosulfan / Nuvacron @ 1.5 ml/litre of water to control pests at weekly intervals and drench the bags with bavistin (4 gm/litre of water) to control leaf diseases just before grafting and afterwards at 15 days intervals till the grafts are well established and grown.

June to September is ideal period for soft wood grafting recording about 60% success during these months

3.5. Cashew Orchard Establishment and Maintenance

3.5.1. Selection of Site and Land Development

When selecting land for cashew, soils with salinity/alkalinity or waterlogging should be avoided. Soil depth, slope, course texture, soil fertility and water availability seem to impose very little limitations as cashew is a hardy crop. For establishing new plantations, land preparation should begin with the first pre-monsoon rains. Land should be cleared of shrub vegetation before digging pits for planting.

3.5.2. Planting Season

Planting of grafted plants is usually carried out during the monsoon season from July-August both in the west coast as well as in the east coast. Orchards should have pits dug to receive grafted plants well in advance of the main monsoon weather.

3.5.3. Spacing and Planting Systems

A spacing of 7.5m x 7.5m or 8m x 8m is recommended for cashew which gives a tree density of 175 and 156 trees per ha, respectively. High density planting at 4m x 4m giving a tree density of 625 trees per ha in the initial years and subsequently thinning in stages to reach a final spacing of 8m x 8m is also practiced in some areas. This enables higher returns during the initial years and as the canopies grow in volume, alternate trees are removed to achieve the desired final spacing. In level sites however, it would be advantageous to plant cashew at a spacing of 10m x 5m which will give a tree density of 200 trees per ha and at the same time providing sufficient space for growers to plant inter-crops during the initial years of establishment.

3.5.4. Field Planting of Cashew

Pits are usually dug at the onset of the pre-monsoon rains to a size of 60cm x 60cm x 60cm in light to medium soils. If a hard substrate like laterite is present pits may be 1m x 1m to compensate for the lesser depth of soil. It is preferable to dig pits 15-20 days before planting to expose planting holes to direct sunlight which can help remove termites and other harmful insects that can damage young plants, if present. When filling, top soil mixed with compost (5 kg) or poultry manure (2 kg) and 200g of rock phosphate are placed in the pits. Contour planting is usually followed in sloping areas. Standard conservation measures need to be followed on steep lands when establishing cashew plantations.

Young plants are planted in the months of July-August. Most nurseries supply 5-12 month old grafted plants in polybags. At planting, the polythene bag is removed without disturbing the ball of earth and the roots. Care is taken to place the grafted plant in the pits leaving the graft joint at least 5 cm above ground level. Normally the scion is staked to avoid damage from wind and the support should remain up to the third year from planting. Most orchard growers use mulch around the planting hole to suppress weeds and conserve moisture.

i. Planting distance

Planting distances of 8 x 5 m is recommended. The trees grow vigorously in the first 3 years and as soon as the crowns touch each other alternate trees should be removed until the permanent planting distance of 10 to 12 m is reached. Branches hanging on the ground should be removed because they interfere with harvesting. In other parts of the world cashew trees bear well, in spite of the little attention devoted to the orchards.

Growth and production of cashew trees can be enhanced by establishing clonal orchards, and improving fertilising and irrigation practices

ii. Grafting

Two grafting techniques, namely side grafting and wedge grafting are practised with success. Grafting should commence as soon as possible (seedlings of 3-4 months old) and planted out in the orchard to prevent the tap-root from bending.

iii. Flowering to harvest time

Flowering is affected by weather conditions and also varies from tree to tree, but continues for a period of 3 months. High temperatures lead to earlier flowering. Both male and bisexual flowers are borne on one cluster. The flowers are very susceptible to mildew and control thereof on the leaves and flowers is a prerequisite for good production.

Pollination is mostly by insects. After pollination it takes 6 to 8 weeks for the fruit to develop. The nut develops first while the apple develops and enlarges only 2 weeks before fruit fall. Nuts should be harvested as soon as possible, especially under wet conditions and should be dried before storage.

iv. Irrigation

Irrigation is important during establishment of young trees because it doubles the growth tempo of young trees in a dry season. Due to the deep root system the trees can survive several months without irrigation. Mature trees should receive 1,800 litres of water per tree every 2 weeks.

vi. Application of Manures and Fertilizer

Application of 10-15 kg of farmyard manure or compost annually is generally recommended for cashew. In addition, the current fertilizer recommendation is 500g N (1.1 kg urea), 125g P_2O_5(625g rock phosphate) and 125g K_2O (208g muriate of potash) per tree per year. This has increased production in the All India cashew trials carried out at the research centers. These trials also showed that the cashew responds well to increased N applications up to 750g. Since local NPK fertilizer mixtures do not deliver the required nutrients, application of straight fertilizer is recommended.

Fertilizer is applied annually at the end of the rainy season into a shallow trench at the drip line of trees. It is also recommended that fertilizer be applied in split doses during pre-monsoon (May-June) and post-monsoon (September-October) periods to assure better uptake of nutrients. If a single application is done, the post-monsoon period is more suitable when ground moisture is adequate. One third the recommended dose is applied in the first year, two third the dose in the second year and the full dose thereafter (Table 3).

Recommended Doses of NPK Fertilizer for Cashew (g/plant)

Year	Urea (gm)	Rock Phosphate (gm)	Muriate of Potash
1	330	200	70
2	660	400	140
3 onwards	1,100	625	208

Based on the results of research conducted by the National Coordinated trials, the following methods of fertilizer application are recommended to cashew growers. In the red loamy soils in low rainfall areas such as the east coast, fertilizers have to be applied and raked into the soil along the drip line of tree canopies. In laterite soils and steep lands of the west coast, fertilizer is applied in circular trenches of about 25 cm width along the drip line of trees. Trenches are filled and mulch is applied to ensure soil moisture retention.

vii. **Weeding** and **Weed control**

Grass strips in the inter-rows between the tree lines are ideal to prevent erosion and should be cut regularly.

Until tree canopies shade out the weeds, weeding is essential around the tree trunks up to a radius of about 2 m. The rest of the orchard requires slashing of under growth at least twice a year. The weeding cycles are generally confined to the pre-monsoon and post-monsoon periods to coincide with the fertilizer application.

Alternatively, weedicides may also be applied after slashing, well in advance of the rainy season if the under growth is too dense. The recommendation is to apply Agrodar-96 (2-4 D) at the rate of 4 ml/litre of water followed by Grammoxone at the rate of 5ml/litre of water. Approximately 400 litres of spray is required to cover one ha. The spraying is repeated in the post monsoon season if the weed load is heavy.

viii. Mulching

In low rainfall areas, mulching around the base of trees helps in the control of weeds, retention of moisture and modulation of soil temperature, especially in the hot summer months. This becomes an essential operation as cashew is usually planted in very dry areas where other crops are seldom grown. Most growers utilize the slashed weeds to mulch their orchards.

ix. Training and Pruning

During the initial phase of orchard establishment, shoots arising on the rootstock have to be regularly removed to promote better scion growth, particularly in the first year after planting when scion rejection could occur if rootstock shoots are left unchecked. Training of young trees during the first three years is essential to develop uniform canopies. Training in the juvenile phase comprises of removing basal branches and water shoots. The plants are trained to a single stem and branches are allowed to grow about 0.75-1m from ground level. Deformed branches are also removed during the first few years. Since cashew trees tend to spread their canopies and lodge easily, proper staking is also essential. Trees are kept under check by topping off the main stem at a height of 4-5m from ground level. Orchard operations such as terracing, weeding, fertilizer application, nut collection and stem/root borer infestation control can be easily achieved if trees are properly trained. Pruning should be carried out in August-September at least once in three years when unwanted growth is removed to provide adequate sunlight into the canopy. Since fruiting is only encouraged from the third year, de-blossoming has to be carried out as flower clusters appear during the juvenile phase.

x. Pests and Disease control

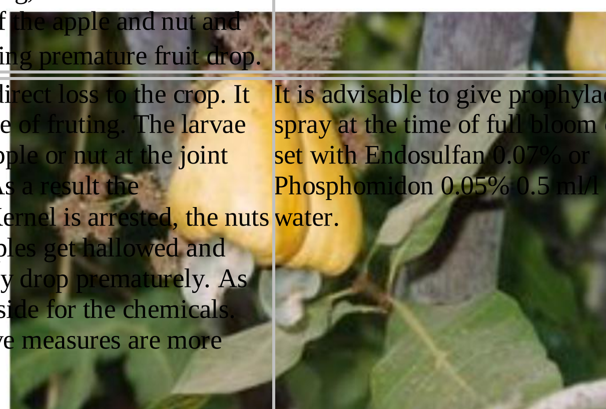
More than 60 species of insect pests have been identified in cashew. The major pests are the tea mosquito, stem/root borer, leaf minor, leaf and blossom webber and flower thrips. No major diseases that cause economic losses have been reported so far in cashew.

For efficient management of the tea mosquito bug (*Helopeltis antonii*), it is important to check the build up of the pest population on the cashew crop as well as on the alternate hosts such as neem, drumstick, cocoa, guava etc. Tea mosquito bugs can be effectively controlled by three sprays at flushing, flowering and fruiting stages with endosulfan or monocrotophos (0.05 %) for the first and second sprays and carbaryl (0.15 %) for the third spray. In case of severe infestation, it may sometimes lead to die-back caused by a secondary infection of *Botrydiplodia theobromae.* In such instances it will require pruning of the diseased shoots and swabbing of the cut surfaces with 10 % Bordeaux paste and spraying the trees with a 1 % solution of Bordeaux mixture.

The stem and root borer (*Plocaecderus ferrugineus* L.), is capable of killing cashew trees. In severe cases of injury by this pest, gummosis of the stem and yellowing followed by drying of leaves can occur. The effective control measure is to remove immature stages of the pest and swabbing the trunk and exposed roots with carbaryl (0.2 %) or neem oil (5 %) and application of Sevidol 8G (75g/tree) into the basin around the tree. Prophylactic treatment of swabbing the trunk up to one meter height with coal tar and kerosene in the ratio of 1:2 twice a year during March and November could also give effective control. The spray schedule indicated for tea mosquito bug will also be effective against the control of other foliage and inflorescence pests.

Name of the Pests/Diseases	Symptoms	Control measures
PESTS Stem and root borer (Kandamu Mariyu Vera Toluchu Purugu) Plocaederus Ferrugineus L.	This pest is common in old and neglected plantations. It occurs throughout the year, but more prevalent during the rainy season. The adult lays eggs in crevices and cracks of bark on the trunk. The hatched grubs bore into the bark. As a result the vascular tissues are damaged, the ascent of the plant sap is arrested, leaves turn yellow and are shed and finally the tree dies. The grubs pupates in a calcareous cocon in the soil. The symptoms of infestation include the presence of small holes in the collar region, gummosis, extrusion.	After identifying the infested tree, the bark is peeled, the grubs are removed and destroyed. After the removal of the grubs, the peeled portion of the bark is smeared with Bordeaux paste. As a prophylactic measure, the orchard should be kept clean and the soil around the trunk should be mixed with 5% carbaryl dust before the onset of monsoon rains.
Leaf and Blossom webber (Aaku Mariyu Putha Mudutha purugu) Macalla moncusalis W	This is a major pest in the state, appearing regularly throughout the year particularly at the time of emergence of new flush. Generally young trees suffer more. The adult moth lays eggs at the growing point. The caterpillar on emergence webs the terminal leaves as well as panicles and feeds inside by scrapping the epidermal layers. The pest can be identified by such webs on the plants. As result flowers fail to open and there will be no crop. It also feeds on tender, developing nuts and	Since the pest is out of reach in the webs, it is better, first to disturb the webs, machanically and then spray the chemical. Quinalphos 0.5% or Endosulfan 0.07% 2ml/lt of water.

	apples by scrapping the epidermal nuts and applets by scrapping the epidermal layers, which drop prematurely.	
Leaf minor (Aaku Toluchu Purugu) Acrocerops Syngramma M.	This pest appears regularly at the time of emergence of new flush. The caterpillars mine into the young and developing leaves and cause blisters on the leaves and feed on the tissues.	The pest can controlled by spraying Phosphomidon 0.05% 0.5 ml/l or Fenitrothion 0.05% I ml/l or Endosulfan 0.07% 2ml/l concentration at the time of emergence of new flush.
Shoot and infloresence tip borer (Komma Mariyu Putha Chivaralanu Toluchu Purugu) Chelaria haligramma M.	The pest appears throughout the years, particularly at time of flowering and fruiting. Caterpillar feeds on leaves, tender shoots, inflorescence stalks, apples and nuts, At the time of new flush the caterpillar folds the tender leaves from one margin and feeds inside. Then it enters the tender shoots by feeds a hole at the tip and feeds inside, causing drying of twigs and particles. At fruiting, the larva enters the fruit at the joint of the apple and nut and feeds inside, causing premature fruit drop.	Fenitrothion 0.05% 1 ml/l or Endosulfan 0.07% 1 ml/l when sprayed twice, one at the time of new flush and next at the time of fruiting, effectively control the pest.
Apple and nut borer (Apple Mariyu Kaya Toluchu Purugu) Nephopteryx sp.	This pest causes direct loss to the crop. It appears at the time of fruting. The larvae bore into either apple or nut at the joint and feed inside. As a result the development of Kernel is arrested, the nuts get shrivelled, apples get hallowed and shrivelled and they drop prematurely. As the caterpillars reside for the chemicals. As such preventive measures are more important. **Note:** There are no serious diseases on cashew	It is advisable to give prophylactic spray at the time of full bloom or fruit set with Endosulfan 0.07% or Phosphomidon 0.05% 0.5 ml/l of water.



Root and stem borer infestation is usually controlled with swabbing tree trunks with carbaryl (2 %) or using a coal tar/kerosene suspension (1:2). After pruning of trees, a standard practice is to smear all cut surfaces with Bordeaux mixture paste (10 %) to prevent fungal infections and die-back. A 1 % Bordeaux spray is also administered if the cut surfaces are small.

3.6. Harvesting Of Nuts and Cashew Yields

Bearing commences after the third year of planting and the trees will be in full production by the tenth year whilst the economic life of a tree is about 20 years. The main harvesting season is from February to May. Most farmers harvest their crop before they drop to prevent pilferage. This very often results in poor quality of the kernels.The optimum stage of harvest is when nuts drop to the ground. High quality nuts are obtained when freshly fallen nuts are separated from the cashew

Cashew fruit

apples and sun dried for 2-3 days to bring down the moisture percentage from about 25 percent to below 9 percent. It is very essential to dry the nuts in order to prevent spoilage during storage. The drying process helps to retain flavor and quality of the kernels. When cashew apples are used for processing, harvesting has to be carried out before they drop. A simple test of maturity is to float nuts in water when mature nuts will sink while the immature and unfilled nuts will float. Nuts are usually gathered every week during the harvest season. Cashew apples for the fresh fruit market should be harvested daily. Normally, about 92 % of the trees yield by the third year from planting. The average yield per tree increases from about 2 kg at 3-5 years to 4 kg at 6-10 years and 5-10 kg when trees are 11-15 years of age. Thereafter, trees yield in excess of 10 kg as the trees get older.

3.7. Processing of Cashew: a comparison of two Methods

a. Cashew Processing in Gampaha - Sri Lanka

Introduction

In Sri Lanka, cashew processing is one of the main agricultural enterprises in rural areas. It is usually carried out by small-scale processors. Gampaha, a rural area in Sri Lanka close to Colombo, is famous for its cashew nuts. Most of the families living there are involved in cashew nut processing, and for women it is the main source of income. Women play a very important role in the whole process, from cashew collection to the labour intensive preparation of the cashews. Processing cashew is an extremely skilled task that includes shelling, drying and removing the inner red shell.

In the past, one of the problems faced by the women cashew processors was that cashews are a seasonal crop and the women could not afford to buy huge stocks that could be processed throughout the year. This meant that the women remained dependent on middlemen who sold them cashew nuts which they would then buy back after the processing had been completed. By controlling the market, the middlemen were able to make a much larger profit than the skilled cashew processors.

Before the intervention of the development agency, ITDG (Intermediate Technology Development Group), the small-scale cashew processors had no access to government support programmes or services. However, ITDG started working with the rural women to develop ways of working which produce high quality cashew nuts, they have been able to prove their credit worthiness and crack the export market.

Tray Dryer

The women wanted a dryer that would help them to dry the cashew nuts and improve the quality of their product so that they could sell them direct to the wholesalers and cut out the middlemen.

The dryer has a wooden cabinet which holds six trays made of aluminium/steel with wire meshed bottoms. The stove is fuelled using paddy husk or sawdust. It is placed outside the cabinet and provides the necessary heat for drying. The heat generated by the stove is channelled through a set of tubes situated at the bottom of the cabinet that act as heat exchangers. The air around the tubes is heated and the hot air rises and moves through the trays full of cashew, taking the moisture with it. The excess heat is directed through a pipe that is built outside the cabinet and expelled through a chimney.

Cashews are loaded into all the trays and the heat is gradually increased. The cashews in the tray nearest the bottom of the cabinet dry first and the tray is then removed. The other trays are lowered and a new tray is introduced into the top of the dryer. This means that the cashews are gradually heated and are slowly moved down the dryer to higher temperatures. The temperature of the dryer is usually kept between 70-75ºC and is controlled by altering the amount of fuel on the stove.

These conditions lead to evenly dried ivory coloured cashew nuts that have a good demand in the export markets.

Advantages of the Tray Dryer

- The energy source of the dryer is paddy husk or saw dust which are freely available in rural cashew growing areas. This means that the dryer can be operated in places without electricity.
- The dryer is semi-continuous which means a tray can be removed when the material is dry and a new tray with fresh cashew can be loaded. This improves the output, quality and fuel efficiency.
- The problem of burning the cashews has been overcome by controlling the heat flow and rotating the trays.
- The dryer can be made at small workshops. It provides a low cost operation and the maintenance is easy.

Qualities of a Good Dryer

- It should burn cheap fuel, such as waste materials.
- It should be made from parts available locally.
- It should be easy to operate.
- It should generate an even heat.
- The trays should rotate.

Cashew Processing as a Collective Activity

The women formed a small group for the purpose of conducting cashew processing as a collective activity. They selected a site belonging to one of its members to install the tray dryer and obtained a written lease for two years. Together, the group built a processing unit at the selected site and collectively bore the cost of the building. The processing unit is small and temporary but addresses all the basic requirements.

Intermediate Technology advised in the planning and guidance for building according to the requirements of hygiene. The development group provided the dryer for the women who agreed to pay for it within one year by monthly instalments. They were trained in the operation of the dryer once it had been installed.

b. Processing the Cashew Kernel in India

There are two ways to remove the cashew shell, the inside fluid and the thin brown skin. Washing the raw nut in a water bath and storing it in moist heaps or silos for 12 hours makes the shells brittle as long as they maintain 7% to 10% humidity. The shell will rupture and liberate cardol fluid.

The older method is to roast the whole nut in shallow pans over an open charcoal fire with constant agitation. The process was used in native marketplaces and was dangerous and disagreeable. Shells burst, spurting the caustic fluid and releasing clouds of acrid fumes which blistered the skin. At the same time, the heat caused the caustic fluid to dissipate.

Modern extraction methods are to put the nuts in a large perforated cylinder which rotates at a declining angle above the heat. As the nut travels down through the roasting cylinder, the liquid flows from the shell and is collected in troughs and commercially sold. Some kernels get scorched because they become overheated near the bottom of the pile. These become second and third grades in quality. As the nuts emerge from their journey, they are water sprayed and set aside to cool and dry.

Nut cracking in small batches is done manually by native laborers. They place the nut on a hard flat stone and crack the brittle shell, hitting it with a wooden mallet.

Grading.

This manual cracking results in many broken kernels which bring a lower market price. Cashews are graded on how white they are and how broken the kernel is. There are four colour grades, four styles of break on the kernel and six sizes (or maximum number of kernels per pound).

1 is the whitest kernel and the best
2 is lightly scorched

3 is scorched and dark
4 is extremely dark and not in much demand

We purchase many grades and sizes because our customers have different needs. That's why the price varies as the nuts get larger and whiter. Whole sizes cost more than pieces. We buy the top grades of cashews - only the whitest and highest quality.

Mixed Nuts.
There are very few nut roasting plants. Only four of us exist in the northwestern United States. Each prides themselves on their different nut mixtures. Like a winery or coffee roasting company, we are famous for how our nuts taste. The **mixed nuts** and **nut-fruit mixtures** are signature products of our plant.

Factory Processing of Cashew nuts

At The Nut Factory, the cashew kernel are roasted at 325 degrees Fahrenheit in hot roasting oil for between 5 and 12 minutes. This softens the kernel and gives it a buttery taste. No two batches of cashews roast the same, so it requires skill and careful watching of the exact moment when the nut starts to turn an ivory color. Only by roasting in small batches can we get the perfect roast on each nut.

As the nut starts to go from the white stage to a light ivory color, the nut are removed and drained. The kernels are them cooled on stainless steel tables that hold 250 pounds. As they cool, they become crunchy and sweet, and they slowly turn a rich light brown color. At this stage, the nuts are salted while they are still warm to get the maximum rich taste. Some of the roasted nuts are set aside for unsalted uses.

Cashews nuts are received from many countries and each lot is different.

The Brazilian cashew is the largest, softest and whitest cashew. Some find them sweeter or richer in taste. Health food stores love large, white Brazilian cashews.

Cashews from India are smaller and much crisper. They can be sweet, but they can be bland. Indian cashews are more ivory in color. Cashews from China and Vietnam.are extremely sweet.

Customers love large sizes of the Brazilian cashew Similarly, they love the crispness found in the Indian, African and Vietnamese cashews, even though they are smaller in sizes.

Student Self Assessment Exercise 2

- Which portion of the cashew fruit that is generally required at the:
    - industrial stage

- beverage level

3.9. Uses of the *Cashew Tree* (Traditional and Modern Medicines & Construction)

i. Uses of Cashew Nut

Cashew nut is the most versatile of all nuts. The kernels are rich in nutrients and are put to use in a variety of ways. The kernels are used in cocktail parties, in confectioneries. They are mostly salted. The kernels are low in carbohydrates. The kernels are low in carbohydrates but rich in proteins, fats and vitamins.

The kernel oil is reported to be superior to olive oil and almond oil.

The testa of the kernel is rich in tannins and hence mainly uses in leather industry. It is also used as poultry feed.
The cashew nutshell liquid extracted form the hard shell. It is a by-product of the cashew industry. It is a versatile industrial raw material being used in preparation of resins, varnishes, paints, plastics, insecticides, brake linings, wood preservatives etc. The brightly colored, swollen peduncle of cashew fruits is cashew apple. The apple is fleshy,

cashew fruit juicy and is rich in vitamin C. However, at present most of the produce is not at all utilised. From cashew apple, tasty drinks can be prepared mixing with juice of lime, pineapple, grapes, etc., jam; chutney and pickles can also be prepared out of cashew apple. Liquor can also be prepared.

ii. The ***cashew apple*** is used for its juicy but acidic pulp, which can be eaten raw or used in the production of *jam*, chutney, or various beverages. Depending on local customs, its

juice is also processed and distilled into *liquor* or consumed diluted and sugared as a refreshing drink, *Cajuína*. Ripe cashew apples also make good *caipirinha*. In Goa, India, the cashew apple is the source of juicy pulp used to prepare *fenny*, locally popular distilled liquor. The cashew apple contains much *tannin* and is very perishable. For this reason, in many parts of the world, the false fruit is simply discarded after removal of the cashew nut.

The urushiol must be removed from the dark green nut shells before the seed inside is processed for consumption; this is done by shelling the nuts, a somewhat hazardous process, and exceedingly painful skin rashes (similar to poison-ivy rashes) among processing workers are common. In India urushiol is traditionally used to control tamed elephants by its mahout (rider or keeper). The so-called "raw cashews" available in health food shops have been cooked but not roasted or browned.

Cashew nuts are a common ingredient in *Asian cooking*. They can also be ground into a spread called cashew butter similar to *peanut butter* . Cashews have a very high oil content, and they are used in some other nut butters to add extra oil. Cashews contain 180 calories per ounce (6 calories per gram), 70% of which are from fat.

Cashew nuts

The liquid contained within the shell casing of the cashew, known as Cashew Nut Shell Liquid (CNSL), has a variety of industrial uses which were first developed in the 1930s. CNSL is fractionated in a process similar to the distillation of petroleum, and has two primary end products: solids that are pulverized and used as friction particle for brake linings, and an amber-colored liquid that is aminated to create phenalkamine curing agents and resin modifiers. Phenalkamines are primarily used in epoxy coatings for the marine and flooring markets, as they have intense hydrophobic properties and are capable of remaining chemically active at low temperatures.

iii. Use of Cashew Wood Resin

In terms of wood quality, the cashew tree is known for producing wood with high levels of resin. The resin from the cashew wood is made into a varnish which is known to prevent deteriation ants and other home- invading insects. The leaves, bark, and fruit also contain caustic oil which can cause skin irritations in some people.

In its raw form, the cashew nut is not edible. However through processing, the caustic oil is removed from the cashew nut shell. This caustic oil is referred to as Cashew Nut Shell Liquid (CNSL) and is located in the tissue between the two walls of the nut shell. CNSL has many industrial uses which include automobile and airplane brake fluid, adhesives, paints and varnishes, insecticides, electrical insulation, and anti-microbials. In addition to CNSL, resins and gums from fruit stems or bark is used as a varnish for books, wood, and flooring to protect from ants and other home-invading insects.

iv. Traditional and Modern Medicines made from the Cashew Tree

There are many medicinal uses of cashew leaves , bark, and juice from the cashew apple. In Brazil, cashew bark teas were used to stop diarrhea while the caustic shell oil was used to treat skin infections, warts, intestinal worms, and parasitic larvae beneath the skin.
Teas and fruit juices from the cashew apple and leaves are known to have antimicrobial, anti-inflammatory, astringent, diuretic, hypoglycemic, and other medicinal properties. The active ingredients in the teas and juices are thought to be tannins, anacardic acid, and cardol. Modern uses of shell oil and fruit juice include facial peels and scalp conditioners and shampoos. The cashew apple has also been a long time nutrional supplement as it contains up to 5 times more vitamin C than citrus and strawberries.

4.0. CONCLUSION

Originally spread from Brazil by the Portuguese, the cashew tree is now cultivated in all regions with a sufficiently warm and humid climate.

Cashew is produced in around 32 countries of the world. The world production figures of cashew crop is around 2.7 million tons per annum. The major raw cashew producing countries with their production figures in 2005 (as per the UN's Food and Agriculture Organization) are Vietnam (960,800 tons), Nigeria (594,000), India (460,000 tons), Brazil (147,629 tons) and Indonesia (122,000 tons).

World's total area under the cultivation of cashew is around 35,100 km². India ranks first in area utilized for cashew production, though its yields are relatively low. The world's average yield is 700 pounds per acre (780 kg/hectare) of land.

Collectively, Vietnam, India and Brazil account for more than 90% of all cashew kernel exports. Some varieties of cashews come from Kollam or Quilon in Kerala, South India which alone produces 4,000 tons of cashews per annum. The major trading centers of cashew in India are Palasa, Kollam or Quilon Mangalore and Kochi.

5.0. SUMMARY

- The Cashew (Anacardium occidentale) is a tree in the flowering plant family Anacardiaceae. The plant is native to northeastern Brazil, where it is called by its Portuguese name Caju (the fruit) or Cajueiro (the tree).
- It requires a warm humid climate, with a minimum of 600mm rainfall, but well distributed rainfall is more important. Cashew thrives under a wide range of temperatures from 15 to 40 degrees Celsious
- More than 60 species of insect pests have been identified in cashew. The major pests are the tea mosquito, stem/root borer, leaf minor, leaf and blossom webber and flower thrips.

o . The flowers are produced in a panicle or corymb up to 26 cm long,

o The true fruit of the cashew tree is a kidney or boxing-glove shaped drupe that grows at the end of the pseudo-fruit. Actually, the drupe develops first on the tree, and then the peduncle expands into the pseudo-fruit

- The processing of cashew involves the following steps Preliminary cleaning , Roasting , Shelling and separation , Drying , Peeling
- The oil (referred to commercially as CNSL, cashew nut shell liquid) contains 90% anacardic acid and 10% cardol.
- CNSL has found important commercial usage as the phenolic raw material for the manufacture of certain resins and plastics having unusual electric and frictional properties.

- The cashew tree has been cultivated for food and medicine for 400 years. Cashews have served nutritional, medicinal and wartime needs. More recently, they have been used in the manufacture of adhesives, resins and natural insecticides.
- Cashew nut shell liquid is also used in mouldings, acid-resistant paints, foundry resins, varnishes, enamels and black lacquers for decorating vases, and as insecticides and fungicides. In tropical medicine, CNSL has been used in treating leprosy, elephantiasis, psoriasis, ringworm, warts and corns.
- India is the world's largest cashew producer and exporter. India is the leading cashew supplier to the United States, all of the major European markets, the Middle East, Russia, Eastern Europe, Australia and Japan
- Processed Cashew Exporters are India, Brazil, Mozambique, Tanzania, Kenya Vietnam & Indonesia.
- Business Opportunities are in cashew nut cultivation, collection of nuts, distribution of nuts collected domestically and those imported, processing of raw nuts, collection and marketing of processed nuts.

6.0. TUTOR MARKED ASSIGNMENT

1. Describe the nursery operations required in cashew cultivation.
2. Describe some of the field operations in the area of pests and diseases management in cashew plantation.
3. Discuss the processing of cashew nuts and fruits.
4. Mention some of the uses of cashew nuts and fruits

7.0. References and external links

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UNIT 9: BANANAS AND PLANTAINS

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UNIT 9: BANANAS AND PLANTAINS

1.0. INTRODUCTION

Banana plants are of the *family* ***Musaceae***. They are cultivated primarily for their fruit, and to a lesser extent for the production of fibre and as ornamental plants. Because of their size and structure, banana plants are often mistaken for trees. The main or upright growth is called a *pseudostem*, which for some species can obtain a height of up to 2– 8 m, with leaves of up to 3.5 m in length. Each pseudostem produces a single bunch of bananas, before dying and being replaced by a new pseudostem.

The banana fruit grow in hanging clusters, with up to 20 fruit to a tier (called a *hand*), and 3-20 tiers to a bunch. The total of the hanging clusters is known as a bunch, or commercially as a "banana stem", and can weigh from 30–50 kg. The fruit averages 125 g, of which approximately 75% is water and 25% dry matter content. Each individual fruit (known as a banana or 'finger') has a protective outer layer (a peel or skin) with a fleshy edible inner portion. Typically the fruit has numerous strings (called 'phloem bundles') which run between the skin and the edible portion of the banana, and which are commonly removed individually after the skin is removed. Bananas are a valuable source of Vitamin A, Vitamin B6, Vitamin C, and potassium.

Bananas are grown in 132 countries worldwide, more than any other fruit crop. In popular culture and commerce, "banana" usually refers to soft, sweet "dessert" bananas that are usually eaten raw. The bananas from a group of cultivars with firmer, starchier fruit are generally used in cooking rather than eaten raw. Bananas may also be dried and ground into banana flour. Although the wild species have fruits with numerous large, hard seeds, virtually all bananas have ***seedless fruits***. Bananas are classified either as dessert bananas (meaning they are yellow and fully ripe when eaten) or as green cooking bananas. Almost all export bananas are of the dessert types; however, only about 10-15% of all production is for export, with the **United.States of America (USA**). and **Europian Union (EU)** being the dominant buyers.

2.0. UNIT OBJECTIVES

At the end of this unit, you are expected to :

- Identify a banana plant
- Distinguish between the different types of cultivars of the Musa Spp.
- Discuss the cultivation of bananas
- Identify steps to combat and control diseases in banana plantations.
- Identify some of the uses of banana
- Discuss banana trade.
- Identify some scientific technologies in the improvement of banana cultivars

3.0. UNIT CONTENTS

3.1. BOTANY OF BANANAS AND PLANTAINS

Musa (bananas and plantains)

***Kingdom* -Plantae; *Division*-Magnoliphyta; *Class*-Liliopsida;(Life; *Embryophyta* (plants); Angiospermae (flowering plants); Monocotyledons); *Order*: Zingiberales;** Family**: Musaceae; *Genus*: Musa.**

The domestication of bananas took place in southeastern Asia. Many species of wild bananas still occur in New Guinea, Malaysia, Indonesia and the Philippines. Recent archaeological and palaeoenvironmental evidence at Kuk Swamp in the Western Highlands Province of Papua New Guinea suggests that banana cultivation there goes back to at least 5000 BC, and possibly to 8000 BC. This would make the New Guinean highlands the place where bananas were first domesticated. It is likely that other species of wild bananas were later also domesticated elsewhere in southeastern Asia.

All edible bananas orginate in whole or in part from *Musa acuminata* which is native to the Malaya Peninsula and adjacent regions. In prehistoric times, people selected plants with seedless fruits and since then they have been propagated vegetatively from suckers. Although the majority of bananas are grown by small farmers in tropical countries for local consumption, there are huge commercial operations exporting bananas from tropical regions to rich countries in temperate regions,.

Bananas come in a variety of sizes and colours; most cultivars are yellow when ripe but some are red. The ripe fruit is easily peeled and eaten raw or cooked. Depending upon cultivar and ripeness, the flesh can be starchy to sweet, and firm to mushy. Unripe or "green" bananas and plantains are used in cooking and are the staple starch of many tropical populations.

Most production for local sale is of green cooking bananas and plantains, as ripe dessert bananas are easily damaged while being transported to market. Even when only transported within its country of origin, ripe bananas suffer high rate of damage and loss.

The commercial dessert varieties most commonly eaten in temperate countries (species *Musa acuminata* or the hybrid *Musa x paradisiaca*, a cultigen) are imported in large quantities from the tropics. They are popular in part because being a non-seasonal crop they are available fresh year-round. In global commerce, by far the most important of these banana cultivars is ' Cavendish', which accounts for the vast bulk of bananas exported from the tropics.

Musa acuminata is a species native to the Malay Peninsula and adjacent regions and is thought to have given rise in total or in part to all edible banana varieties. Some of the varieties have arisen as a result of hybridisation between *Musa acuminata* and *Musa balbisiana* the latter of which is found from India eastwards to the tropical Pacific. This hybridisation probably occurred as *Musa acuminata* plants (2*n* genome = AA) were increasingly cultivated over the distributional range of *Musa balbisiana* (2*n* genome = BB). Although the *Musa acuminata* cultivars were sterile because of being seedless, they did produce fertile pollen.

GENOME	VARIETIES
AA	Diploid (2*n* = 22) wild *Musa acuminata*. Human selection in prehistoric times resulted in the production of seedless cultivars. These diploid varieties are still grown in New Guinea.
AAA	Triploid (3*n*) mutants of *Musa acuminata*. Probably arose a number of times in early cultivation of bananas in the Malaysian region. They are more productive, quicker growing and develop larger fruit than the diploid cultivars. Most cultivated bananas are of this triploid type and two important clone varieties have predominated: • **Cavendish**. Named after the family name of the Duke of Devonshire in England who in 1836 managed to get this clone to flower in his greenhouse. The clone came from Southeast Asia, south China and the East Indies and in the 1800's was spread from this region by the British and French to other tropical and subtropical regions, with the notable exception of Central and South America where it took quite a time before it predominated over the Gros Michel clone. It has ultimately become the main clone grown world wide in commercial banana production. Although not shipping as well as the Gros Michel clone, it has the advantages of being resistant to a devastating soil fungus (see below) and also of being more productive. • **Gros Michel**. This clone was originally propagated in gardens of Burma, Thailand, Malaya, Indonesia and Ceylon. From 1825 to 1875 it was introduced to the islands of the West Indies and to some of the Pacific Islands. However, the region that adopted it to the greatest extent was tropical America where it was the main clone grown in the huge banana plantations that were owned and controlled by a U.S. company called the United Fruit Company. Countries with these plantations were effectively controlled by this company and became known as 'banana republics', and the term is now generally used in a derogatory way to refer to small tropical countries that depend on foreign investment. The United Fruit Company developed methods of shipping the bananas to the U.S. quickly before they became overripe. Gros Michel bananas, compared to Cavendish, shipped better because they could take rougher handling when green and could be shipped in whole bunches rather than having to have hands of bananas individually wrapped. Gros Michel predominated in this region until the arrival from the East Indies in about 1893 of a devastating parasitic soil fungus called *Fusarium oxysporum* to which Gros Michel was susceptible and which spread slowly through this region. The approach of the United Fruit Company was to abandon plantations where the fungus had become established (or grow some

	other crop on them) and start new plantations on virgin land. This resulted in the shift of plantations from the Caribbean east coast of America to the Pacific west coast. Another fruit company called the Standard Fruit Company, operating initially from Honduras, solved the fungus problem by growing the non-susceptible Cavendish clone and developing methods of breaking the banana bunches into hands and packing these in cardboard boxes for shipping, thus solving the shipping issue for this particular clone. This method of shipping also has the added benefit of enabling mechanisation (lifting boxes is easier than lifting large ungainly bunches) and speeding up distribution at the country of destination. Eventually, United Fruit Company also started growing the Cavendish variety. After the Second World War there was a strong move towards commercial growing of bananas by independent growers who formed cooperatives which sold to export companies.
AB and AAB	Cultivars with a single *Musa balbisiana* genome are sweet and include the Ladyfinger Banana.
ABB	Yields starchy bananas used in cooking and called **plantains** although this term is sometimes used confusingly for normal bananas.

Despite the huge commercial operations exporting bananas from tropical countries to rich, temperate countries mainly in North America and Europe, it has been estimated that about 85% of all bananas produced, are grown by small farmers for local consumption.

Varieties of bananas and Plantains

3.2.Cultivation

Banana Corms

While the original bananas contained rather large seeds, triploid (and thus seedless) cultivars have been selected for human consumption. These are propagated asexually from offshoots of the plant. The plant is allowed to produce 2 shoots at a time; a larger one for fruiting immediately and a smaller "sucker" or "follower" that will produce fruit in 6–8 months time. The life of a banana plantation is 25 years or longer, during which time the individual stools or planting sites may move slightly from their original positions as lateral rhizome formation dictates. Latin Americans sometimes comment that the plants are "walking" over time.

Cultivated bananas are sterile (*parthenocarpic*), meaning that they do not produce viable seeds. Lacking seeds, another form of propagation is required. This involves removing and transplanting part of the underground stem (called a corm). Usually this is done by carefully removing a sucker (a vertical shoot that develops from the base of the banana pseudostem) with some roots intact. However, small sympodial corms, representing not yet elongated suckers, are hardier to transplant and can be left out of the ground for up to 2 weeks; they require minimal care and can be boxed together for shipment.

.In some countries, bananas are commercially propagated by means of tissue culture. This method is preferred since it ensures disease-free planting material. When using vegetative parts such as suckers for propagation, there is a risk of transmitting diseases (especially the devastating Panama disease).

Student Self Assessment Exercise 1

1. Distinguish between Banana and Plantain.
2. What is the commonest way of propagating banana and why?
3. Why is banana plantation called a ‘moving plantation’?

3.3. Pests and diseases

While in no danger of outright extinction, the most common edible banana cultivar 'Cavendish' (extremely popular in Europe and the Americas) could become unviable for large- scale cultivation in the next 10-20 years. Its predecessor 'Gros Michel', discovered in the 1820s, has already suffered this fate. Like almost all bananas, it lacks genetic diversity, which makes it vulnerable to diseases, which threaten both commercial cultivation and the small-scale subsistence farming. Major diseases include:

i.Panama Disease (Race 1) – fusarium wilt (a soil ***fungus)***. The fungus enters the plants through the roots and moves up with water into the trunk and leaves, producing gels and gums. These plug and cut off the flow of water and nutrients, causing the plant to wilt. Prior to 1960 almost all commercial banana production centered on the cultivar 'Gros Michel', which was highly susceptible to fusarium wilt. The cultivar 'Cavendish' was chosen as a replacement for 'Gros

Michel' because out of the resistant cultivars it was viewed as producing the highest quality fruit. However, more care is required for shipping the 'Cavendish' banana and its quality compared to 'Gros Michel' is debated.

ii.Tropical Race 4 - a reinvigorated strain of Panama Disease first discovered in 1993. This is a virulent form of fusarium wilt that has wiped out 'Cavendish' in several southeast Asian countries. It has yet to reach the Americas; however, soil fungi can easily be carried on boots, clothing, or tools. This is how Tropical Race 4 moves from one plantation to another and is its most likely route into Latin America. The Cavendish cultivar is highly susceptible to TR4, and over time, Cavendish is almost certain to be eliminated from commercial production by this disease. Unfortunately the only known defense to TR4 is genetic resistance.

iii.Black Sigatoka - a fungal leaf spot disease first observed in Fiji in 1963 or 1964. Black Sigatoka (also known as Black Leaf Streak) has spread to banana plantations throughout the tropics due to infected banana leaves being used as packing material. It affects all of the main cultivars of bananas and plantains, impeding photosynthesis by turning parts of their leaves black, and eventually killing the entire leaf. Being starved for energy, fruit production falls by 50% or more, and the bananas that do grow suffer premature ripening, making them unsuitable for export. The fungus has shown ever increasing resistance to fungicidal treatment, with the current expense for treating 1 hectare exceeding US$1000 per year. In addition to the financial expense there is the question of how long such intensive spraying can be justified environmentally. Several resistant cultivars of banana have been developed, but none has yet received wide scale commercial acceptance due to taste and texture issues.

In the past, the banana was a highly sustainable crop with a long plantation life and stable yields year round. However with the arrival of the ***Black Sigatoka fungus***, banana production in eastern Africa has fallen by over 40%. For example during the 1970s, Uganda produced 15 to 20 tonnes of bananas per ha. Today production has fallen to only 6 tonnes per ha.

The situation has started to improve as new disease resistant varieties have been developed such as the FHIA-17 (known in Uganda as the Kabana 3). These new varieties taste different from the traditionally grown banana which has slowed their acceptant by local farmers. However, by adding mulch and animal manure to the soil around the base of the banana plant, these new varieties have substantially increased yields in the areas where they have been tried.

The Rockefeller Foundation has started trials for genetically modified banana plants that are resistant to both Black Sigatoka, and banana weevils. It is developing varieties specifically for smallholder or subsistence farmers.

iv.Banana Bunchy Top Virus (BBTV) - this virus is spread from plant to plant by aphids. It causes stunting of the leaves resulting in a "bunched" appearance. Generally, a banana plant infected with the virus will not set fruit, although mild strains exist in many areas which do allow for some fruit production. These mild strains are often mistaken for malnourishment, or a disease other than BBTV. There is no cure for BBTV, however its effect can be minimised by planting only tissue cultured plants (In-vitro propagation),

controlling the aphids, and immediately removing and destroying any plant from the field that shows signs of the disease.

These four diseases represent the main threats to both commercial cultivation and the small-scale subsistence farming of bananas.

Even though it is no longer viable for large scale cultivation, 'Gros Michel' is not entirely extinct, as it is still grown in some areas where Panama Disease is not found. Likewise, 'Cavendish' is in no danger of complete extinction, but there is a possibility that it could leave the shelves of the supermarkets for good if disease winnows the harvest down to where it can no longer hope to supply the global market. It is unclear if any banana cultivar currently existing could replace 'Cavendish' on a scale needed to fill current demand, so various hybridisation and genetic engineering programs are working on creating a disease-resistant, mass-

Australia is relatively free of plant diseases and therefore prohibits imports. When Cyclone Larry wiped out Australia's domestic banana crop in 2006, bananas became relatively expensive, due to low supply domestically, and laws prohibiting banana imports.

3.4. World Production of Bananas

Top Banana Producing Nations - 2005
(in million metric tons)

India	16.8
Brazil	6.7
China	6.4
Ecuador	5.9
Philippines	5.8
Indonesia	4.5
Costa Rica	2.2
Mexico	2.0
Thailand	2.0
Colombia	1.6
Burundi	1.6
World Total	**72.5**

Source: UN Food & Agriculture Organisation

In 2003, India led the world in production, representing approximately 23% of the worldwide crop, most of which domestic consumption. The four banana exporting countries were Costa Rica, Philippines, and Colombia, accounted for about two-thirds of the exports, each exporting more than 1 tons. Ecuador alone provided more than of global banana exports, according to statistics.

The vast majority of producers are small-scale **farmers growing the crop either for home consumption or for local markets. Because** bananas and plantains will produce fruit year- round, they provide an extremely valuable source of food during the hunger season (that period of time when all the food from the previous harvest has been consumed, and the next harvest is still some time away). It is for these reasons that bananas and plantains are of major importance to food security.

Student Self Assessment Exercise 2

1. Why is the control of pests and diseases so important in banana plantation?
2. Mention some of the most notorious diseases of banana.

3.5. Trade and Uses of Bananas

Bananas are among the most widely consumed foods in the world, and the only fruit to appear amongst the top ten most consumed food crops. Most bananas grown worldwide are used for local consumption. In the tropics, bananas, especially cooking bananas, represent a major source of food, as well as a major source of income for smallholder farmers. It is in the East African highlands that bananas reach their greatest importance as a staple food crop. In countries such as Uganda, Burundi and Rwanda per capita consumption has been estimated at 450kg per year, the highest in the world.

Most banana farmers receive a low price for their produce as supermarkets have leveraged their size to negotiate lower year-round contract prices for bananas. Supermarkets have reduced their margins in recent years which in turn has led to lower prices for growers. Chiquita, Del Monte, Dole and Fyffes grow their own bananas in Ecuador, Colombia, Costa Rica, Guatemala and Honduras. Banana plantations are capital intensive and demand high expertise so the majority of independent growers are large and wealthy landowners of these countries. This has led to bananas being available as a " fair trade" item in some countries.

The banana has an extensive trade history beginning with the founding of the United Fruit Company (now Chiquita) at the end of the nineteenth century The United Fruit Company based its business almost entirely on the banana trade The term " banana republic" has been broadly applied to Costa Rica, Honduras, and Panama countries with economies dominated by the banana trade.

The countries of the European Union have traditionally imported many of their bananas from the former European island colonies of the Caribbean, paying guaranteed prices above global market rates. As of 2005 these arrangements were in the process of being withdrawn under pressure from other major trading powers, principally the United States. The withdrawal of these indirect subsidies to Caribbean producers is expected to favour the banana producers of Central America, in which American companies have an economic interest.

It is common for fruit exports to be dominated by a single or very few cultivars. The most important properties making 'Cavendish' the main export banana are related to transport and shelf life rather than taste; major commercial cultivars rarely have a superior flavour compared to the less widespread cultivars. Export bananas are picked green, and then ripened in ripening rooms when they arrive in their county of destination. These are special rooms made air-tight and filled with ethylene gas to induce ripening.

The flavour and texture of bananas is affected by the temperature at which they ripen. Bananas are refrigerated to between 12 and 14 °C (54 and 57 °F) during transportation [1]. At lower temperatures, they spoil and turn grey.

Bananas are normally shipped to supermarkets when they are still partially green, however, a banana is considered ripe and ready for eating when it is fully yellow, and speckled with small brown spots. Sometimes bananas will bypass the ripening room, and show up at the supermarket still fully green; these almost never ripen into quality fruit, if they ripen at all.

Banana chips are a snack produced from dehydrated banana slices. These dried bananas have a dark brown colour and an intense banana taste. Bananas have also been used in the making of jam. However unlike other fruits, bananas are difficult to extract juice from because when compressed a banana simply turns to pulp.

In addition to the fruits, the flower of the banana plant (also known as *banana blossom* or *banana heart*) is used in Southeast Asian, Bengali and Kerala (India) cooking, either served raw with dips or cooked in soups and curries. The tender core of the banana plant's trunk is also used, notably in Burmese, Bengali and Kerala cooking.

Banana leaves are large, flexible, and waterproof; they are used in many ways, including as umbrellas and to wrap food for cooking. Chinese zongzi and Central American tamales are sometimes steamed in banana leaves, and the Hawaiian imu is often lined with them.

Seeded bananas (*Musa balbisiana*), considered to be one of the forerunners of the common domesticated banana, are sold in markets in Indonesia.

225 grams (1 cup) of banana has 806 mg of potassium (23% of Recommended Daily Allowance), 200 Calories, 6 g dietary fiber, and 19.6 mg of vitamin C (33% of RDA).

3.6. Properties and Uses of Banana Fruits

Banana, raw
Nutritional value per 100 g (3.5 oz)

Energy 90 kcal 370 kJ

Carbohydrates	22.84 g
- Sugars 12.23 g	
- Dietary fiber 2.6 g	
Fat	0.33 g
Protein	1.09 g
Thiamin (Vit. B1) 0.031 mg	2%
Riboflavin (Vit. B2) 0.073 mg	5%
Niacin (Vit. B3) 0.665 mg	4%
Pantothenic acid (B5) 0.334 mg	7%
Vitamin B6 0.367 mg	28%
Folate (Vit. B9) 20 µg	5%
Vitamin C 8.7 mg	15%
Calcium 5 mg	1%

Iron 0.26 mg	2%
Magnesium 27 mg	7%
Phosphorus 22 mg	3%
Potassium 358 mg	8%
Zinc 0.15 mg	1%

Percentages are relative to US recommendations for adults.
Source: USDA Nutrient database

Bananas come in a variety of sizes and colors; most cultivars are yellow when ripe but some are red or purple. The ripe fruit is easily peeled and eaten raw or cooked. Depending upon cultivar and ripeness, the flesh can be starchy to sweet, and firm to mushy. Unripe or green bananas and plantains are used in cooking and are the staple starch of many tropical populations.

Most production for local sale is of green cooking bananas and plantains, as ripe dessert bananas are easily damaged while being transported to market. Even when only transported within their country of origin, ripe bananas suffer a high rate of damage and loss.

The commercial dessert cultivars most commonly eaten in temperate countries (species *Musa acuminata* or the hybrid Musa × paradisiaca, a cultigen) are imported in large quantities from the tropics. They are popular in part because being a non-seasonal crop they are available fresh year-round. In global commerce, by far the most important of these banana cultivars is 'Cavendish', which accounts for the vast bulk of bananas exported from the tropics. The Cavendish gained popularity in the 1950s after the previously mass produced cultivar, Gros Michel, became commercially unviable due to Panama disease, a fungus which attacks the roots of the banana plant.

The most important properties making 'Cavendish' the main export banana are related to transport and shelf life rather than taste; major commercial cultivars rarely have a superior flavour compared to the less widespread cultivars. Export bananas are picked green, and then usually ripened in ripening rooms when they arrive in their country of destination. These are special rooms made air-tight and filled with ethylene gas to induce ripening. Bananas can be ordered by the retailer "ungassed", however, and may show up at the supermarket still fully green. While these bananas will ripen more slowly, the flavour will be notably richer, and the banana peel can be allowed to reach a yellow/brown speckled phase, and yet retain a firm flesh inside. Thus, shelf life is somewhat extended. The flavour and texture of bananas are affected by the temperature at which they ripen. Bananas are refrigerated to between 13.5 and 15 °C (57 and 59 °F) during transportation. At lower temperatures, the ripening of bananas permanently stalls, and the bananas will eventually turn grey.

It should be noted that *Musa × paradisiaca* is also the generic name for the common plantain, a coarser and starchier variant not to be confused with *Musa acuminata* or the Cavendish variety. Plantains have all but replaced the Cavendish in markets dominated by supply-side logistics.

3.7. Banana Fibre

Banana plant, Luxor, Egypt - Bananas are continually cropped, fruits from higher in the inflorescence being taken before the lower part opens.

The banana plant has long been a source of fibre for high quality textiles. In Japan, the cultivation of banana for clothing and household use dates back to at least the 13th century. In the Japanese system, leaves and shoots are cut from the plant periodically to ensure softness. The harvested shoots must first be boiled in *lye* to prepare the fibres for the making of the yarn. These banana shoots produce fibres of varying degrees of softness, yielding yarns and textiles with differing qualities for specific uses. For example, the outermost fibres of the shoots are the coarsest, and are suitable for tablecloths, whereas the softest innermost fibres are desirable for *kimono* and *kamishimo*. This traditional Japanese banana cloth making process requires many steps, all performed by hand.

In another system employed in Nepal, the trunk of the banana plant is harvested instead, small pieces of which are subjected to a softening process, mechanical extraction of the fibres, bleaching, and drying. After that, the fibres are sent to the *Kathmandu valley* for the making of high end rugs with a textural quality similar to silk. These banana fibre rugs are woven by the traditional Nepalese hand-knotted methods, and are sold *RugMark certified*.

Banana fibre is also used in the production of *banana paper*.

3.8. Other Uses of Bananas

In addition to the fruit, the ***flower*** of the banana plant (also known as *banana blossom* or *banana heart*) is used in Southeast Asian, Bengali and Kerala (India) cuisine, either served raw with dips or cooked in soups and curries. The tender core of the banana plant's trunk is also used, notably in the Burmese dish mohinga, Bengali and Kerala cooking. Bananas fried with batter is a popular dessert in Malaysia, Singapore and Indonesia. Banana fritters can be served with ice-cream as well. Bananas are also eaten deep fried, baked in their skin in a split bamboo, or steamed in glutinous rice wrapped in a banana leaf in Myanmar where bunches of green bananas surrounding a green coconut in a tray is an important part of traditional offerings to the Buddha and the Nats. The juice extract prepared from the tender core is used to treat kidney stones.

The ***leaves*** of the banana are large, flexible, and waterproof; they are used in many ways, including as umbrellas and to wrap food for cooking, carrying and packing cooked foods. In south India, foods are served only on banana leaves in households and hotels as well. Some farmers prefer to grow banana plants only for their leaves. Chinese zongzi (bamboo leaves are more commonly used where available) and Central American tamales are sometimes steamed in banana leaves, and the Hawaiian imu is often lined with them. Puerto Rican "pasteles" are boiled wrapped and tied inside the leaf.

Banana chips are a snack produced from dehydrated or fried banana or, preferably, plantain slices, which have a dark brown colour and an intense banana taste. Bananas have also been used in the making of jam. Unlike other fruits, it is difficult to extract juice from bananas because when compressed a banana simply turns to pulp.

Seeded bananas (Musa balbisiana), considered to be one of the forerunners of the common domesticated banana, are sold in markets in Indonesia.

It is reported that in Orissa, India, ***juice is extracted from the corm and used as a home remedy for the treatment of jaundice. In other places honey is mixed with mashed banana fruit and used for the same purposes.***

Culinary usage

Note: this list is not, and will probably never be complete, due to the tremendous diversity of the fruit.

There are various other uses to which plantains and bananas can be put include:

Banana pudding
Banana bread
Banana chips
Bánh chuối
Bananas Foster
Banana ketchup
Flavored liquor: notably Cruzan Tropical Rum and Malibu Tropical Banana
Rum Banana pudding
Grilled peanut butter and banana sandwiches, favored by Elvis Presley
Banana sauce
Banana split
Banania
Chunky Monkey, the Ben & Jerry's ice cream flavor

Student Self Assessment Exercise 3

- What are the uses of bananas fruits and fibres**?**

4.0. CONCLUSION

The banana is the fruit of the genus Musa, of the family Musaceae, one of the most important food crops of the world. The banana is consumed extensively throughout the tropics, where it is grown, and is also valued in the temperate zone for its flavour, nutritional value, and availability throughout the year. The banana is one of the world's oldest natural fruits.

The plant is a gigantic herb that springs from an underground stem, or rhizome, to form a false trunk 3–6 m (10–20 feet) high. This trunk is composed of the basal portions of leaf sheaths and is crowned with a rosette of 10 to 20 oblong to elliptic leaves that sometimes attain a length of 3–3.5 m (10–11.5 feet) and a breadth of 65 cm (26 inches).

It takes about 39 weeks to mature and then regularly produces new plants (or stems) over a period of years, each one in turn producing a bunch of bananas weighing anything upto 45 kilos.

A large flower spike, carrying numerous yellowish flowers, emerges at the top of the false trunk and bends downward to become bunches of 50 to 150 individual fruits, or fingers. The individual fruits, or bananas, are grouped in clusters, or hands, of 10 to 20. After a plant has fruited it is cut down to the ground, because each plant produces only one bunch of fruit. The dead plant is replaced by others in the form of suckers, or shoots, which arise from the underground stem at roughly six-month intervals. The life of one underground stem thus continues for many years, and the weaker suckers that it sends up through the soil are periodically pruned, while the stronger ones are allowed to grow into fruit-producing plants.

There are hundreds of varieties of banana in cultivation; confusion exists because of diverse names applied to one and the same variety in different parts of the world. Perhaps the most important species is the common banana, M. sapientum; this type has several varieties, the most widely consumed of which is the Gros Michel. Consumption of the banana is mentioned in early Greek, Latin, and Arab writings.

Alexander the Great saw bananas on an expedition to India. Shortly after the discovery of America, the banana was brought from the Canary Islands to the New World, where it was first established in Hispaniola and soon spread to other islands and the mainland. Cultivation increased until it became a staple foodstuff in many regions, and in the 19th century it began to appear in the markets of the United States.

Banana plants thrive naturally on deep, loose, well-drained soils in humid tropical climates, and they are grown successfully under irrigation in such semiarid regions as the southern side of Jamaica. Suckers and divisions of the pseudo-bulb are used as planting material; the first crop ripens within 10 to 15 months, and thereafter fruit production is more or less continuous.

Frequent pruning is required to remove surplus growth and prevent crowding in a banana plantation. Bananas are rich in vitamins, minerals, and other nutrients. The stalk and fiber can be made into quality paper products, cloth, rope, bags, and other handicraft items. Banana can also be used as a feed supplement for livestock feeding.

Desirable commercial bunches of bananas consist of nine hands or more and weigh 22–65 kg (49–143 pounds). Three hundred or more such bunches may be produced annually on one acre of land. The ripe fruit contains as much as 22 percent of carbohydrate, mainly as sugar, and is high in potassium, low in protein and fat, and a good source of vitamins C and A. A ripe banana is 75 percent water. Though most commonly eaten fresh, bananas may be fried or mashed and chilled in pies or puddings. They may also be used to flavour muffins, cakes, or breads.

Cooking varieties, or plantains (M. paradisiaca), differ from other bananas in that the ripe fruit is starchy rather than sweet. They are extensively cultivated and used in tropical regions and are marketed in large urban areas worldwide. The United States imports more bananas than any other country; large quantities are also shipped to Great Britain and western Europe.

Even for local consumption, bananas are not allowed to fully ripen on the plant. For export, the desired degree of maturity attained before harvest depends upon distance from market and type of transportation.

Frequently, ripening is artificially induced after shipment by exposure to ethylene gas. (In botany, ethylene is a plant hormone that inhibits growth and promotes leaf fall. In fruit, however, ethylene is regarded as a ripening hormone. Involved in its action in fruit is some other factor that influences ethylene sensitivity of the tissues.) Specially designed refrigerated ships transport bananas from tropical countries to consumption centres in North America and Europe.

The chief producers of bananas in Middle America and the West Indies are Costa Rica, Honduras, Guatemala, Mexico, Panama, the Dominican Republic, Guadeloupe, Jamaica, and Martinique; in South America, Brazil, Colombia, and Ecuador; in Africa, Spain's Canary Islands, Ethiopia, Cameroon, Guinea, and Nigeria; and in Asia, Taiwan

5.0. SUMMARY

A **banana** plant is a herb in the genus, *Musa*, which because of its size and structure, is often mistaken for a tree. It is cultivated for its fruit, which also bears the same name. Bananas are of the Family Musaceae and closely related to plantains. Globally, bananas rank fourth after rice, wheat and maize in human consumption; they are grown in 130 countries worldwide, more than for any other fruit crop. Bananas are native to tropical southeastern Asia.

The main or upright growth is called a *pseudostem*, which when mature will obtain a height of 2–8 m (varies by cultivar), with leaves of up to 3.5 m in length. Each pseudostem produces a single bunch of bananas, before dying and being replaced by a new pseudostem. The base of the plant is a rhizome (known as a corm). Corms are perennial, with a productive lifespan of 15 years or more.

The term *banana* is applied to both the plant and its elongated fruit (technically a false berry) which grow in hanging clusters, with up to 20 fruit to a tier (called a *hand*), and 5-20 tiers to a bunch. The total of the hanging clusters is known as a bunch, or commercially as a "banana stem", and can weigh from 30–50 kg. The fruit averages 125g, of which approximately 75% is water and 25% dry matter content. Bananas are a valuable source of Vitamin A, Vitamin C, and potassium.

In 2003 India led the world in banana production, representing approximately 23% of the worldwide crop, most of which was for domestic consumption. The four leading banana exporter countries were Ecuador, Costa Rica, Philippines, and Colombia; accounted for about two thirds of the worlds exports; with each exporting more than 1 million tons. Ecuador alone provided more than 30% of global banana exports according to FAO statistics.

Bananas are classified either as dessert bananas (meaning they are yellow and fully ripe when eaten) or as green cooking bananas/plantains. Almost all export bananas are of the dessert variety; however, only about 10-15% of all production is for export, with the US and EU being the dominant buyers.

Bananas and plantains constitute a major staple food crop for millions of people in developing countries. In most tropical counties green (unripe) bananas used for cooking represent the main cultivars. Cooking bananas are very similar to potatoes in how they are used. Both can be fried, boiled, baked or chipped and have similar taste and texture when served. Nutritionally one green cooking banana has about the same nutritional and calorie content as one potato.

The vast majority of producers are small-scale farmers growing the crop either for home consumption or for local markets. Because bananas and plantains will produce fruit year - round, they provide an extremely valuable source of food during the hunger season (that period of time when all the food from the previous harvest has been consumed, and the next harvest is still some time away). It is for these reasons that bananas and plantains are of major importance to food security.

6.0. TMA s

1. What is the difference between banana and plantain?

2. Bearing in mind the cultivation and propagation method of Bananas, how best can the cultivars be improved?

3. Describe the field maintenance operations in banana plantation.

4. What are the uses of bananas?

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Module 5: LATEX CROPS

Unit 10 Rubber: Hevea Brasiliensis

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Module 5: Latex Crops

Unit 10: Rubber: *Hevea Brasiliensis*

1.0. Introduction

Hevea brasiliensis is a tropical tree. It is native to the Amazon Basin in Brazil and adjoining countries. In the early stages (that is up to about 1910) most rubber was harvested from "wild trees" growing in the Amazon Basin and to a lesser extent from other natural sources of natural rubber (such as *Ficus elastica*) growing in the Congo Basin of Africa. Hevea was taken from the Amazon to South Asia (Sri Lanka) and South East Asia (Singapore and Malaysia) by the British Colonial Office where it was grown experimentally and later on plantations (see history). Subsequently, cultivation spread to what was then Indochina (Vietnam and Cambodia), the Dutch East Indies (Indonesia) and Thailand, and subsequently to Africa (Liberia, Nigeria, Cote d'Ivoire). Initially cultivation took place on plantations, but smallholders rapidly adopted it as a source of income.

2.0 Objectives of the Unit

At the end of this unit, you should be able to:

- Identify and describe a rubber plant
- enumerate the different types available in Nigeria
- Describe the nursery operations in rubber cultivation
- describe field operations in maintenance of rubber plantation
- enumerate the tools used in tapping rubber latex
- describe the process of tapping and the processing of latex
- enumerate the uses of rubber

3.0. Subject – Matter Content of the Unit

The subject matter content of this unit starts with the history and the development of rubber. The botany of the rubber tree was then discussed. Climatic and edaphic requirements for the cultivation of rubber were then treated. Nursery and field operations in the agronomic management of the crop were carefully treated. Harvesting and processing of latex were similarly elaborated.

3.1. History

In its native Central America and South America, rubber has been cultivated for a long time. The Mesoamerican civilizations used rubber mostly from *Castilla elastica*. The Ancient Mesoamericans had a ball game using rubber balls (*see: Mesoamerican ballgame*), and a few Pre-Columbian rubber balls have been found (always in sites that were flooded under fresh water), the earliest dating to about 1600 BC. According to Bernal Díaz del Castillo, the Spanish Conquistadores were so astounded by the vigorous bouncing of the rubber balls of the Aztecs that they wondered if the balls were enchanted by evil spirits. The Maya also made a type of temporary rubber shoe by dipping their feet into a latex mixture. Rubber was used in various other contexts, such as strips to hold stone and metal tools to wooden handles, and padding for the tool handles. While the ancient Mesoamericans did not have vulcanization, they developed organic methods of processing the rubber with similar results, mixing the raw latex with various saps and juices of other vines, particularly *Ipomoea alba*, a species of Morning Glory. In Brazil the natives understood the use of rubber to make water-resistant cloth. A story says that the first European to return to Portugal from Brazil with samples of such water-repellent rubberized cloth so shocked people that he was brought to court on the charge of witchcraft.

When samples of rubber first arrived in England , it was observed by Joseph Priestley, in 1770, that a piece of the material was extremely good for rubbing out pencil marks on paper (see eraser), hence the name.

The Para rubber tree initially grew in South America, where it was the main source of what limited amount of latex rubber was consumed during much of the 19th century. About 100 years ago, the Congo Free State in Africa was a significant source of natural rubber latex, mostly gathered by forced labour. The Congo Free State was forged and ruled as a personal colony by the Belgian King Leopold II. After repeated efforts (see Henry Wickham) rubber was successfully cultivated in Southeast Asia, where it is now widely grown.

In India commercial cultivation of natural rubber was introduced by the British Planters, although the experimental efforts to grow rubber on a commercial scale in India were initiated as early as 1873 at the Botanical Gardens, Kolkata. The first commercial Hevea plantations in India were established at Thattekadu in Kerala in 1902.

3.2. Botany of Rubber

Many plant species produce natural rubber. Considerations of quality and economics, however, limit the source of natural rubber to one species, namely *Hevea brasiliensis*. It is a native of the Amazon basin and introduced from there to countries in the tropical belts of Asia and Africa during late 19th century. It can be termed as the most far reaching and successful of introductions in plant history resulting in plantations over 9.3 million hectares, 95 per cent of it across the globe in Asia.

Many plant functions have been attributed to ***latex***. Some regard it as a form of stored food, while others consider it an excretory product in which waste products of the plant are deposited. Still others believe it functions to protect the plant in case of injuries; drying to form a protective layer that prevents the entry of fungi and bacteria. Similarly, it may provide some protection against browsing animals, since in some plants latex is very bitter or even poisonous. It may be that latex fulfills all of these functions to varying degrees in the numerous plant species in which it occurs.

Latex has many uses, from clothing to paint, but its first and foremost is rubber. Chicle, widely used as a base for chewing gum, is another latex product. Latex paint uses synthetic latex as a binder, which is not flammable, has little odor, and cures to form a dry paint film. Natural latex is used in the manufacturing of latex mattresses, beauty application pads, and cushioning. Finally, poppy latex is a source of opium and its many derivatives.

Hevea brasiliensis, also known as the Para rubber tree after the Brazilian port of Para, is a quick growing, fairly sturdy, perennial tree of a height of 25 to 30 metres. It has a straight trunk and thick, somewhat soft, light brownish gray bark. The young plant shows characteristic growth pattern of alternating period of rapid elongation and consolidated development. The leaves are trifoliate with long stalks. The tree is deciduous in habit – sheds leaves during the dry season and new leaves are formed thereafter. This phenomenon is called **Wintering.** During wintering, which lasts for sixteen weeks (December to February in Nigeria), the metabolism of the tree and the constitution of its latex are substantially affected. The yield is also reduced, and this, together with other climatic factors, accounts for marked seasonal variations in NR production in producing countries. Quick refoliation and copious flowering follow wintering. Flowers are small but appear in large clusters. Fruits are three lobed, each holding three seeds, quite like castor seeds in appearance but much larger in size. The seeds are oil bearing.

The rubber tree may live for a hundred years or even more. But its economic life period in plantations, on general considerations is, only around 32 years – 7 years of immature phase and 25 years of productive phase.

Humid tropical climate prevails in the rubber-growing tract. Average annual rainfall in the tract varies from about 2000-4500 mm. The southern parts of the traditional tract enjoy southwest and northeast monsoons almost equally while the northern areas receive mostly the southwest monsoon. From south to north the drought period extends from two to five months in a year and the distribution of rainfall becomes more uneven. However, variation in temperature and humidity in the rubber tract is not so marked as that of the rainfall. The temperature remains very warm and humidity very high throughout the year.

3.3. Agro-Climatic Requirements for Rubber Production

i. Climatic factors

Hevea brasiliensis is a tropical tree. It grows best at temperatures of 20-28°C with a well-distributed annual rainfall of 1,800-2,000 mm. It grows satisfactorily up to 600 metres above sea level (but is capable of growing much higher - to at least 1000 metres near the

Equator), and will perform on most soils provided drainage is adequate. Hevea tends to be damaged by high winds. Its required temperature and rainfall define its prime growing area as between the 10° latitudes on either side of the equator, but is cultivated much further north (Guatemala, Mexico and China) and south (Sao Paulo region of Brazil).

ii. Maturity

Mature Hevea trees on rubber plantations are 20-30 metres high, with graceful upwards-extending branches and a relatively slim trunk. Such trees flower once a year, and after insect cross-pollination produce large fruits containing several thimble-sized seeds with hard outer coats. If satisfactorily germinated and planted within 2-3 weeks, seeds grow to produce seedling plants. Depending on conditions, the latter then take 5-10 years to reach 'maturity', which is defined as the stage when tapping can be started. In practice, this is the time when the trunk has about 500 mm circumference at 1 metre above ground level.

iii .Biosynthesis

Hevea trees convert inorganic nutrients from the soil, and carbon dioxide from the atmosphere, into organic carbohydrates which are then turned into rubber latex. The latter passes up the tree through millions of capillary vessels located in the soft outer bark of the rubber plant.

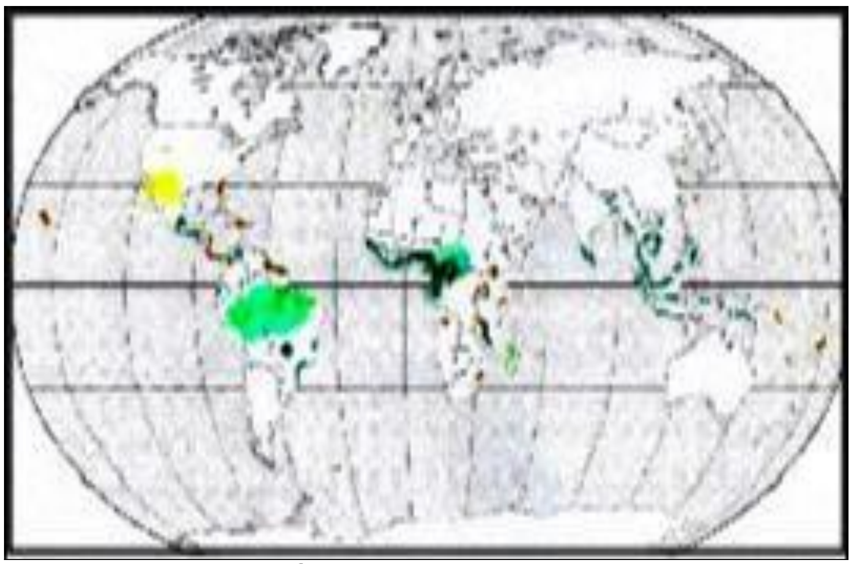
3.4 Soil Requirements

Soil in the rubber tract is generally highly weathered and consists mostly of laterite, lateritic types. Sedimentary types and nonlateritic red and alluvial soils are also seen in some non-traditional areas. The laterite and lateritic soils are mostly very porous, well drained, moderately to highly acidic, deficient in available phosphorus and varying in potassium and magnesium content. Red soil found in some areas is characterized by reddish to brown colour and fine loamy texture. This soil is generally acidic and highly deficient in available phosphorus.

Soil for rubber cultivation should have a minimum depth of one metre without any intervening hardpan or impenetrable layer. Water table should also be well below one metre so that at least one metre of soil with good aeration, essential for root penetration is available Well-drained soil is essential for optimum growth and yield of rubber plants. In marshy areas, owing to poor physical properties and waterlogged conditions growth of rubber is always found to be very poor.

3.5. Rubber Growing Regions of the World.

Rubber is grown within the equatorial belt that lie 15º N. through 15ºS. of the equator. The major countries include: Malaysia, Sri Lanka, India, Indonesia, Brazil, Mexico, Liberia, Nigeria, Ecuador Congo (Zaire). Malaysia is the leading world producer, producing over 40% of world production



World map of rubber growing areas:

(light green: indigenous (in Africa & South East Asia includes non-Hevea, such as Ficus elastica)

dark green: cultivated Hevea, brown: experimental/historical, yellow: guayule)

3.6. Propagation of Rubber

The following topics will be treated as part of the agricultural management of rubber cultivation.:

Clones
Nursery Establishment
Land Preparation
Field Planting
Intercropping
Cover Crops
Mulching, Shading and Whitewashing

Diseases and Pests Management
Manuring / Fertiliser Application
Induction of Branches
Tapping and Stimulation
Processing
Uses of rubber

Clonal Seeds

In Nigeria, *Hevea* seeds normally ripen during September- December when the seeds are collected and seedlings raised. All earlier plantations were raised from unselected seeds. The yield potential of these having been low, the production of those plantations was poor. Selection work on *Hevea* with a view to improving the planting materials and the introduction of vegetative propagation by budding led, in course of time, to the establishment of numerous valuable clones.
Seeds of clones are termed clonal seeds. There are different kinds of clonal seeds – monoclonal, polyclonal, legitimate and illegitimate. Monoclonal seeds of clone Tjir 1 which gave rise to seedlings superior to seedlings from ordinary, unselected seeds were once encouraged for planting extensively in our country. Evolution of newer, improved planting materials then progressively replaced Tjir 1 clonal seedlings. Hybrid polyclonal seeds collected from approved polyclonal seed gardens are the only seed material recommended for planting now. For production of good quality polyclonal seeds, gardens have been established in Kanyakumari district. Polyclonal garden seeds in the name Prang Besar Isolated Garden (PBIG) seeds from Malaysia used to find limited market in India until a few decades ago.

Handling the Ungerminated Seeds Fresh and healthy seeds collected from the field can be kept under shade without much loss of viability for about seven days. Storing fresh seeds in water at ambient temperature increases their water content, which in turn prolongs the viability. By packing seeds loosely in well-aerated containers with powdered charcoal having 20 per cent moisture, 70 per cent viability can be retained up to 30 days. Storage of seeds at 4oC in sealed polythene bags is also considered to be a reliable method for retaining viability up to four months.

Immediately after collection, seeds are generally packed in powdered charcoal of 20 per cent moisture for transportation. Containers usually used are wooden boxes, double gunny bags, bags lined with polythene or polythene bags. For transporting over very long distance, seeds may be packed tightly in layers in aerated cases with damp sawdust-charcoal powder mixture, at least 2 cm thick between two layers of seeds.

3.7. Nursery Establishment

Nurseries are required for raising seedlings, budded stumps and budwood. As far as possible open and level land should be selected for raising nursery. Water should be easily available for irrigation. The soil should be deep, well drained and fertile.

The land should be dug to a depth of 75 cm and all stumps, roots, and stones should be removed. Nursery beds should be prepared with 60 to 120 cm width and convenient lengths and with pathways laid in between to facilitate manuring, watering, weeding etc.

Planting distances should vary according to the type of planting materials to be raised in the nursery. The ideal spacing for seedlings is 30 cm X 30 cm. For budwood nurseries, the plants may be at distances of 60 X 90 cm or 60 X 120 cm or 90 X 90 cm

Nursery management aims at the most rapid production of standard healthy planting materials. More intensive care can be exercised in a nursery than in a field. Plants which are obviously unsuitable can be eliminated at an early stage.

Mainframe operations for nursery include weeding, mulching, irrigation during dry months, manuring and disease and pest control.

Planting materials for establishing rubber plantations are generated in seedling, budwood and polybag nurseries. The type of nursery will therefore depend on the type of planting materials to be raised there from.

i. Preparation of Nursery Beds

For the preparation of a ground nursery, the soil is first dug to a depth of 60 to 75 cm. Stones, stumps, roots, etc present in the soil are removed and the soil is brought to a fine tilth. Beds should be 90 to 120 cm wide and of convenient length. In the level lands, raised beds are made with footpaths of about 45 cm width between the beds, and in undulating lands, beds are prepared along the contours, one below the other. At the time of preparation of nursery beds, 25 kg of compost or well-rotten cattle manure and 4 kg of powdered rock phosphate (18% P2O5) are incorporated for every 100 m2 of nursery bed. When nurseries are established in newly cleared forest areas rich in organic matter, compost or cattle manure need not be applied during the first year. Similarly when the same area is repeatedly used as a nursery, rock phosphate need be applied only once in three yeas. Drainage and pathways should be provided appropriately.

ii. Germination of Seeds Rubber seeds lose viability very rapidly if left in the field. The seeds are therefore picked up daily during the seed fall season and quickly transported to nurseries for germination and planting.

For germination, raised level beds with a 5 cm thick layer of river sand, 90 cm wide and of convenient lengths are used. Partial shade in order to prevent strong sun is necessary. The seeds are sown in a single layer touching one another and germination beds are kept moist, but not wet, by evenly sprinkling water during morning and evening. The seeds are covered with loosely woven coir matting or gunnies.

Germination starts 6 to 7 days after sowing. Seeds sprouted each day should be picked and planted in nursery beds or in the field as the case may be. Germinated seeds will have young roots emerging first. That is the ideal stage for nursery planting. The sproutings are tender and require careful handling. Usually, germinated seeds are carried to nursery beds in buckets half filled with water.

About 75 percent germination is considered good. Pickings are done for about 21 days after sowing.

iii. Planting in Nursery. For planting germinated seeds in the nursery beds, small holes enough to accommodate the seeds in a horizontal position and approximately 5 cm deep are made. The seeds are carefully placed in the holes with the radicle pointing downwards and covered with soil. The sprouted seeds should be planted when the young root is less than 2 cm long. The germinated seeds should be carefully handled to prevent damage of the radicle. Spacing varies according to the type of planting material to be raised in the nursery. The common spacing adopted for raising seedling stumps is 30 x 30 cm. To produce green-budded stumps 23 x 23 cm spacing may be followed. For brown-budded stumps a spacing of 30 x 30 cm or staggered pairs of rows 60 cm apart and 23 cm between plants may be adopted. A spacing of 60 x 60 cm, 90 x 30 cm, 90 x 60 cm or 90 x 90 cm is required to produce various kinds of stumped buddings. For raising soil core plants, a spacing of 35 x 35 cm, 38 x 30 cm or 60 x 60 cm may be followed. The spacing adopted for budwood nursery is 90 x 60 cm or 120 x 60 cm. wider spacing being between rows.

The rows are first marked on either end of each nursery bed using row markers. A long cord of coir rope, wire or country twine, with the planting distance along the row marked on it, is stretched tight along the length of the bed on the row markers on either end and germinated seeds are planted at each mark along the line. In budwood nursery, budded stumps are planted at the required spacing. Alternatively, seeds can be directly sown in the beds at the required spacing and budded in situ. After budtake they are cut back and the scion allowed to develop.

iv. Types of Nursery

a. Polybag Nursery. Planting materials in polybags can be prepared by two different methods. Budded stumps can be planted in polybag and the scion allowed to develop till they are ready for planting in the field. In the other method, germinated seeds are planted in polybags and bud-grafted when five to six months old. The former gives greater opportunity for selection of the most vigorous plants and avoids wastage of bags containing poor seedlings and budding failures. The roots of budded stumps can be treated with indolebutyric acid (IBA), a hormone which enhances root growth. Dipping root in cow dung slurry before planting enhances root development.

The bags may be of black or transparent polyethylene. Transparent bags, when used, should always be kept buried in soil, as otherwise, the development of roots will be affected. The use of black polyethylene bags is generally preferred. Depending on the size of the plant to be produced, bags of different dimensions may be used. Polythene bags of lay flat dimension 55 to 60 cm length and 25 to 30 cm width which can hold about 8 to 10 kg of soil are usually used for raising plants up to two to three whorl stage. For producing plants of six to seven whorls, larger bags of 65 x 35 cm size and holding about 23 kg soil should be used. In order to facilitate drainage, sufficient number of holes should be punched on the lower half of the bags. Low density polyethylene (LDPE) sheet of 400 gauge and 500 gauge thickness are usually used for making small bags and large bags respectively. Bags made of high density polyethylene (HDPE) sheets can also be used for this purpose. However, such bags are likely to deteriorate when exposed to sunlight for long periods.

The soil used for filling the bags should have good moisture and nutrient retention capacity, promote root development and bind the roots firmly to prevent damage during transport. Soils with clay-loam texture, good structure and friability are ideal for this purpose. The fertile topsoil collected after removing the surface vegetation and leaf litter is ideal for filling the bags. Before filling the holes, large clods of soil are broken, and if too wet, they are firstly partially dried. The soil is cleaned by removing stones, roots and stubbles. While filling, the bag should be gently tapped to ensure compact filling of soil without leaving air spaces. The bag is filled up to about 2 cm below the brim. Powdered rock phosphate at the rate of 25 g for small bags and 75 g for large bags is mixed with the top layer of soil. The filled bags can be kept in the nursery either in trenches or on the ground supported with wooden poles. The former method is better as it would give greater protection of the bags and better growth of the plants. Trenches having width equal to the diameter of the bag are usually dug in pairs. For small bags, depth of trench may be about 20 cm and the distance between rows in a pair of trenches 15 cm. The corresponding depth and distance for large bags are 30 cm and 20 cm. The gap between bags of same trench is 10 cm. Footpath of 75 cm width may be left between two pairs of trenches. After placing the bag in the trench, the excavated soil is filled in the gap between them. The remaining soil is mounted around the bags. Planting of budded stumps or sprouted seeds is undertaken thereafter. When budded stumps are used, the bud patch should face the footpaths to facilitate growth of sprouts. Regular cultural operations like manuring, watering, weeding, shading and plant protection are adopted. Application of NPK Mg 10-10-4-1.5 mixture is done at monthly intervals. During the first month 10 g of the mixture is given per bag which is gradually increased to 30 g in four months time. Fertilizer application should be avoided when the leaves are very tender. While applying fertilizer, care should be taken to prevent it from coming in contact with the young plant as it may cause scorching. Watering should be done soon after manuring. During dry periods, irrigation should be done regularly. Watering can be done manually in small nurseries while sprinklers or drip irrigation system is more economical in large nurseries. Too much watering should be avoided to prevent water logging. During summer months, partial shade may be provided to the plants by erecting overhead shade. Appropriate prophylactic and curative measures may be taken against diseases and pests.

Polybag plants are advanced planting materials which contribute to reduction in immaturity period. Bagged plants should be transplanted to the field, with minimum disturbance to the root system for proper establishment. Such plants also help to achieve a uniform stand and are also useful for vacancy filling and late planting. Because of these advantages the use of polybag plants has become very popular.

Transplanting the Polybag

At the time of planting, the top whorl of leaves of the polybag plant should be fully mature. The soil around the bag is removed and the bags are taken out of the trench. Dressing of the lateral roots and taproot, if grown out of the bags, may be necessary. Then they are carried to the planting points.

A planting hole that is slightly bigger than the size of the bag is made. The bottom of the bag is completely cut and then the bag along with the plant is inserted into the planting hole. A vertical cut is made at the bottom of the plastic sleeve, taking care not to damage the roots. Then the cut is continued upwards as the hole is gradually filled so that the cylinder of soil is unbroken. When the hole is partially filled, the bag is slit along its full length and carefully pulled away. The soil is finally packed firmly around the plants. While planting, the scion of the polybag plants should be directed towards north east to minimize the adverse effect of direct sunlight on the bud patch.
While transporting polybag plants utmost care should be given to prevent any damage to the soil core. If the soil core is damaged roots may break and consequently the plant will be deprived of all the advantages of bag planting. Transporting over a short distance is done by carrying them on the head or shoulder. Vehicles like lorry, truck, tractor, etc. are used for transporting over long distances. While transporting by vehicles, the bags are stacked on the platform tightly to reduce their swaying and shaking to the minimum. Providing shade for protection from hot sun is also desirable. The bag should always be kept in a vertical position while loading, unloading and transporting. Carrying them in inclined or horizontal position may cause breaking of soil core. Care should also be taken to avoid tearing of the bags as it also can increase the chances for breaking of the soil core.

b. Seed Germination Beds

Rubber seeds are first germinated in germination beds and then planted in nursery. A well-drained area with moderate shade is the ideal site for germination beds. Level beds of 90 cm width and convenient length are prepared with walking space in between. The beds should be raised 10 to 15 cm above the soil surface to avoid water logging. A free draining friable material, like river sand, spread above the bed to a thickness of 5 cm is used as the medium for germination. Rubber seeds are viable only for a short period and are put in germination beds as soon as obtained. Seeds are washed thoroughly to remove charcoal and other packing debris and spread over the bed in a single layer touching one another and pressed gently into the sand. In order to prevent loss of too much moisture from the rooting medium, the beds are covered with a thin layer of gunny bag, coir matting or similar material. A high level of moisture is maintained in the bed by evenly sprinkling water early in the mornings and late in the evenings. Germination of the seeds starts within six to seven days after sowing. The beds should be inspected daily and the germinated seeds picked up and collected in a bucket containing water as soon as the radicle emerges for planting in the nursery beds or main field. If the picking of germinated seeds is delayed, chances of damage during handling will be greater. Seeds which do not germinate within two to three weeks should be discarded as they are likely to give rise to weak seedlings.

c. Budwood Nursery

The aim of manuring budwood nurseries is to obtain the maximum quantity of good quality budwood per plant at the intervals of 10-12 months with an initial period of 12 to 18 months for the first crop of budwood.

1. Incorporate 165 kg of powdered rock phosphate per ha i.e., 1.65 kg per 100 sq. metres of the nursery bed as a basal dressing at the time of preparing the nursery bed.
2. For the first crop of bud-wood apply 250 g of 10-10-4-1.5 NPKMg mixture per plant in two equal split doses. Apply the first split of 125 g per plant two to three months after planting the budded stump or cutting back if budding is carried out in situ. The second dose of 125 g per plant should be applied eight to nine months after planting.
3. For the second and subsequent crops of bud-wood from the nursery, apply 125 g of 10-10-4-1.5 NPKMg mixture per plant in one single dose two to three months after cutting back.

The fertiliser application should be made during September – October and March-April either in a band 8 cm away from the base of the plant or in between two rows and lightly forked with a hand rake. For the second and subsequent crops of bud-wood the one round of fertiliser application recommended should be applied during September-October season adopting the same method.

Seedling Stumps. Seedling prepared to a convenient size by pruning the stem and roots are called seedling stumps. Healthy and vigorous one year old seedlings are generally used for this. The seedlings should have a minimum girth of about 7.5 cm at the base and brown colour up to a height of 45 cm or more. For stumping, at first, the seedlings are cut back at some point between 45 and 60 cm, where the brown colour ends. Pruning is always done with a slanting cut, preferably above a whorl of buds. While cutting back green or partially brown stem should not be retained on the plant. Transpiration can take place through such regions and the resulting loss of water may lead to the drying of the stumps after planting. The plants are left in the nursery for 7 to 10 days. During this period a few buds below the cut end become activated and swell. At this stage the decapitated plants are pulled out without causing much damage to the roots and bark of the stem. The taproot is pruned to the maximum possible length, but not more than 60 cm and not less than 45 cm. The minimum of 45 cm is insisted for the sake of better establishment and the maximum of 60 cm is fixed for the convenience of handling. Lateral roots are pruned to a length of 10 to 15 cm. Plants infected by diseases or having defective roots are discarded. If more than one taproot is present the most vigorous one alone should be retained and all others pruned off at the base. After preparing the seedling stumps by proper pruning of roots and stem, the cut end of the stem is immediately sealed by dipping in molten paraffin wax. For transporting over short distances they are tied into bundles and then covered with a layer of grass or leaves. In this manner they can be stored up to three days. If transporting over large distances and storing for days together are required, it is better to avoid stumping the seedlings days before pulling out. Pruning of shoot and roots may be carried out after pulling out. The stumps in such cases are packed in boxes along with wet saw dust in alternate layers

Stumped Buddings. Stumped buddings are mainly of two types, mini stumps and maxi stumps. To prepare ministumps the scion is cut back when it develops brown colour up to a height of 60 cm from the bud union. Pruning is done at the point where brown colour ends preferably below a whorl of buds. The cut end is treated with any wound dressing material to prevent dehydration. Stem is then white washed with hydrated lime to avoid sun-scorching. Ten days are given for the activation of buds. Then the plants are pulled out and the roots pruned as in the case of budded stumps. If pulling out is found to be difficult due to the deep taproot it can be made easy by removing the soil at one side of the taproot up to a depth of 45 to 60 cm. A crowbar is inserted through this opening and the taproot is severed at the desired depth. This is called tailing.

For preparing maxi stumps cutting back of the scion is carried out when brown colour is formed up to a height of 240 cm. First step in the extraction of the plant is the tailing which is done five weeks before pulling out. Early tailing reduces the transplanting shock and enhances the development of new roots from the cut end after transplanting. After tailing soil removed for this purpose is placed back. Pollarding of the stem is done 10 days before pulling out at a height of 240 cm. where brown colour ends. As in the case of mini stumps pruning of stem is done below a whorl of buds. Wound dressing, white washing, pulling out and pruning of lateral roots are also undertaken as done for ministumps. Packing and transporting of mini stumps are similar to that of seedling stumps. Maxi stumps are not usually made into bundles due to their large size. They are packed head to tail on lorries or trailers, using grass or leaves as packing medium to prevent bruising and drying

d. Seed at Stake Planting The system of planting seeds in situ is called seed at stake planting and it is followed by field budding. Two or three germinated seeds may be planted in a line or triangle. The weaker plants should be thinned out later, allowing the most vigorous one to grow on which field budding is carried out at the appropriate stage.

e. Tissue Culture Propagation of rubber is possible through tissue culture also. Tissue culture or micro propagation is the technique of producing plants from small (micro) pieces of plant tissues. Studies on tissue culture of rubber plants were started in 1966.

Different parts of the plant such as embryo, anther, shoot tip and integument can be used for tissue culture.

Rubber Research Institute of India has developed a technique for the production of tissue culture plants from shoot tips as well as somatic embryogenesis of different tissues. Rubber plants were developed by the somatic embryogenesis of anther tissue, integument tissue, immature inflorescence etc. Attempts are being made for the tissue culture of other plant parts like leaf, floral buds, ovules and micro spores.

Key steps in tissue culture of hevea include collection of the explant, sterilization, inoculation of the explant in a nutrient media supplemented with growth hormones and sucrose. The cultures were kept under optimum light and temperature conditions for the required period.

Plants were formed in about eight months. They were then transferred to small polybags and kept in a green house for hardening. Even for the same clone the culture conditions vary with the physiological stage of the explant, seasons, part of the plant used etc. Because of these variations separate protocols have to be developed for each clone. This is a laborious and time-consuming process. However, procedures have been perfected for the propagation of several important clones by optimising these parameters. As in the case of most other tree crops, multiplication rate in tissue culture is very low for rubber. Further in the post-laboratory stages mortality is very high. However, after overcoming all these hurdles the RRII has successfully developed a large number of plants through various methods of tissue culture. These plants have been established in the field. Test tapping carried out on certain clones over their bud-grafted control and they are under different stages of evaluation.

v. Nursery Management

For rapid and economic production of good quality planting materials, very careful management of the nursery is necessary. Efficient nursery management should aim at production of the maximum number of buddable or transplantable seedlings at the end of the 10 month period. Unhealthy and weak seedlings should be removed. The ideal time for this culling is three to four weeks after the first fertilizer application, by which time the vigorously growing and stunted plants can easily be distinguished.

The nursery beds should always be kept free of weeds. Generally three rounds of weeding are needed. In India, hand weeding is commonly practiced. The first weeding is done just before application of the first dose of fertilizers and the second weeding before the second dose. The third round of weeding is done just before commencement of budding during May or June. The first round of manual weeding can be replaced with the application of pre-emergence herbicides. After the final preparation of the nursery beds, diuron at the rate of 2.5 kg per ha in 700 L water is sprayed on the beds and germinated seeds planted five days later. However, planting germinated seeds on the same day of herbicide application does not result in any harmful effect that there is only minimum disturbance to soil while planting the seeds. The beds can be kept free of weeds till the first round of fertilizer application (6 - 8 weeks) by adopting this method. Mulching is an important operation to be followed in seedling nurseries before the beginning of the summer season and after the second round of fertilizer application. Natural materials such as tree loppings, dry leaves, undergrowth from forests, grass cuttings and cut cover crop material are commonly used after they are dried. A single round of good mulching in December is adequate. Black polythene sheets properly anchored to the soil to prevent them from being blown away by wind can also be used for mulching. Spreading a thin layer of soil above the sheet is an effective way to achieve this.

Manuring may preferably be carried out after ascertaining the specific requirements of individual nurseries by soil analysis. If this is found difficult, the general fertiliser recommendation may be followed which ia given under the title "Manuring/Fertiliser Application".

During the dry period which usually extends from December to April, the nurseries should be irrigated. In large nurseries, overhead sprinkler irrigation systems are ideal. Manual watering is convenient and cheap for small nurseries. The nursery beds should be mulched before commencement of irrigation. The quantity of water required varies with soil, climate and age of plants. Daily watering is preferred during the initial weeks. Later, the frequency of irrigation can be reduced to once in two or three days. When the seedlings are sufficiently grown they are used for budding or directly used as seedling stumps.

vi.)Seedling Nursery: Basic Fertilizer Application Needs

Basal Dressing – Incorporate two and a half tonnes of compost or well rotted cattle manure and 400 kg of powdered rock phosphate (18% P2O5) for every effective ha, i.e., 25 kg of compost and 4 kg of rock phosphate per 100 m2 of the nursery bed. If the nursery is opened in a newly cleared forest area, addition of compost or cattle manure may not be necessary during the year of opening and application of rock phosphate alone is sufficient. If the same bed is used repeatedly, application of rock phosphate is necessary only once in three years.

Top Dressing - Apply 2500 kg of 10-10-4-1.5 NPKMg mixture per effective ha, i.e., 25 kg per 100 m2 of the nursery bed six to eight weeks after planting. Again apply 550 kg of urea per effective ha, i.e., 5.5 kg per 100 m2, six to eight weeks after the first top dressing. After fertiliser application the plant bases can be mulched with suitable mulch material.

The first application of the recommended quantity of NPKMg mixture should be made during September-October period, i.e., six to eight weeks after planting the germinated seeds in the nursery beds. The fertiliser should be spread about eight cm away from the base of the plants in a 14 cm wide linear band in between two rows and gently forked in with a hand rake. The fertiliser should not come into contact with the stem of the seedling to avoid injury to the plants and ensure that there is sufficient moisture in the soil at the time of application.

vii. Budding

The principle involved in budding is the replacement of the shoot system of a plant with that of another more desirable plant. In this process, a patch of bark of the seedling plant (stock) is replaced by a patch of bark with a dormant bud (bud patch) taken from the clone to be multiplied. The bud patch gets attached to the stock permanently and becomes a part of it. The stock is then cut off above the budded portion and the grafted bud develops into a shoot (scion) exhibiting the characters of the plant from which it was taken. The new tree thus formed is a two-part tree, comprising a root system belonging to the stock plant and a shoot system contributed by the donor of the bud.

Depending on the colour and age of the buds as well as the age of the stock plants used, three types of buddings are mainly recognized. These are brown (conventional) budding, green budding and young budding. In the first method, older buds having brown colour are used while in the other two, green tender buds are utilised.

Depending on the part of the stock where budding is carried out, buddings are classified into four types: base budding, crown budding, over budding and high budding. Base budding is carried out at the base of the stock plant and includes brown budding, green budding and young budding.

a. Brown Budding

Brown budding is generally carried out by grafting brown coloured buds taken from budwood of about one year's growth onto stock plants of 10 months or more growth. Vigorously growing healthy stocks having a girth of 7.5 cm at the collar region are ideal for budding. Stocks should be budded when the bark peels off very easily. Peeling is usually good when the top whorl of leaves is well developed, but before further extension growth commences. Test peeling of a small patch of bark above 15 cm from the base is the sure method to assess the peeling quality of the bark. Since all stock plants may not attain this stage at the same time, more than one round of budding may be necessary to cover all the stocks.

Brown buds are usually obtained from brown budwood produced by budded plants raised in budwood nurseries. Buds found in the axils of fallen leaves are generally utilised for budding. Budwood should be collected when the top whorl of leaves have fully expanded but not hardened to ensure proper peeling of the bark and high budding success. Test peeling may be carried out before harvesting the budwood. Collection of budwood should be done with sufficient care so as to avoid bruising. As far as possible, budwood should be collected in the morning or evening, and should preferably be utilized for budding as soon as collected. If budding is delayed, special measures should be adopted for preventing moisture loss. Budwood is harvested as per the requirement and cut into pieces of convenient length, usually 1 m. Good quality budwood will have around 20 healthy, well formed buds per metre length. Weak and poorly formed buds should not be used. While handling budwood of different clones, proper labelling has to be done for identification.

Budding is usually carried out with a specially designed knife having two blades, called budding knife. However, an ordinary pen-knife with a blade of 7 to 8 cm length could also be used. The first step in the preparation of the stock plant for budding is thorough cleaning of the basal 15 cm to remove dirt, soil, etc. Cleaning can be done with cotton waste or rags. Then two parallel vertical cuts starting from about 2.5 cm above the collar are made. The length of these cuts should be a little more than 5 cm and 1.5 cm apart. Then a horizontal cut joining the bottom ends of the vertical cuts is also made. All the three cuts should be made deep enough to reach the wood. After making these cuts the latex is allowed to completely ooze out for a few minutes through the cuts. During this time the budder can mark a few more stocks in a similar manner. When the latex flow ceases, it is wiped off from the surface. The flap of bark separated by the three cuts is then gently lifted with the aid of the knife and peeled upwards. Alternatively, the upper ends of the vertical cuts may be connected by the horizontal cut and the flap peeled downwards. The practice of removing the flap completely is also adopted. The exposed region is called the budding panel.

The bud patch used for brown budding should have a length of about 5 cm and a width of about 1.5 cm. For preparing the bud patch, two parallel vertical cuts having a length of 5 cm are made on the two sides of a bud, 1.5 cm apart. Then two horizontal cuts are made connecting the lower and upper ends of these cuts. A little time is allowed for the latex to ooze out. During this time, incisions are made around neighbouring buds of the same budwood. When the oozing of latex stops, it is wiped off and the bud patch marked out by the four cuts is stripped off by gently pushing to one side.

After removing the bud patch from the budwood, the inner side is examined carefully for the presence of the core of the bud, which appears as a slight projection. If it is not present, the bud patch should be discarded. The bud patch should be handled with utmost care so as to avoid any damage to the cambium. It should always be held at the edges without touching the cambium. Foreign matter like water, soil and sweat should not be allowed to fall on the cambium. Similarly exposing the cambium to strong sunlight or dry wind can result in its drying. All these can cause damage to the cambium. Damage to the cambium of the budding panel also should be avoided. The four edges of the bud patch are then slightly trimmed. The bud patch is then gently placed in the budding panel after lifting the flap. It should be placed in such a way that the bud is above the leaf scar and its inner side is in contact with the budding panel. Exposure of too much area of the budding panel around the bud patch is unfavourable for budding success. At the same time the edges of the bud patch and budding panel should not touch each other. After placing the bud patch in the budding panel in the above manner, the flap, if retained, is placed back over it and is then bandaged using polythene strips of 45 cm length, 2.5 cm width and 250 gauge thickness. Bandaging should commence at the bottom and move upwards in a close spiral. During the first few turnings of the bandage, the lower end of the flap should be kept gently pressed over the bud patch to prevent it from slipping.

Bandaging should be tightened to keep the cambium tissues of the budding panel and the bud patch in intimate contact with each other. The end of the tape is finally kept intact with a knot. In the field and along borders of nurseries it may be necessary to shade the bud patch against strong sunlight. This can conveniently be done by tying a rubber leaf over the bud patch.

If the budding is successful, the cambium of the stock plant and that of the bud patch unite and the bud patch establishes as a part of the stock. The process requires 15 to 20 days and the plant is left undisturbed for 20 days after which the bandage is removed. The flap, if it had been retained, is cut a little above the upper end of the bud patch and removed. Freshness of the bud patch indicates initial success of the budding. The final success is ascertained in a similar manner after another 10 days.

b. Green Budding

Both the stock plant and budwood used for green budding are very young. Seedlings which are five to seven months old are used as stock. Buds are collected from six to eight weeks old budwood, also known as bud shoots or bud sticks. Buds found above the scale leaves of the shoots alone are used for budding. These buds are green in colour and hence the name green budding.

Young, vigorous seedlings raised in nursery or in polythene bags are used as stock plants for green budding. Plants having a girth of about 2.5 cm at the base, with brown bark up to a height of about 15 cm, can be used for this purpose. The stock plants require about four to five months to attain this size. By proper care, this period could be further reduced.

Green budwood is obtained from budwood plants (source bushes) grown in nurseries for this purpose. They are collected when six to eight weeks old, when they have a length of 30 to 60 cm with a whorl of leaves at the top. The bud shoots are harvested by cutting at the base with a sharp knife. For proper peeling of the bud patch, harvesting should be done when the leaves are copper brown to dark green in colour. After harvesting, the leafy portion of the shoot is cut off. The non-leafy portion shows two to five scale leaves with axillary buds which are utilised for budding.

After cleaning the basal portion of the stock, two vertical incisions, a little more than 5 cm long and 1 cm apart are made starting from a point about 2.5 cm above the collar region. The lower ends of these cuts are joined by a horizontal cut and a few minutes allowed for the cessation of latex flow. The flap is then cut off leaving a short "tongue" of about 1.5 cm at the top. The stock is now ready to receive the bud patch.

The bud patch can be stripped from the bud shoot in the same way as in the case of brown budding. However, other methods can also be employed for this purpose. In one such method, a 6 cm long bud patch shaped like a pointed tower is marked out. Then the top 1 cm is separated from the bud shoot and holding on to this portion (by touching the inner and outer sides), the whole bud patch is gently stripped off. The top 1 cm of the bud patch with damaged cambium is pruned off. In a third method the bud patch along with a thin slice of wood is first taken from the bud shoot. This is the bud slip. The two sides of the bud slip are trimmed to the required width. The bud patch is then gently separated from the wood by pulling them apart. While doing so, care should be taken to see that the bud patch does not bend.. After separation, the lower and upper ends of the bud patch are also trimmed. When finally prepared, the bud patch should have a length of approximately 5 cm and a width of 1 cm, so that it fits snugly into the budding panel.

The upper end of the bud patch prepared in the above manner is gently inserted under the `tongue' and placed in the budding panel. Then the bud patch is secured firmly by bandaging with a transparent polythene strip as in the case of brown budding. This strip should be about 25 cm long and 2 cm wide. Transparent tape is insisted upon as it allows light to fall on the green bud patch which in turn enhances budding success. For the same reason, no shading is given. Buds are examined three weeks after the budding by observing through the bandage or after removing the bandage. Retention of the green colour is the indication of budding success. Final observation on budding success is done after 10 more days. If the observations are made through the bandage, after the second observation, the bandage is removed. The plant is now ready for cutting back.

Budding can be carried out at any time of the year. However, too dry or very wet weather is unsuitable. Generally more success is obtained during rainy season than in summer. Experiments have shown that in India the period from April to October is generally suited for brown budding. The success rate of green budding is more during summer months also. However, heavy rainfall is not suited for budding. For best results, budding should be carried out either in the early morning hours or in the evenings.

Both brown budding and green budding have certain advantages and disadvantages.

Advantages of Green Budding over Brown Budding

i. It utilizes the growth of the stock more efficiently, i.e. when green budded plants are cut back, only a small amount of stock growth is lost,
ii. Green budding is simpler and faster than brown budding and hence more number of plants can be budded reducing the labour cost per budding,
iii. It gives higher percentage of success during summer than brown budding,
iv. Opening of the budding and cutting back can be done simultaneously, thus saving labour cost,
v. Yield of green buds from a unit area of nursery is two to three times that of brown buds,
vi. Since the polythene strip used for green budding is smaller, cost incurred for this material is reduced,
vii. After cutting back green buds develop earlier than brown buds,
viii. Green budding is more suitable for crown budding.

Major Defects of Green Budding Technique

i. Green bud shoots cannot be retained in the nursery for long after they become mature enough for harvesting,
ii. After harvesting, green sticks cannot be kept for long periods, unlike in the case of brown budwood
iii. Scion of green budding is less vigorous than that of brown budding and hence it requires very careful attention during the early period of growth, especially in the field.

c. Young Budding.

This is a kind of green budding carried out on very young plants less than two months old. Stocks are raised in small bags of lay flat size 33 x 15 cm. The plants are given intensive nursing such as foliar application of fertilisers and fungicides twice weekly and soil application of NPKMg mixture weekly. When seven to eight weeks old, they are green budded. Four weeks after budding, plants are cut back leaving a snag of 20 to 25 cm length. Buds on the snag are nicked or the shoots coming from then pruned off promptly. When the scion develops two or three whorls of leaves, the plants are transplanted to the field.

This technique has got certain advantages over the normal green budding technique. By adopting this technique bag plants could be produced within seven months after the planting of germinated seeds in the bags, which is usually done in August/September. In our country, the time required for this is around nine months in the case of normal green budding. Since small bags are used for the production of plants transportation is easier.

The cost of production is also slightly less compared to the normal method. Since the stock plants required for young budding are raised by sowing seeds directly in the bag, these plants have a better developed root system than the plants raised from green budded stumps. A well-developed root system prevents breaking of soil core and ensures faster and easier establishment of plants after transfer to the field.

However, under the climatic conditions existing in our country this method does not have much practical application because by the time the bag plants produced from young buddings are ready (February - March) the climate becomes unfavourable for field planting. Hence planting has to be delayed up to the onset of monsoon (June). Bag plants produced from green buddings also becomes ready by this time.

d. Crown Budding

Replacing the undesirable crown of a high yielding clone with a desirable crown is of practical significance. In many of the modern clones, though the trunk possesses a capacity for high yield, the crown shows many undesirable characters like susceptibility to wind and diseases. An undesirable crown can be replaced by a desirable one through crown budding. The tree produced by crown budding is a three- part-tree comprising the root system of the stock plant, trunk of one clone and the crown of another clone. Thus the desirable characters of the trunk of one clone and crown of another clone are combined.

Crown budding is ideally carried out when the scion of the budded plant has attained a height of 2.4 to 3 m. One to two years are usually required for the plants to attain such a growth. The height of the plant is more important than the age. Crown budding may be commenced when 50 to 60 per cent of the plants in the field are buddable. Budding is carried out at a height of 210 to 240 cm on the inter- whorl region below the top whorl of leaves. It should be done only when the top flush of leaves are fully expanded and hardened. Stem tissue should be green or dark green at the time of budding. This ensures maximum budding success.

Too tender or too mature stem tissues adversely affect budding success. If the topmost flush of leaves are not mature enough, budding could be done below the second whorl of leaves provided all other conditions are satisfied.

Plants having height up to 4.5 m can also be used for crown budding. In the case of such overgrown plants having green tissue at a height higher than the prescribed, the height of budding has to be raised correspondingly so as to carry it out below the top whorl.

For crown budding, the green budding technique is followed. Since the budding has to be done at a higher level, a self-supporting ladder should be used. On no account should the plant be bent for budding or any other operations. If the budding is a failure, rebudding is done on the opposite side of the stem, 5 cm above or below the first budding.

Successfully budded plants are cut back leaving a snag of about 5 cm. Treating the cut ends of the stem with some wound dressing compound is desirable. After cutting back, usually many trunk shoots arise. All of them should be pruned regularly at fortnightly intervals with a knife having a long handle. This should be continued until the crown bud sprouts and the crown shoot grows to a length of about 2.5 cm. After that, two or three trunk shoots arising about 15 to 45 cm below the crown shoot are allowed to grow. These shoots should be spaced apart and be on different sides of the stem as far as possible. They should never be allowed to become more dominant than the crown shoot, as this may suppress the growth of the latter. For this, if necessary, the top portion of the trunk shoots may be pruned. About nine months after cutting back, when the crown-trunk union is firmly established, the trunk shoots are pruned. Necessary precautionary measures have to be taken for the protection of the crown shoot especially from wind damage and perching of birds. The crown shoot later on fully establishes itself and in due course develops to be the crown of the three-part tree. If the crown shoot is lost for some reason before the pruning of the trunk shoots, the most vigorous among them is again crown budded, if possible, or allowed to develop as the crown.

e. Over Budding

Budwood plants are sometimes budded at higher levels for converting an existing budwood nursery of a clone to another clone without replanting. This is termed as over budding. The method adopted is to carry out budding at the basal portion of the brown budwood before harvesting it. The budwood is harvested after the new bud is successfully attached to the plant, by cutting above the budded portion. Since the budding is carried out on a well-established plant, the scion emerging from the new bud grows vigorously producing more budwood compared to a newly established budwood plant. Thus it is a quick and economic method for converting budwood nursery of one clone to that of another.

vii. Preparation and Packing of Propagation Materials

The propagation materials handled by rubber growers are ungerminated seeds, germinated seeds, seedling stumps, brown budwood, green bud shoot, brown budded stumps, green budded stumps, polybag plants and stumped buddings. Specific techniques are required for the preparation of these materials. If not properly prepared, their quality could be reduced, which in turn adversely affects the establishment after planting. After preparation, these materials may require storing and/or transportation. During storage and transit they are likely to get damaged by loss of moisture or by breaking, rubbing, bruising, crushing, etc. To avoid these and to give ample protection to these materials, certain specific methods are adopted for packing and transporting

.**Student Self Assessment Exercise 1**

1. Describe the soil requirements for the production of rubber.
2. Identify areas where rubber is grown arround the world.
3. What are rubber clones?
4. How are the clones produced?
5. What are the different methods of raising seedlings for a rubber planations?
6. Why is budding so important in rubber propagation?

3.8. **Land Preparation.**

In Nigeria, rubber plantations are established in the rain forest areas. Most of the areas available for rubber cultivation vary from gentle undulating slopes to flat land. The land needs to be cleared before planting rubber can take place. All the pre-planting operations should be completed before the onset of rain season. These activities include but not limited to the followings:

- Clearing Roads, Constructing Fences and Buildings
- Lining
- Terracing
- Drainage
- Construction of Silt Pits and Contour Bunds
- Pitting and Refilling

Lining

Lining should be based on plant spacing and planting density to be adopted. Rubber can be planted by adopting square or rectangular planting system. Square planting is suitable for level and near level lands. Rectangular system can be adopted in flat lands and slopes. In rectangular planting the lines should be oriented in the East West direction to intercept maximum sunlight. Contour lining is done in undulating and hilly areas where the slope exceeds 8 per cent. Here the planting points are marked as lines passing through points of the same elevation. The planting density recommended is 420 to 500 plants per ha in the case of buddings or plants proposed to be field budded and 445 to 520 plants per ha in the case of seedlings. Higher initial stand is recommended for allowing proper thinning out.

Terracing

On hilly and undulating terrain, cutting of terraces along the contour is a recommended practice to conserve moisture and prevent erosion.
The soil on the hill side is cut from a distance of 60-75 cm in front of the planting row and thrown back in such a way that the terraces so formed will have a width of 1.25 to 1.5 metre and an inward drop of 20-30 cm. Steps of uncut earth are left out at intervals along the terraces to check lateral flow of water. For economy, planting on hillside may be done on square platform of size 1.25 x 1.25 metre (honey comb terrace) during the year of planting and later on joined together to form a complete terrace.

Digging (Pitting) and Refiling of Field holes.

Pitting is necessary to provide an ideal medium for the proper growth of the young rubber root system. The standard size of the pit is 75cm x 75cm x 75cm. The size of the pits varies depending upon the planting material to be used. Stumped buddings need comparatively deeper and larger pits. Smaller pits are sufficient for small and medium sized polybag plants. In deep, loose and friable soils, pits are sometimes dug wider at the top and tapering towards the bottom or the depth is reduced to 60 cm with a central hole of 15 cm or more depth for taproot. But in hard, stony and compact soils, the pits should be widened.
Pitting should be started sufficiently early and filling should be completed well in advance of planting so that the filled soil will get sufficient time to settle. While digging, the topsoil is kept on one side and the subsoil on another side. Filling should be done with the top fertile soil as far as possible. The organic manure and phosphatic fertilisers applied to the pits should be mixed with the top 20 cm soil in the pit. The pits should be filled to about 5 cm above ground level. A peg is placed in the centre of the pit to locate the planting point.

Tractor - mounted hole digging machines are increasingly utilised for pitting. Machines which dig pits of 60 cm diameter and up to 90 cm depth are now available.

3.9. Field Planting

The success of planting depends on the prevailing weather conditions, quality of the planting materials used and the care with which the planting operation is done. Continuous wet weather can be expected during May- July in the major rubber growing areas in Nigeria and hence this period is considered to be ideal for planting rubber. The actual method of planting will depend on the materials used for planting. Different types of planting materials used are seeds, seedling stumps, budded stumps and polybag plants. Of these, the last two are the most common ones.

3.9.1. Intercropping

v During the initial years of a rubber plantation, the land area is not fully occupied by the rubber plants and inter spaces are available in the plantation which receive plenty of sunlight. These interspaces can be utilized for growing intercrops, which will help the farmer to generate additional revenue. Intercrops should be planted atleast 1.5 M away from plant bases. Intercrops should be separately and adequately manured.

The topography of the rubber plantations vary from level lands to gentle, moderate and steep slopes. The high rainfall in the rubber growing regions and the undulating topography in many situations make the soil vulnerable to erosion hazards. Growing of inter crops necessitates soil disturbing tillage operations of various kinds. This will predispose the top soil to erosion losses in steep and undulating lands. The growing of intercrops, therefore has to be restricted to level lands and gentle slopes. Even in such lands it should be ensured that leguminous cover crops are established side by side with intercrops or immediately after the intercropping is stopped. The general practice of growing leguminous ground covers has to be strictly followed in plantations of moderate and steep slopes.The common intercrops cultivated in Rubber Plantations include: banana, plantains, cassava, yams, pineapple and vegetables.

3.9.2. Mulching, Shading and Whitewashing

Mulching or covering the plant basin with dry leaves, cover crop cuttings, grass cuttings, paddy straw etc is a recommended practice in rubber plantations to protect soil in the immediate vicinity of the plants from direct impact of heavy rains and sunlight causing soil degradation. Dried African Payal (Salvinia sp.) also can be effectively used as mulch at the rate of 5 kg per square metre (sun dried material).

Benefits of Mulching

- Improvement of water and plant nutrient holding capacity of the soil.
- Maintenance of the soil around young rubber plants in a cool and moist condition during summer months.
- Multiplication of microbial population of the soil, ensuring better nutrient availability.
- Protection of the soil from beating effect of heavy rainfall resulting in soil erosion.
- Control of weeds around the plant bases.

Mulching should be undertaken in nurseries and young plantations after fertiliser application and before the onset of regular summer. Usually, November is the ideal time for mulching to protect the plant from adverse effect of drought.

During the year of planting young plants may be protected by shading before the beginning of summer. Plaited coconut leaves or used gunny bags can be used for this purpose. The brown bark of the young plants can be protected from the scorching action of the sun by whitewashing the main stem of the plant from the second year of planting. This may be continued till canopy of the plants develops and partially shades the plantation. However, plants on the roadsides may need whitewashing for a longer period as they are more exposed to sunlight. Whitewashing can be done using lime or china clay.

3.9.3. Diseases and Pests

Crop losses resulting from ravages of disease causing agencies in rubber plantations are substantial. Timely plant protection operations ensure healthy growth and economic production. The major diseases and pests of rubber are given below.

- Abnormal Leaf Fall
- Shoot Rot
- Powdery Mildew
- Colletotrichum Leaf Disease
- Bird's Eye Spot
- Leaf Spot
- Pink Disease
- Patch Canker or Bark Canker
- Black Stripe, Black Thread or Black Rot
- Dry Rot, Stump Rot Collar Rot or Charcoal Rot
- Brown Root Disease
- Poria Root Disease
- Scale Insect
- Mealy Bug
- Termite (White Ant)
- Cockchafer Grub
- Bark Feeding Caterpillar
- Mites
- Slug and Snail
- Rat
- Porcupines and Wild Pigs
- Cover Crop Pests
- Parasitic and Non-Parasitic Maladies

i.Shoot Rot

Causative Agent: *Phytophthora palmivora* (Butl.) Butl and *P.meadii* Mc Rae

Occurrence: Noticed during south west monsoon period. Occurrence is common during heavy rainfall periods.

Symptoms: The tender green shoots rot. This is more damaging for nursery seedlings and the young plants in the field.

Clonal Susceptibility: Clones, which are susceptible to abnormal leaf fall disease, are severely affected by this disease.

Control Measures: Prophylactic spraying as above for mature plants. For young plants in the nursery as well as in the field, spraying with copper fungicides before the onset of south west monsoon coupled with repeated spray rounds during bright breaks protect the plants. Phosphorus acid 0.16% (Akomin and Phosjet 4 ml/L) and metalaxyl Mz 0.2% (Ridomil Mz 2.77 g/L) are aslo effective. For ensuring proper sticking of the spray on tender foliage sticker (Sandovit, Tenac, Teepol, Triton AE etc) may be added at the rate of 0.5 ml/litre of spray fluid.

ii. Abnormal Leaf Fall

Causative Agent: *Phytophthora palmivora* Butl. *P. meadii* McRae. & *P.nicotianae var parasitica* and *P. botryosa* (Chee)

Occurrence: Annual recurrence during southwest monsoon period. Prolonged wet weather coupled with humid atmospheric conditions favour the disease. Disease incidence is less in Kanyakumari District, but increasingly heavy northwards along the southwestern coast.

Symptoms: First the fruits rot, later infected leaves fall in large numbers prematurely, either green or after turning coppery red. A black lesion may develop on the petiole with a drop of latex, often coagulated, in the centre. Lesion may develop on the midrib and leaf blades also. Heavy defoliation may lead to considerable loss of crop and die-back of terminal twigs.

Clonal Susceptibility: Clones like PB 86, PB 235, PB 260, PB 311, PB 28/59, RRIM 600, RRIM 628, RRIM 703, RRII 5, PR 255, PR 261 and Tjir 1 are susceptible to the disease. RRII 105, PB 217, GT 1 and GL 1 are clones showing some tolerant reaction to the disease.

Control Measures: Prophylactic spraying of the foliage prior to the onset of south west monsoon with (1) Bordeaux mixture using high volume sprayers or (2) Oil-based copper oxychloride dispersed in diluent spray oil employing either low volume airblast sprayers from the ground or through aerial application. For micron spraying, based on the tree spread, foliage intensity, planting material used and age of plants, two rounds of spray using about 17 to 22 litres of fungicide oil mixture per hectare per round (1:6 proportion) with a gap of 10 to 15 days or a single round of spray with about 30-40 litres of fungicide oil mixture per hectare (1:5 proportion) may be necessary. For aerial spraying 6.2 litres of 40% oil based copper oxychloride paste in 37 litres of diluent oil or 8 kg oil dispersible copper oxychloride powder 56% in 40 litres of oil is used per hectare. Spraying should be done as close to the monsoon as possible.

iii.Mealy Bug

Causative Agent: *Ferrisiana virgata* Ckll

Occurrence: Seen mostly in nurseries in all rubber areas

Symptoms: Soft bodied small insects with white mealy outer covering. Occurrence and damage similar to scale insects.

Clonal Susceptibility: Clones RRII 105 and RRIM 600 are affected

Control Measures: Spray Organophosphorus insecticides like malathion 0.1% (2 ml/l) or quinalphos 0.075% (Ekalux 25EC3 ml/L)

iv.Bark Feeding Caterpillar

Causative Agent: *Aetherastis circulata* Meyr. *Ptochoryctis rosaria* Meyr

Occurrence: Nagercoil, Nedumangad, Punalur, and Thrissur localities.

Symptoms: The caterpillars build galleries with faecal matter and silk all over the trunk region and branches of trees. Generally feed on dead bark and occasionally on live bark causing exudation of latex. Deep scar found at the regions of feeding.

Clonal Susceptibility: PB 86, PB 235 and PB 311 are highly susceptible clones.

Control Measures: When the infestation is severe apply Sevin 5% at the rate of 10 kg per hectare or Fenval 0.4% dust at the rate of 7 kg per hectare (provisional recommendation) with a power duster. Spraying the trunk with fenvalerate 0.02% (Tatafen 20 EC, Arfen 20 EC 1 ml/L) is also effective.

v.Termite (White Ant)

Causative Agent: *Odontotermes obesus* Rambur

Occurrence: Dry regions of Central Kerala (Thrissur & Palakkad) and non-traditional areas like Dapchari in Orissa.

Symptoms: Feeds on the dead bark of trees and young plants. Builds covered passageways of soil on the tapping panel and collection cup. Sometimes young plants dry up due to attack.

Clonal Susceptibility: Clones PB 86, Tjir 1and RRII 105 are affected

Control Measures: Drench the soil at the base of affected plants with Chlorpyriphos 0.1% solution. When mulch is present spray the mulch also

vi. Scale Insect

Causative Agent: *Saissetia nigra* Nietn.

Occurrence: Seen generally in young plantations and nurseries in almost all rubber areas.

Symptoms: Small insects with an outer black, dome-shaped covering. Occur on leaflets petioles and tender shoot portions and suck the sap, severely affected portions dry up and die. Ants and sooty mould are associated with this.

Clonal Susceptibility: Clones RRII 105 and RRIM 600 are affected

Control Measures: Natural enemies like insect parasites and entomogenous fungi keep this pest in check. When severe infestation is noted, spray Organophosphorus insecticides like Malathion at 0.05% concentration.

vii. Mites

Causative Agent: *Hemitarsonemus dorsalis*

Occurrence: Sporadic incidence on young rubber plants in nurseries.

Symptoms: Not a serious pest. Minute organisms with four pairs of legs. Suck sap from the leaves resulting in crinkling and shedding.

Clonal Susceptibility: Clones like PB 217, RRII 105 and RRIM 600 are susceptible.

Control Measures: Dust sulphur or spray sulphur 0.2% (Sulfex 80 WP 2.5g/L) or dicofol 0.05% (Kelthane 18 EC 3ml/L)

Nutritional Disorders Commonly Observed in Nigeria

Rubber plants are found to exhibit typical symptoms of nutritional disorders caused by deficient and/or excessive supply of individual plant nutrients. Deficiency symptoms due to lack of magnesium, potassium and in some isolated cases zinc and manganese have been observed in rubber nurseries and field plantings.

Magnesium deficiency is the commonly observed nutritional disorder. The characteristic symptom of magnesium deficiency is the development of chlorosis (yellowing) in the interveinal areas on exposed mature leaves giving rise a herringbone pattern. The deficiency incidences are seldom seen in Kanyakumari district and in the northern parts of rubber growing tract, consisting of Thrissur, Palakkad, Malappuram, Kozhikode, Kannur and Kasaragod districts.

Potassium deficiency is commonly found in rubber grown in highly impoverished soils. The characteristic symptom of potassium deficiency is the development of marginal and tip chlorosis which is followed by marginal necrosis. Only older leaves exhibit the deficiency symptoms. Size reduction of the leaves and the absence of herringbone pattern of yellowing allow potassium deficiency symptoms to be distinguished from those of magnesium deficiency.

Zinc deficiency causes interveinal chlorosis of leaves. The outstanding features of this deficiency are that the laminae become much reduced in breadth in proportion to their length and the young leaflet becomes incurved towards one another and present a hooked or claw appearance. Zinc deficiency incidences have been noted so far only in the case of young rubber plants either in the nursery or in the field. In most cases these deficiencies are noticed to be only transient. The cause of deficiency appears to be heavy application of phosphatic fertlisers resulting in poor availability of Zinc.

The typical manganese deficiency symptom is an overall paling and yellowing of the leaf with bands of green tissue outlining the midrib and main veins. Though this deficiency is widespread, it has been found to be only very mild in intensity.

Apart from these disorders connected with nutrition, problems such as pre-coagulation of latex on the tapping panel and excessive drainage of latex causing dryness of trees have also been reported from rubber plantations. The pre-coagulation of latex on the tapping panel has been found to be due to excessive supply of magnesium to rubber. Also, there are indications to believe that unbalanced nutrition can cause excessive drainage of latex resulting in the dryness of trees.

The incidence of nutritional disorders mentioned above is known to affect the growth and productivity of rubber to a great extent. Therefore, the planters are advised to consult the Rubber Research Institute of Nigeria if any of these disorders is noticed in their plantations and to take necessary preventive measures without delay.

Student Self Assessment Exercise 2

1. What are the major diseases of rubber?
2. Discuss any five of the major diseases of rubber and how best to treat them.

3.9.4. Weeds and Weeds Management

Methods of Weed Control

Rubber plantations are infested by various weed species throughout the year and present major problems of access and competition. Weeds compete with rubber for light, soil moisture and nutrients and also serve as alternate hosts for insects and pathogens. Therefore, management of weeds is an important cultural operation to be followed in rubber plantations.

In the newly cleared areas, the growth of weeds is fast as the soil and climatic conditions are favourable. Maintenance of a luxuriant ground cover in the early phase of plantation can minimize the weed infestation to a great extent. However, during the first year till the cover crops are fully established, the weeds that are sprouting around the cover crops patches should be controlled for their early establishment. Once the ground cover is established, the weed management operations need be concentrated only on the planting strips. Management of weeds can be done either manually or with the use of post emergent herbicides as mentioned earlier, depending upon the conditions and the nature of weed flora.

It is worthy of note that as the trees grow old, the foliage is at a great height from the ground which permits more sunlight into the inter row spaces. As a result, weeds reappear, which can be controlled either by slash weeding or by the use of herbicides. Weeds can be controlled by either manual methods or with the use of chemicals known as herbicides. However, an integrated method involving a combination of these two methods is more economical and eco friendly.

i. Manual Weeding

This involves slashing, scraping, uprooting etc. As manual clean weeding will expose soils to erosion, mulching should be done immediately after weeding.

ii. Chemical Control

Weeds can be controlled with the use of herbicides or weedicides. There are two main types of herbicides, the pre-emergent and post-emergent herbicides

Pre-emergent Herbicides

Pre-emergent herbicides are soil-applied chemicals used for killing weeds before they emerge from soil. In newly prepared planting strips, the application of pre-emergent herbicides immediately after planting can check the weed growth for 6-7 weeks.

Post-emergent Herbicides

These herbicides are applied on the weeds and are used to kill the **weeds, which have emerged and are actively growing**.

Schedule of Manual Weed Management Operations		
Year of planting	**Operations recommended**	**Rounds per year**
1st year	Overall manual weeding in inter rows and planting strips	4
2nd year	Manual weeding on planting strips - Overall weeding including uprooting of noxious weeds	5
3rd year	Manual weeding on planting strips - Overall weeding in the inter rows	4
4th year	Manual weeding on planting strips - Overall weeding in the inter rows	4
5th and subsequent years	Overall weeding including weeding in the planting strips	2

iii. Integrated Weed Management

This approach involves an integration of manual and chemical weed control methods along with the establishment of cover crop during the first year itself which helps in smothering weeds in the inter spaces and thereby reducing the usage of herbicide to the minimum. Application of herbicides in the plant basin alone and slash weeding the remaining inter plant area along the planting strip was found to be cost effective and sustainable.

Recommended Doses and Combinations of Herbicides				
Name of the chemical (Brand name in brackets)	**Dose/ha**	**No. of rounds per year and interval requiredbetween rounds**	**Target** weedspecies	**Volume per effective ha.**
Paraquat (Gramoxone) and 2,4,D (Fernoxone)	2.25 litres 1.25 kg	4 rounds at an interval of 6-8 weeks	Broad leaf weeds like Chromolaena sp. Borreria sp.	500-600 litres
Glyphosate(Glycel Weed off or Round up)	2 litres	2-3 rounds at 3 months interval and spot application of 0.5 to 2.5 litres Gramoxone per ha	Grass weeds and, overall weed control	400 litres

3.9.5. Sowing of Cover Crop Seeds

Pre-sowing Treatment of Seeds

Seeds of cover crops have very hard seed coat which delays or inhibits germination. Therefore pre-sowing treatment is done to ensure uniformity and higher percentage of germination. This also helps in reducing the toxic compounds present in the seed coat, which inhibit the nodule forming bacteria.

Common Pre-sowing Treatments

i) Acid Treatment
Seeds are treated with concentrated sulphuric acid for a period of 10 minutes for P. phaseoloides, 30 minutes for M. bracteata and 20 to 30 minutes for C. mucunoides. The seeds are put in a glass or any other acid resistant container and stirred after adding sufficient concentrated sulphuric acid. The seeds thus treated should be placed in a large container having cold water and washed well to remove the acid completely. Acid treatment may adversely affect C. pubescens seeds. Acid treated seeds can be stored under dry conditions for about 10 days.

ii) Hot Water Treatment
This method is suitable for the seeds of P. phaseoloides and C. mucunoides. The percentage of germination may not be as high as in acid treatment. Hot water treatment

is carried out by soaking cover crop seeds in hot water at 60 - 80oC for a period of 4 to 6 hours before sowing.

iii) Abrasion Treatment
Abrasion treatment is done by mixing the seeds with sand (about 1-2 times the quantity of seeds) and then grinding them gently in a mortar. Scarification of seeds by rotating in drums lined with sand paper can also be adopted. After treatment, the seeds may be soaked in water overnight before sowing

The pretreated seeds are mixed with equal quantity of rock phosphate and sown in rows or in equidistant patches between the plant rows. The planting patches should be clean weeded and forked well. In drought prone areas, for the establishment of cover plants, the germinated seeds may be sown during January or February in coconut husks filled with soil and the plants allowed to grow under shade till the pre-monsoon showers are received. The plants with husks should then be planted in prepared patches in the main field. The young cover plants in patches should then be protected from weeds for four to five months. Cattle grazing and cutting away of the crop for fodder purpose also should be avoided for ensuring the proper development of the ground cover.

Cover crops are generally established from seeds. However, *P. phaseoloides and M. bracteata* can also be propagated by stem cuttings.

Cover crops established in patches will spread very rapidly and cover the intervening spaces, smothering the weeds in most cases within a year. Cover crop should not be allowed to grow in a circle of about 2 metres diameter around the plants or along the contour terraces for 3 to 4 years to prevent its competition with the young rubber.

Common Leguminous Cover Crops Grown in Rubber Plantations

i) Pueraria phaseoloides.

This is a very popular cover crop in rubber plantations. It is a vigorous twiner and creeper and forms a dense thick ground cover when established. It can withstand strong sun and smother weeds. It is propagated through seeds and cuttings. Seed rate about 3.0 to 4.5 kg per ha. A disadvantage is that it is grazed by cattle unless afforded protection.

ii) Mucuna bracteata.
It is a deep-rooted fast growing legume with moderate drought resistance and shade tolerance. A native of Tripura, it forms a thick luxuriant cover and suppresses all weeds. The dried leaves form thick mulch that smothers weeds. Propagation of *Mucuna bracteata* is through seeds and rooted cuttings. The seeds are comparatively big and the seed rate is 200g/ha. Fruits are covered by stinging hairs. However the plant does not bear fruits in low elevation situations.. Fruit set is copious in low temperature conditions as in winter.

iii) Calopogonium mucunoides.
It is a twiner and creeper with tolerance for poor soils. It has a rapid initial growth and dies off during the dry months and is a prolific seeder. Seed rate is 3.0 to 4.5 kg. per ha.

iv) Centrosema pubescens.
This is a perennial climber and creeper that can grow in shade. It grows slowly and is not tolerant to wet conditions. It smothers weeds. Seed rate is 3-4.5 kg per ha

Advantages of Cover Crops

1. Prevent the beating action of rain and effectively reduces run off
2. Increase soil moisture and keep down the temperature during summer
3. Smother weeds
4. Add large quantities of organic matter and improve soil structure
5. Fix atmospheric nitrogen resulting in improved soil fertility

3.9.6. General Fertiliser Recommendation

The general fertiliser recommendation for rubber is derived based on the results of the fertiliser experiments conducted by the Rubber Research Institute of India on rubber of different age groups. Majority of the rubber growing soils belong to the laterite and lateritic types and hence this general fertiliser recommendation can be followed. However, practicing discriminatory fertiliser recommendation based on soil and leaf analysis will be more advantageous.
The nutrient requirements of rubber plant vary considerably during the three important stages of growth; the nursery, immature and mature stages. The table that follows is fertilizer recommendations for the first four years of the plantation life.

Mature Rubber under Tapping

The general recommendation is 30-30-30 NPK kg/ha. This can be supplied through mixing straight fertilisers or through mixtures. The quantity of the same is provided in an earlier session (manuring from 5th year till attainment of maturity for well maintained plantations). Discriminatory fertiliser application based on the results of soil and leaf analysis should be practiced for mature rubber wherever it is possible.

Method of Application
Fertilisers should be applied in square or rectangular patches in between rows, each patch serving four trees. Once the canopy of the plants closes, say, 5 to 6 years after planting, light forking to incorporate the fertilisers into the top soil is necessary. In areas where the legume ground cover is present or where the legume cover has died out leaving a thick mulch, it is enough to broadcast the fertilisers between two rows of rubber trees. Deep pocket placement of fertilisers and application too close to the base of the trees should be avoided.

Schedule during the initial period of immaturity						
Year of planting	Month after planting	Time of application Std	Dose of NPK mixture per plant (g)		Quantity of mixture per ha with 440-450 plant points (kg)	
			12-12(6)-6	12-12-6	12-12(6)-6	12-12-6
1st year*	2-3 weeks	Apr - May	280	---	125	---
	3 months	Sep - Oct	500	---	225	---
2nd year	9 months	Apr - May	500	---	225	---
	15 months	Sep - Oct	500	---	255	---
3rd year	21 months	Apr - May	---	600	---	270
	27 months	Sep - Oct	---	600	---	270
4th year	33 months	Apr - May	---	475	---	215
	39 months	Sep - Oct	---	475	---	215

3.9.7. Induction of Branches

It has been observed that to achieve a high rate of girth increase the rubber plant should produce branches at a height of about 2.5 to 3.0 m from the ground. In high branching trees girth increment has been found to be poor compared to low branching trees. Some plants show a tendency for high branching, particularly clones like RRIM 600 and GT 1. In such cases branching has to be induced by encouraging a few lateral buds to develop. The branches thus induced should develop in different directions in an equally spaced manner to ensure a well-balanced canopy. Techniques like the double blade ring cut device and the leaf cap method can be utilized for this.

The double-blade ring-cut device has two V-shaped blades fixed 20 cm apart on a rod. By pressing the V-shaped blades and rotating them around the trunk complete ringing of the bark is done down to the surface of the wood. The cuts are made above a cluster of leaf scars so that a number of trunk shoots is produced around this region. This method can be applied only on greenish brown or brown tissues and is not suitable for young green tissues. In young green tissues, the leaf folding or leaf cap method can be used. In the leaf folding method, the leaves of the top whorl are folded down at the point of contact of the petiole with the lamina using only the upper few leaves to enclose the apical bud. The leaves are then tied with a rubber band. After three to four weeks they are released. In plants where the terminal whorl of leaves is in the leaflet or bud break stage, the leaf cap method is recommended. Here, three mature leaflets are taken to form a cap to enclose the terminal bud and tied with a rubber band. The cap is then removed three to four weeks later.

3.10. Tapping and Simulation

Latex is obtained from the bark of the rubber tree by tapping. Tapping is a process of controlled wounding during which thin shavings of bark are removed. The aim of tapping is to cut open the latex vessels in the case of trees tapped for the first time or to remove the coagulum which blocks the cut ends of the latex vessels in the case of trees under regular tapping.

Bark. This consists of an inner layer of soft bast, an intermediate layer of hard bast, and an outer protective layer of cork cells can be distinguished in the rubber tree. The vessels are concentrated in the soft bast arranged in a series of concentric rings of interconnecting vessels. The number and distribution of latex vessels and the proportion of hard bast show much variation from tree to tree in seedling population. Such wide variations generally do not occur in a population of budded trees of a clone.

Latex. *Hevea* latex in the latex vessels of tapped trees contains 30-40 per cent rubber in the form of particles. Latex is a hydrosol in which the dispersed particles are protected by a complex film. It contains more than one disperse phase. Besides rubber particles, the latex contains certain other particles like lutoids and frey wyssling particles. Lutoids are associated with the process of latex vessel plugging which stops the flow of latex a few hours after tapping.

Latex Flow. When the tree is tapped and the vessel is cut the pressure at the location of the cut is released and viscous latex exudes. This exudation of latex would result in the displacement of latex along the length of the latex vessel and laterally owing to strong forces of cohesion existing in the liquid phase. This would result in a fall in pressure in the vessels leading to entry of water from surrounding tissues which makes the latex more dilute. The dilution would make the latex less viscous. Subsequently disturbances in the osmotic concentration in latex vessel would cause damage of lutoid particles. Damage of lutoid releases a protein named 'hevein' which forms cross link between rubber particles resulting in coagulation of latex at the cut ends of latex vessels. This leads to plugging of the vessels and cessation of latex flow. Hevein binding is most efficient in acidic pH.

Standard of Tappability and Height of Opening. Budded plants are regarded as tappable when they attain a girth of 50 cm at a height of 125 cm from the bud union. In seedlings, the first opening for tapping is recommended at a height of 50 cm when the girth is 55 cm. If opening at a higher level is preferred, the seedling trees can be opened at a height of 90 cm when the girth at that level is 50 cm. In a budded tree. subsequent panels are also opened at the same height i.e., 125 cm. The height specified for opening subsequent panels on a seedling tree is 100 cm.

It will be generally economic to begin tapping when 70 per cent of the trees in the selected area attain the standard girth. In the traditional region it takes an average of seven years to reach this state. Planting of advanced materials like polybag plants reduce the immaturity period.

In India, the best period to open new areas for tapping is March-April. The trees that are left behind during the season for want of sufficient girth may be considered for opening in September.

Tapping Systems. Response to different tapping systems varies from clone to clone. In general budded trees are tapped on half spiral alternate daily (1/2S d/2) system and seedlings on half spiral third daily (1/2S d/3) system. Alternate daily tapping is the recommended frequency for medium yielding clones (RRIM 600, GT 1, PB 28/59 etc). For high yielding clones like RRII 105, PB 260, PB 217 etc, low frequency tapping systems with stimulation may be practiced. However, low frequency tapping can be adopted for medium yielding clones also. (See description on low frequency tapping)

Tapping Notations

Tapping notations are sets of symbols and numbers describing mode of tapping and its frequency. An internationally recognised system is in existence. This consists of three parts to indicate

1. Tapping method
2. Panel position and type
3. Stimulation followed for cut tapping and puncture tapping

The notations for tapping method include notations for type of cut, length of tapping cut, direction, frequency etc.

Some Examples

S :One full spiral cut
V :One full V-cut
½ S :One-half spiral cut
¼ S :One-fourth spiral cut
2 X ¼ S :Two one-fourth spiral cuts on the same tree
½ S up :One-half spiral cut tapped upwards
2 X ½ S down :Two half spiral cuts, one tapped upward and the other tapped downward
d/1 :Daily tapping
d/2 :Alternate daily tapping

d/3	:Third daily
d/2 6d/7	:Alternate daily, six days in tapping followed by one day rest.

Standard system is taken as ½ S d/2 and intensity is taken as 100%.
Relative intensities of others are worked out by multiplying the fractions in the notation and then multiplying the product so obtained by 400.

Example: ½ S d/3 : ½ X 1/3 X 400 = 67%

Panel Notation
Panel is the area of bark in which tapping cut is located. Panel notation indicates the panel position and renewal succession of the panel. This helps to describe tapping.

Common Panel Notation

Old Notation	New Notation	Description
A	B0-1	First basal panel of virgin bark
B	B0-2	Second basal panel of virgin bark
C	BI-1	First renewed bark of B0-1
D	BI-2	First renewed bark of B0-2
E	BII-1	Second renewed bark of B0-1
F	BII-2	Second renewed bark of B0-2

First, second, third and fourth high panels of the virgin bark above the standard height of opening are indicated by HO-1, HO-2, HO-3 and HO-4 respectiveley. Renewed bark is usually not tapped in high panels.

Low Frequency Tapping (LFT)
Survival of natural rubber industry is being threatened by low and fluctuating prices, escalating cost of production and scarcity of skilled tappers. Tapper wages constitute a major component of cost of production. In view of the situation, low frequency tapping systems, which judiciously combine stimulation, is favoured in most countries. From the d/2 system, the initial shift was towards d/3, with a subsequent shift to d/4 system. Weekly tapping (d/6) has also been attempted.

Trees under low frequency tapping (d/3, d/4 & d/6) have to be stimulated from opening onwards for achieving maximum sustainable yield. Number of stimulations to be given vary with clone, age of the tree and frequency. In high yielding clones like RRII 105 and PB 217 under third daily (d/3) tapping frequency, 15 to 30% sustainable yield increase can be achieved by three annual stimulations (April, September and November). In the case of medium yielding clones like RRIM 600 and GT1, four annual stimulations (April, August, October and December) are recommended under third daily (d/3) tapping frequency.
Comparable yield to that under d/3 frequency of tapping with stimulation can be achieved from d/4 frequency of tapping. Six annual stimulations (April, June, August, September,

November and December) are recommended for clone RRII 105 and five (April, June, August, October and December) for clone PB 217. In the case of clone GT 1, seven annual stimulations (March, April, June, August October, December and January) have to be given.
For weekly tapping of clone RRII 105 fortnightly stimulation is to be given in the initial two years after opening, and monthly in the subsequent years. When trees which have undergone higher frequencies of tapping for the initial two or more years are converted to weekly tapping, fortnightly stimulation need not be done. In such fields monthly stimulation may be followed.
Stimulation recommended is 2.5% Ethephon on the panel in all the above cases.
Low Frequency Tapping (LFT) with stimulation can be practiced from the first year of tapping. Trees under high frequencies of tapping can also be converted to LFT. Conversion to d/3, d/4 or d/6 frequency will result in substantial saving in cost of production. However, when such conversions are done there will be atemporary yield depression for 3-4 months. Hence, such conversion may be done during lean months (Feb-April)
Under d/4 frequency, one panel can be tapped for at least 8 years and under d/6 frequency the duration can be increased further to 10 years. Combined with CUT, economic life can be increased to at least 50 years from the current 30 years provided sufficient stand exists. When tapping is done by the grower himself, weekly tapping with rain guard would be most appropriate.

Benefit to tappers from low frequency tapping is also substantial through increased over poundage. This will lead to substantial increase in the standard of living of tappers. While adopting low frequencies of tapping it may be ensured that tapping is done regularly with rain guarding. Under the agro climatic conditions in some areas, d/3 frequency of tapping with stimulation can be practiced without rain guarding. However, for d/4 and d/6 frequencies of tapping, rain guarding has to be practiced in this region also. Whenever tapping is not done due to absence of the tapper or holiday, the field/block scheduled for such day/s should be tapped on the next day. If such blocks are tapped on the 8th or l2th day, there will be severe temporary reduction in yield. Delayed/second collection has to be done for around six months. If DRC falls below 30%, stimulation may be suspended, till it is improved.

Schedule of Stimulant Application under Low Frequency Tapping

Clone	Tapping System	No/Year	Schedule
RRII 105	1/2S d/3 6d/7	3	Apr, Sept, Nov
RRII 105	1/2S d/4 6d/7	6	Apr, June, Aug, Sept, Nov, Dec
RRII 105	1/2S d/6 6d/7		All months*
PB217	1/2S d/3 6d/7	3	Apr, Sept, Nov, (No Stimulation in the initial two years)
PB217	1/2S d/4 6d/7	5	Apr, Jun, Aug, Oct, Dec
GT1	1/2S d/3 6d/7	4	Apr, Aug, Oct, Dec
GT1	1/2S d/4 6d/7	7	Mar, Apr, Jun, Aug Oct, Dec., Jan

RRIM 600 1/2S d/3 6d/7 4 Apr, Aug, Oct, Dec

* Fortnightly stimulation in the initial two years.

NB:

1. Diluent- Palm oil/coconut oil
2. 5% lace application before third tapping after opening
3. All the above recommendations are applicable under rain guarded condition except d/3 frequency in Kulasekhararn)
4. Stimulation may be done between 48-72 hours before tapping

Intensive Tapping
Intensive tapping is generally done on old rubber trees for a few years prior to their removal. The methods of intensive tapping depend on the condition of the trees, previous tapping systems, availability of the bark and the period available for exploitation before felling. The methods employed are increased tapping frequency, extension of tapping cut, opening of double cuts and use of yield stimulants. While opening two cuts at the same time, the cut should be sufficiently apart at least by 45 cm to avoid the interference of drainage area between the cuts.

High Level Tapping
When tapping of renewed bark on basal panels becomes uneconomic, new cuts are opened at higher levels, 180 cm from bud union or even higher.
The tapper uses a small ladder to reach the cut. Since ladder tapping is more strenuous and time-consuming, usually reduced tapping tasks are given (135 trees).

Controlled Upward Tapping
Controlled upward capping (CUT) can be practiced for longer exploitation of the virgin bark above the basal panel. In CUT instead of using ladder, a long handled modified gouge knife is used for upward tapping from the ground. Bark consumption is minimised as far as possible. Higher yield can be obtained for many years as there is neither any bark-island effect nor any injury to cambium. CUT can be adopted in plantations under the following situations

1. Low yield from the renewed bark
2. Renewed bark is unsuitable for tapping because of outgrowths, diseases, panel dryness etc.
3. For prolonged exploitation of high panels or for prolonging economic life after the completion of B1-2 panel (D Panel).
4. For simultaneous tapping of both basal and high panels (intensive tapping) for one or two years while in B I-1 and B I-2 stage.

In the first two situations CUT can be adopted after completion of tapping in virgin bark. For CUT, the tapping cut is opened on the virgin bark just above the renewed bark of the base panel. The tapping cut can be 1/4 spiral and its slope 450. Length of the tapping cut would depend on the duration for which controlled upward tapping is to be done. Normally with alternate daily tapping, one panel can be tapped for two years (24 months). Thus with 1/3 spiral cut tapping can be done for six years. The duration can be increased with 1/4 spiral cut. There are many practical problems associated with 1/2 spiral cut and hence it is better to tap quarter or one-third spiral cuts. Experience has shown that it is better to open 1/4 spiral cuts irrespective of girth. Tapping is done on the upper cut with maximum control on bark consumption (not to exceed 3 cm/month) and maintenance of the angle of cut at 450. Injury to cambium should be avoided. For CUT, modified long handled gouge knife must be used. With this, it is easier to minimise bark consumption and to reduce injury to cambium. Another advantage of the knife is reduction in spillage. Length of the handle is 120 cm for tapping up to 40 cm height of the high panel and 180 cm for tapping beyond that height. While tapping, left hand guides the knife and active movements are made by the right hand. The left hand should not be raised above the shoulder and right hand above the elbow.

In CUT, monthly bark consumption is around 3-4 cm in the lower half of the panel and 4-5 cm in the upper half of the panel. If necessary, the support cut may be cleaned at times to prevent spill over. Since it is difficult to rainguard the panel it is advised to rest the panel during rainy season. The best system is periodic panel change i.e. no tapping on upper panel during rainy season (approximately 5-6 months) during which the base panels can be tapped with rainguard. Thus with tapping rest on high panel during rainy season, one high panel can be tapped for minimum of 3 years, leading to increased duration of exploitation on high panel.

Tapping cut in the high panel can be stimulated using 5% ethephon following lace application method. In a year 3-5 monthly applications can be done for 1/2 spiral cuts, while for 1/3 and 1/4 cuts monthly applications can be followed. For 1/2 spiral and 1/3 spiral cuts stimulation has to be avoided during wintering and extreme drought. For quarter spiral cuts stimulation can be done during winter also. However, stimulation during extreme drought may be avoided. When very good yield is obtained from high panel, stimulation need not be done, When tapping is done only in the high panel, for 1/3 or 1/4 spiral cuts, task size can be the same as that for a half spiral cut in the base panel. When simultaneous tapping of high and base panels are done, it is better to tap quarter or one third spiral cut in the high panel. The task can be 50%.

Special training of 3-5 days is required to use the modified gouge knife and to tap without raising the hands above the shoulder.

The tapping frequency for CUT is the same as that of base panel i.e. d/3 frequency for high yielding clones and d/2 frequency for medium and low yielding clones. The best system for CUT in Kerala is periodic panel changing, with base panel tapping with rainguard during rainy season and CUT on high panel during non-rainy season, Around 5O% increase in yield can be achieved by adopting CUT.

Marking. Panels are marked on the trees selected for tapping, using a template and marking knife, parallel to the contour terrace or planting line to facilitate efficient tapping operation. The template is made of a strip of flexible metal, preferably GI sheet (of low carbon content). The width of template will depend on tapping frequency. i.e. under d/2 tapping 23 cm, d/3 - 17 cm d/4 - 15 cm and d/7 - 13 cm. Separate templates are required for seedlings and buddings and should be made in such a way that when used to mark, the slope of the cut should be 250 for seedlings and 300 for buddings.

After deciding the position of the panel, a vertical line, called front channel line, is drawn. On this line, the opening height is marked. Since half spiral tapping is the standard, the half circumference of the tree at the opening height is determined using a measuring tape or string and marked on the back. Another vertical line, called back channel line, is marked on the half spiral point above the opening height. With the aid of the template placed between these two lines, at the opening height, ensuring a high left to low right, the line for tapping cut and a few guidelines are marked through the grooves. The vertical front end of the template should be kept on the front channel of the tree, parallel to it and the free end of the template is wound on the trunk towards the left side. After marking the guidelines, spout and cup hanger are fixed. The marking should be repeated annually.

Slope and Direction of Tapping Cut. The tapping cut of the budded trees should have a slope of about 300 to the horizontal. For seedling trees the cuts need to have a slope of only about 250, since the bark is fairly thick. A very steep cut leads to wastage of bark when tapping reaches the base of the tree and too flat a cut leads to overflow of latex. The slope should be marked, preferably annually, using appropriate template.

A woman harvesting rubber.

The latex vessels in the bark run at an angle of 3-50 to the right and therefore a cut from high left to low right will open greater number of latex vessels.

The extraction of latex from a tree;

Tapping Depth, Bark Consumption and Bark Renewal.

The best yield is obtained by tapping to a depth of less than one millimetre close to the cambium since more latex vessels are concentrated near the cambium. Shallow tapping results in considerable loss of crop. To obtain optimum yield, at the time of tapping care should be taken not to injure the cambium. However, minor tapping wounds which will heal in due course need not be considered as serious in the case of medium and low yielding clones.

To restart flow from a tapping cut in a subsequent tapping, all that is needed is to cut a thin shaving of the bark along with which the plugs of coagulated latex are also removed. Latex flow ceases when latex gets coagulated, clogging the cut ends of the latex vessels in turn with minute plugs of coagulated latex.

The rate of bark consumption will depend much on the skill of the tapper. For obtaining optimum yield, it is preferable to consume about 20-23 cm of bark annually on 1/2S d/2 system without rest period. However removing bark shaving thicker than what is necessary does not increase the latex yield but only wastes the bark.
Bark regeneration is brought about by the activity of the cambium. The rate and extent of renewal are dependent on the inherent genetic characters of the planting materials, fertility of the soil, climatic conditions, tapping system and intensity, planting density, and disease incidence.

Time of Tapping and Tapping Task. It is necessary to commence tapping early in the morning, since late tapping will reduce the exudation of latex due to increased transpiration by the trees leading to lower turgor pressure in latex vessels. Such reduction is more marked in the summer months. For pre-dawn tapping, headlights are used.

The number of trees allotted to a tapper for a day’s tapping is known as tapping task. Task size is fixed on the basis of stand of trees per ha and topography of land. Normal tapping task in India varies from 300 to 400 trees. Task size is reduced when double cut or other intensive systems are adopted.

Rainguarding. During rainy season tapping can be carried out by fixing polythene rainguard to the trunk above the tapping cut. About 35-40 additional tapping days could be obtained every year by rainguarding the trees. But chances of bark rot disease are high when the trees are rainguarded and tapping is continued during rainy season. Hence systematic application of panel protectants at frequent intervals is necessary. Raingurding is recommended only in areas where the yield is 675 kg/ha/annum or more and 25 or more tapping days are annually lost by ain.

By fixing a suitable channel on the trunk just above the tapping cut, flow of water through the main trunk can be channelled out. This method is found to be effective in keeping the tapping cut and the bark below in dry condition during the rainy season. Tapping under ***r ainguarding rubber trees***

1/2S d/3, d/4 or d/7 frequency will be successful only when rainguarding is done.

Four types of rainguard, viz. polythene skirt, ‘Tapping Shade’, ‘Guardian Rainguard' and ‘Tapping Shield' are recommended and popularised.

Frill the polythene at equal distance using a sewing machine, ensuring smaller frills and 40 per cent reduction in length. Gentle scraping to remove dry and flaked bark is carried out on a band of the bark 10-15 cm above and parallel to the tapping cut and extending 15 cm from the back and the front channels respectively. A thin coating of a bitumen-based adhesive is smeared on the scraped portion (3-4 cm width). Frilled polythene of 300 gauge thickness and 45 cm width is then fixed where the adhesive has been applied. A strip of 2 cm wide ‘cora’ cloth or polythene ribbon is placed and stapled at four or five points, covering the upper edge of the frilled polythene. Then another coating of the adhesive is applied so as to make the rainguard leak proof.

Materials required to rainguard 300 trees (average size) following polythene skirt method are:

1. LDPE polythene 300 gauge, 45 cm wide - 12 kg
2. Bituminous rainguard compound - 30 kg
3. Cora cloth - 6 m
4. Staple pins (No. 10 for virgin bark and 24/6 for renewed bark) - 2000 Nos. (2 box)

Ready to use quality rainguard adhesive should be used for fixing. Bituminous adhesive should not be heated by applying fire or mixed with kerosene to make it loose.

Tapping Rest. During refoliation and flowering of rubber trees, the yield will be comparatively poor and normally trees are given about four weeks rest if the soil is very dry and yield is uneconomic

Slaughter Tapping. Highly intensive tapping prior to replanting is the last stage in the tapping cycle and is called slaughter tapping. Tapping on the renewed bark at the lower levels may not be economic at this stage. Therefore slaughter tapping is often done at higher levels, sometimes even on branches, with the help of ladders. As the objective of slaughter tapping is to extract as much latex as possible from the available bark, no consideration is given to the technique, intensity or standard of tapping. It may not be economical to use stimulants during slaughter tapping, because it will not be appreciable on account of the very high intensity of tapping adopted. Rainguarding also being out of question, slaughter tapping is best resorted to during relatively dry months. If needed, rainguarding using 90 cm polythene has to be done.

Owing to high labour requirements and therefore high costs, slaughter tapping will not find favour in times of low prices of rubber. It is generally carried out by contract labour, on piece rate systems. Many contractors buy old rubber trees both for slaughter tapping as well as for timber.

Productive Life of Rubber Trees

Under regular alternate daily tapping (d/2), each basal panel of budded trees can be tapped for five years. Thus from B0-1 to BI-2 panels, crop harvesting can be continued for at least 20 years. BII panels are not suitable for economic exploitation. If slaughter tapping is resorted to after BI-2, the total productive period will be 22 years. If CUT (1/4 S up) is adopted, the productive period can be extended up to 28 years. However, if LFT and CUT are adopted, the life can be extended upto a maximum of 45-50 years depending on frequency of tapping. Overall, the assessment of productive life of rubber trees will depend not only on tapping practices, but also on other factors like price of rubber and wood, availability of new high yielding clones, management practices, policies etc.

Tapping Implements. The main implements used for tapping and collection of latex are knives, spouts, cup hangers, collection cups, collection buckets and scrap baskets.

In Nigeria, two types of tapping knives are used. One of them, the ‘Michie Golledge’ knife is common and widespread. The other one is the ‘Jebong’ knife, commonly used in Malaysia, is more suitable for speedy and easier tapping but with a slightly higher bark consumption. It is now gaining popularity. A third type called modified gouge knife is in use mainly for controlled upward tapping (CUT).

Spout is a metal piece made of galvanized iron (GI) or tin sheet (5 X 3 cm size) bent all along into a V-shape. It is driven into the bark, its length a few inches below the front end of the tapping cut to guide the latex into the collection cup. While fixing the spout, it must be ensured that the cambium is not injured.

Cup hangers are used to keep the collection cups in place below the spouts. They are made of GI wire and tied on the trees with the help of plastic thread. In order to avoid frequent replacement of spout and cup hangers and to increase the efficiency of rainguards, it is advisable to fix them at the half mark of annual bark consumption.

Coconut shells were widely used as collection cups. These are now almost completely replaced by higher capacity (400 – 900 ml) and cleaner plastic cups. Scrap baskets are used for collection of field coagulums or scraps such as tree lace, cup scrap etc. GI buckets are commonly used for carrying away the latex from the field.

Chemical Methods for Yield Increase, Certain chemicals can induce ethylene formation in the plant tissue while certain other groups of chemicals can generate ethylene directly by decomposition. Between the two types of chemicals tested, Ethephon of the second type containing 2-chloro-ethyl phosphonic acid as active ingredient, has proved to be a very potent yield stimulant. There is yet another ethylene generating chemical in which ethylene gas is absorbed in a special powdered material and compounded with suitable viscous carriers. Ethad (R) is one such experimental compound developed by Rubber Research Institute, Malaysia.

Recommendations on Yield Stimulation. Under low frequency tapping systems, trees are stimulated from the first year of tapping using ethephon (2.5%) by panel application method to achieve sustainable yield. Number of stimulations to be given will vary with clone and frequency of tapping. Use of Ethephon is also recommended for trees tapped under d/2 frequency for short term increase in production on panel C (BI-1 i.e., first renewed bark of first panel-bark application-once in a year or lace/groove three times in a year). Trees tapped in panel D (BI-2) may also be stimulated (bark application-thrice; lace/groove-nine times in a year) for such short term increase in production.

In newly opened trees/on trees tapping resumed after annual rest, Ethephon at 5% (active ingredient) concentration may be applied once(over the lace after two tappings).

Methods of Application
Panel application method (ethephon applied with a brush just above the tapping cut to a width of 1 cm) is recommended for general use. Lace or groove method of application can also be adopted. In these methods, ethephon is applied on the cut surface of the bark over the lace or after removing it. Among various methods, panel application is most economic.

Concentration
The ready to use formulation of Ethephon available in the market for use in rubber usually contains 10% active ingredient. Five per cent concentration of the active ingredient is as effective as 10%. The 10% formulation can be diluted to 2.5 % (1:3) or 5% (1:1) with palm oil, or coconut oil . Ethephon-39% a.i. available in the market can also be used. However, dilution may be done carefully. The diluted mixture may be stirred frequently while applying. In newly opened trees or trees tapped after rest, first stimulation may be done by lace application of 5% (a.i.) ethephon after the second tapping.

Duration of Continuous Application
There is declining trend in the response to continuous application of ethephon under 100% tapping intensity (1/2S d/2). Accordingly, continuous application of ethephon is not recommended for periods of more than three years at a stretch, under d/2 frequency of tapping.

Points to Remember
* Do not stimulate trees with TPD symptoms.
* Do not stimulate trees tapped daily.
* Do not apply Ethephon on the portion of hark previously treated.
* Do not apply Ethephon during drought period under 1/2S d/2 and 1/2Sd/3 system.

Under low frequency tapping (d/3, d/4 & d/6), the stimulation shedules recommended will not result in yield decline, any injurious effect or increased panel dryness (brown bast) in the course of time. However, if trees under alternate daily tapping are stimulated for more than two years, there will be increased panel dryness.

Some Useful Materials needed in Rubber Plantations.

- *Acetic Acid*
- *Akomin*
- *Ammonia*
- *Bavistin*
- *Bordeaux Mixture*
- *Bordeaux Paste*
- *Brodifacoum*
- *Calixin*
- *Diluent Spray Oil*
- *Dithane (Indofil) M-45*
- *Ethrel*
- *Fenvalerate*
- *Formalin*
- *Formic Acid*
- *Lime Wash*
- *Malathion*
- *Metaldehyde (Meta)*
- *Oil Dispersible Copper Oxychloride*
- *Panel Protectant/Wound Dressing and Bark Renewing*
- *Phosjet*
- *Pidivyl*
- *Sevin*
- *Sodium Sulphite*
- *Sulphur*
- *Snail Kill*
- *Temik*
- *Thiride (wet)*
- *Tilt*
- *2,4 D Acid (2.4 Di-Chlorophenoxy Acetic Acid)*
- *2,4,5-T Acid (2,4,5-Tri-Chlorophenoxy Acetic Acid)*
- *Zinc Phosphide*
- *Contaf*
- *Roban*
- *Thimet*

Student Self Assessment Exercise 3

1. How do you prevent fresh rubber latex from:
   a. coagulation?
   b. rain water?
2. Describe the processing of latex into rubber sheet.
3. Explain the tapping notation

3.11.Processing of Latex.

The latex from multiple trees is poured into pans or other containers and then mixed with formic acid, which serves as a coagulant. After a few hours, the very wet sheets of rubber are wrung out by putting them through a press before they are sent onto factories where vulcanization and further processing is done. For technically specified rubber, one manufacturing process involves coagulating the field latex with acid and passing the coagulated latex through cutting machines and a series of creping rollers. Hammer mills or granulators convert the product to rubber crumbs, which are screened, washed, dried, baled and packed. Another method of technically specified rubber production involves the addition of a crumbling agent before coagulation, followed by crumbling using creping rollers.

Ribbed smoked sheets are produced by passing coagulated latex through a series of rollers to produce thin sheets, which are embossed with a ribbed pattern. The ribbed pattern serves mainly to increase the surface area of the material and aid its drying. The sheets are preserved by placing them in a smokehouse at 60°C for a week, visually graded, sorted and packed in bales.

Compounding formulas used for natural rubbers are essentially the same as those used for most of the unsaturated synthetic rubbers. Accelerators, activators, antioxidants, fillers, softeners and vulcanizing agents may all be required, depending upon what properties are desired in the finished compound.

The hazards arising from the use of mechanized production methods (i.e., rolls and centrifuges) require strict safety controls during installation, use and maintenance, including attention to machine guarding. Appropriate precautions must be used when processing chemicals are used. Attention should be paid to the use of appropriate walking and working surfaces to prevent slips, trips and falls. Employees should receive training in safe work practices. Strict supervision is required to prevent accidents associated with the use of heat as an aid in curing.

3.12. Uses of RUBBER

The use of rubber is wide spread, ranging from household to industrial products, entering the production stream at the intermediate stage or as final products. Tires and tubes are the largest consumers of rubber, accounting for around 56% total consumption in 2005. The remaining 44% are taken up by the general rubber goods (GRG) sector, which are all products except tires and tubes.

Other significant users of rubber are hoses, belts and dampners for the automobile industry in what is known as the "under the bonnet" products. Gloves (medical, household and industrial) are also large consumers of rubber, although the type of rubber used is that of the concentrated latex. Significant tonnage of rubber is used as adhesives in many manufacturing industries and products, although the two most noticeable are the paper and the carpet industry.

Natural rubber is often vulcanized, a process by which the rubber is heated and sulfur , peroxide or bisphenol are added to improve resilience and elasticity, and to prevent it from perishing. Vulcanization greatly improved the durability and utility of rubber from the 1830s on. The successful development of vulcanisation is most closely associated with Charles Goodyear. Carbon black is often used as an additive to rubber to improve its strength, especially in vehicle tyres.

4.0. CONCLUSION

Natural rubber is a vital agricultural commodity used in the manufacture of a wide range of products.

Its production from the rubber tree (systematic name: Hevea brasiliensis) plays a major role in the socio-economic fabric of many developing countries. Over 20 million families are dependent on rubber cultivation for their basic source income.

These millions of people, mainly small growers many with holdings of two hectares or less, are dependent upon Hevea for their livelihood. The low prices paid for natural rubber contribute to rural poverty in many countries, especially smallholders in South East Asia where currency turmoil has greatly dimished the purchasing power for essentials like medicines. Estates are now less significant in most countries. An overview of agronomic practices is available.

Products made from natural rubber, especially tyres; engineering components and latex products (used in the battle against AIDS and other disease) are essential to modern life.

5.0. SUMMARY.

The subject matter content of this unit starts with the history and the development of rubber. The botany of the rubber tree was then discussed. Climatic and edaphic requirements for the cultivation of rubber were then treated. Nursery and field operations in the agronomic management of the crop were carefully treated. Harvesting and processing of latex were similarly elaborated. Uses of rubber both at the domestic and industrial levels were briefly treated

6.0. Tutor Marked Assignments

1. What are the different types of nursery operations in rubber?

2. Discuss into details budding in rubber.

3. Identify the cover crops often planted into rubber plantations.

4. Discuss tapping patterns in rubber. What are the advantages of each of the patterns?

5. List the common tools used in rubber planting and production.

6. List the uses of rubber.

7.0. REFERENCES and Links.

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Stop Firestone's Use of Child Labor in Rubber Production

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