COURSE CODE: **PCP 301**

COURSE TITLE: **CROP PRODUCTION 1**

NUMBER OF UNITS: **3 UNITS**

COURSE DURATION: **Five hours per week**

COURSE DETAILS:

Course Coordinator: **Dr (Mrs) Joy Nwakaego Odedina** B. Sc., M.Agric., PhD
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COURSE CONTENT:

1. Manures and Fertilizers. Fertilizer usage.
2. Mineral nutrition of crop plants and deficiency symptoms. Maintenance of soil fertility.
3. Agronomic groupings of crop plants and their characteristics: cereals, legumes, root crops, tuber crops, forage crops, oil crops, fibre crops, beverage crops, sugar crops, fruit and vegetable crops, rubber, cover crops and stimulants. Crop management practices: site selection, land preparation, seeding, fertilizer application, weed, insect and disease management, harvesting, processing, utilization and produce storage for arable and plantation crops.
4. Ecological distribution of crops in Nigeria.
5. Farming system, cropping systems and cropping patterns
6. World, African and Nigerian food production problems and potential solutions. Climatic, economic and social conditions affecting crop distribution and growth.
7. Water requirement of crop plants: hydrophytes, mesophytes, xerophytes.
8. Irrigation: types, purposes, methods and problems.

Practicals

Fertilizer identification and calculation. Crop seed identification. Seed structure and vegetative morphology of cereals, legumes, fibres, root and tuber crops. Identificatiobn of some diseases, weeds and insect pests of some crops. Effects of light on plant growth. Effects of varying moisture levels on plant growth.

COURSE REQUIREMENTS:

This is a compulsory course for all students in the Agricultural programmes in the University. Students are expected to participate in the practicals and lectures and have a minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Agbede, O.O. Understanding soil and plant nutrition. Pp 260. 2009.
2. Sigmund Rehm and Gustav Espig. The cultivated Plants of the Tropics and Subtropics.Verlag Josef Margraf Scientific book, CTA, 1991.
3. Opeke L.K. Tropical Commodity Tree Crops (Second Edition) 2005.
4. Opeke L.K. Essentials of Crop Farming. 2006.
5. R.P.Rice, L.W. Rice and H.D.Tindall. Fruit and Vegetable Production in Warm Climates. 1985.
6. S.P. Palaniapan and K. Sivaraman. Cropping systems in the tropics, principles and management (Second Edition) 2006.
7. Philip O.Adetiloye, Kehinde A. Okeleye and Ganiyu O.Olatunde Principles and Practices of Crop Production. 2006.

LECTURE NOTES

MANURES AND FERTILIZERS

Manures:

What are manures? Manure consists of animal excrement, usually mixed with straw or leaves. The amount and quality of the excrement depend on the animals feed. Good manure contains more than just excrement and urine. Straw and leaves are added and it is aged. Ageing is necessary to retain all the nutrients. Using aged manure is an ideal method to retain and increase soil fertility.

Goals of applying manure:

- Increase the level of organic matter
- Increase the available nutrients.
- Improve the structure (aggregate formation) and water retention capacity of the soil.
- Improve the activities of microorganisms in the soil.

Types of manures

i. Farmyard manure
ii. Compost
iii. Green manures

iv. Concentrated organic manures

Farmyard manure:

When animals are kept in a shed and proper care and good management practices are observed in utilization of all dung, urine and litter for use as farmyard manure, nearly all the elements originally present in the excreta of the animals can be saved and returned in the soil. Fresh stable manure is not very suitable for immediate use. The C:N ratio of fresh manure is high, which can cause nitrogen immobilization. On the average, well rotted farmyard manure contains 0.5% nitrogen (N), 0.2% phosphorus (P) and 0.5% potassium (K)

Compost :

Compost is well-rotted vegetable matter which is prepared from and town refuse. Farm refuse consists of straw, crop residues such as groundnut husks, sugarcane refuse, waste fodder, hedge clippings and dried leaves. Town waste consists of sewage, sludge, street and dust bin refuse, factory waste, wool and cotton waste etc. After the compost had decomposed for about three months and allowed to stay above the ground, well covered by earth for another one or two month, they are ready for use. The N, P and K contents of farm compost are on the average of 0.5%, 0.15% and 0.5% respectively while those of town compost are 1.4%, 1.0% and 1.4%, respectively.

Green manures:

Green manuring is the practice of growing and ploughing in green crops to increase the organic matter content of the soil. A green manure (preferably a leguminous one), should be sown at the beginning of the rainy season. It should be completely decomposed before sowing the next crop.

Concentrated organic manure:

Concentrated organic manures are those that are organic in nature and contain higher percentages of nitrogen, phosphorus and potash than bulky organic manures (farmyard, compost and green manure). Concentrated organic manures are made from raw materials of animal or plant origin. The common concentrated manures are oil cakes, blood meal, fish manure, meat meal and cotton and wool wastes (shoddy).

Assignment: List various types of organic manures you are familiar with. State the components, nutrient composition, merits and demerits of each manure.

Immobilization of Nitrogen (N) and the C:N ratio

Microorganisms decompose organic matter, which releases nutrients. However, the micro-organisms themselves also need carbon and nutrients including nitrogen. The tissue of all organic material is made up nearly half of carbon. The level of nitrogen varies widely between different types of organic material. In general, organic material that is old and tough has a high C:N ratio, in other words the nitrogen content is low compare to the amount of carbon. Young and succulent material generally has a low C:N ratio, that is, it has a high nitrogen content. If organic material is added, that is old and tough (straw for example), then the micro organism initially needs more N than it released from the material. They will then absorb not only all of the nitrogen that is release from the straw but also all the nitrogen that was already available in the soil (for example as nitrate-nitrogen ($NO3^-$) or ammonium –nitrogen ($NH4^+$). After the straw is worked into the soil, there is thus a period of time in which all of the available nitrogen in the soil is taken by the micro organisms. This is called **immobilization.** Little or no Nitrogen is then available for the plants. Once the straw is completely decomposed, there is no longer food available for all the micro-organisms. A large proportion of the micro-organisms dies and decomposes. The nitrogen that the micro-organisms had adsorbed becomes once again available for the plants. In warm, moist conditions this circle occurs quickly, and the period of immobilization is short (weeks). In the dry areas the period of immobilization is long (more than a growing season).

Fertilizers:

What are fertilizers?

A fertilizer is a manufactured product containing a substantial amount of one or more of the primary, secondary macronutrients or micronutrient.

Most often the terms “chemical fertilizer”, “mineral fertilizer” are used to distinguish the manufactured products from natural organic fertilizers of plant or animal origin which are called “organic fertilizers”.

Nutrient elements that are required in relatively large amounts are called macronutrients e.g. carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, and magnesium.

The elements that are required in small amounts are known as micronutrients e.g. boron, chlorine, copper, iron, manganese, molybdenum, and zinc.

Types of fertilizers

We have three major fertilizers; nitrogen fertilizers, phosphate fertilizers and potassium fertilizers.

Nitrogen fertilizers;

1. Sodium nitrate ($NaN0_3$ - chile saltpeter) 16% N.

Definitions

1. Straight single Fertilizer: contains on nutrient element.
2. Complete fertilizer: contains the three major elements: NPK.
3. Fertilizer carrier or material: Any chemical compound which contains one or more plant nutrient element.
4. Mixed/compound/complex fertilizer: One that contains two or more fertilizer material e.g. SSP (Single super phosphate) and urea containing P&N respectively or urea + KCl containing K&N different from KNO_3 having only K and nitrate. It contains two elements but it is in a single fertilizer.
5. Fertilizer formulation: is defined as a chemical compound in a fertilizer consisting of two or more plant nutrients element and manufactured from two or more raw materials.
6. Fertilizer formula: this is an expression of the quantity and analysis of the materials making up a mixed fertilizer.
7. Fertilizer ratio: refers to the relative percent (%) of N, P_2O_5 and K_2O.

8. Fertilizer filler: is any material added to mix fertilizer or any fertilizer to achieve a specific grade. E.g. 900 kg + 100 kg = 1000 kg. e.g. inert materials, sand groundnut hull.
9. Fertilizer brand: this is the name, trade mark or company name for fertilizers.
10. Fertilizer analysis: this is a statement of the proportion of the nutrient element in a fertilizer. The analysis of a straight fertilizer is a % of the nutrient element it supplies e.g. urea supplies 46% N. For a compound fertilizer it is the % of the various elements it supplies.
11. Fertilizer grade: the grade of a fertilizer is the nutrient content in weight percentage of N, P_2O_5 and K_2O in the order N-P-K. The grade is only the amount of nutrient found by prescribed analytical procedures, excluding any nutrient that is unavailable to plants. For example a grade of 10-15-18- indicates a fertilizer containing 10% N, 15% P_2O_5 and 18% K_2O. The grade may also be called "analysis" or "formula". Analysis is graded. Any fertilizer that supplies <15% of the total active nutrient element is referred to as having "Low analysis"

    i.e. <15 % - Low analysis
    15-25 % - medium analysis fertilizer
    25- 30 % - High analysis fertilizer
    >30 % - concentrated fertilizer.

Fertilizer Calculations

Introduction:

Calculating the quantity of fertilizer required to meet the nutrient requirement of a given crop or crops on a specified land area is a task that must be performed from time to time as long as fertilizer application is carried out in crop production. In order to do this effectively, one must be acquainted with various conversion factors as follows:

Conversion factors for plant nutrients:

P_2O_5 x 0.44 =P
P x 2.29 = P_2O_5
K_2O x 0.83 =K
K x 1.20= K_2O
CaO x 0.71=Ca
Ca x 1.40= CaO

MgO x 0.60 = Mg
Mg x 1.66 =MgO
SO_2 x 0.50 = S
S x 2.00 = SO_2

Common fertilizers and percentage nutrients:

AN Ammonium nitrate ----------------- 33-34% N
AS Ammonium sulphate ------------------ 21% N
ASN Ammonium sulphate nitrate ---------- 26% N
CN Calcium nitrate ---------------------------- 15% N
Urea -- 45-46% N
CAN Calcium ammonium nitrate------------- 20-28% N
MOP Muriate of potash(potassium chloride)—60-62% K_2O
SOP Sulphate of potash(potassium sulphate)--- 50% K_2O
SSP Single superphosphate --------------------- 16-22% P_2O_5
TSP Triple superphosphate ---------------------- 44-48% P_2O_5

STEPS IN FERTILIZER CALCULATIONS

1. Decide on whether the nutrient requirement can best be met using a single element fertilizer or compound fertilizer, bearing in mind the available fertilizer materials and the cost.
2. List necessary data such as the recommended application rate (Kg/ha), analysis of the fertilizer showing the percentage of nutrients in it as well as the area to be fertilized in hectare or fractions of hectare (m^2).
3. When a compound fertilizer is to be used in meeting a given nutrient requirement, always calculate the amount of the fertilizer that will be required to meet the requirement of the least nutrient. For example assuming 100 Kg N/ha, 50 Kg P and 60 Kg k is to be supplied using NPK 15:15:15, urea and Muriate of Potash, the compound fertilizer must be used to calculate the required P. Then the balance of N and K will be supplied using the straight fertilized.

Examples:

a. Calculate the quantity of K in 70 Kg K_2O
b. Determine the amount of P in 120 Kg of P_2O_5
c. A maize farm 125 m^2 require 450 Kg/ha N, 250 Kg/ha P2O5 and 300 Kg K_2O /ha. Calculate the quantity of fertilizer that shall be required to meet this requirement using the following fertilizer ingredients:
NPK 15:15:15, super phosphate (18% P_2O_5) and muriate of potash MOP (60% K_2O)

Solution:

b. Formula weight of P_2O_5 = (2 X 30.97) + (5 X 16) =141.94

Ratio of P: P_2O_5 = 61.94: 141.94 expressing this as a fraction = 61.94/141.94 = 0.44 =44%

Therefore, in 100Kg P_2O_5 we shall have 44Kg P

120 Kg P_2O_5 =? P

= 120 x 44/100

=5280/100

= 52.8Kg

Exercises:

1. Calculate the quantity of N in 5Kg of urea 46-0-0.
2. NPK 20:10:10 was used to supply 400Kg N. Calculate the quantity of the fertilizer material in Kg that was used to achieve this.
3. 50g of Muriate of Potash (MOP) was applied to an experimental plot measuring 2m x 5m. What quantity of MOP will be required per hectare?
4. Assuming equal amounts of P_2O_5 and K_2O are required in a fertilizer package for a sweet potato field. If 500 Kg of NPK 20:3:5 had been applied and adjudged sufficient to meet the requirement for K_2O. What quantity of P_2O_5 had been applied?
5. What quantity of single super phosphate (18% P_2O_5) must be applied to furnish 50 Kg P_2O_5?.

Mineral nutrition in plants and their deficiency symptoms

Plant nutrition is the study of the chemical elements that are necessary for plant growth. There are several principles that apply to plant nutrition. Some elements are directly involved in plant metabolism (Arnon and Stout, 1939). Metabolism is the life sustaining chemical activity, i.e. The series of processes by which food is converted into the energy and products needed to sustain life. However, this principle does not account for the so-called beneficial elements, whose presence, while not required, has clear positive effects on plant growth.

Plant nutrition is a difficult subject to understand completely, partially because of the variation between different plants and even between different species or individuals of a given clone. Elements present at low levels may cause deficiency symptoms, and toxicity is possible at levels that are too high. Further, deficiency of one element may present as symptoms of toxicity from another element, and vice-versa. Carbon and oxygen are absorbed from the air, while other nutrients are absorbed from the soil. Green plants obtain their carbohydrate supply from the carbon dioxide in the air by the process of photosynthesis

Plant nutrients

The elements that plants need to survival are called nutrients. Nutrients are usually adsorbed from the soil solution in the form of ions. Ions are dissolved salts (nutrients salts) that have an electrical charge. Positively charged particles are called cations (e.g. ammonium NH_4+), and negatively charged particles are called anions (e.g. nitrate, NO_3-, phosphate, H_2PO_4-). These ions will be mentioned again later.

The nutrients that a plant requires to progress through an entire growth cycle are called the essential nutrients. A deficiency of any one of these will have consequences for the plant, such as limited growth, or a lack of flowers, seeds, or bulbd. In addition to the essential nutrient, plants absorb other nutrients that they do not need (e.g sodium Na) or that can even be harmful (e.g. aliminium A1 or manganese Mn). Plants do not need equal amount of each nutrient. For this reason, the essential nutrients are divided into two groups.

The macro-nutrients, which plants need large amounts of:

Carbon (c)

hydrogen (H)

oxygen (O)

nitrogen (N)

phosphorus (P)

potassium (K)

calcium (Ca)

sulphur (S)

magnesium (Mg)

The micro-nutrients, which plants need only small amounts of

iron (Fe)

manganese (Mn)

boron (B)

zinc Zn)

copper (Cu)

molybdenum (Mo)

The function of the macro-nutrients will be discussed briefly below. The micro-nutrients are just as important for the plant, but they are needed in such small amounts that a deficiency of one or more of them occurs only in special circumstances.

Functions of nutrients

The macro-nutrients

Each of these nutrients is used in a different place for a different essential function.

Carbon

Carbon forms the backbone of many plants biomolecules, including starches and cellulose. Carbon is fixed through photosynthesis from the carbon dioxide in the air and is a part of the carbohydrates that store energy in the plant.

Hydrogen

Hydrogen also is necessary for building sugars and building the plant. It is obtained almost entirely from water.

Oxygen

Oxygen is necessary for cellular respiration. Cellular respiration is the process of generating energy-rich adenosine triphosphate (ATP) via the consumption of sugars made in photosynthesis. Oxygen gas is produced as a by-product from this reaction.

Nitrogen

Nitrogen is an important building block of proteins in the plant. It promotes the growth of stalks and leaves. With sufficient nitrogen, the leaves become big and succulent; with insufficient nitrogen the plant's growth is severely inhibited, and its leaves are small and fibrous. Nitrogen is also needed for the green colour of the plant. If a deficiency will prevent the plant from flowering. If plants absorb too much nitrogen, the stems and leaves will grow bigger but also weaker. Grains can then wilt more readily, and fungi and aphids have a better chance of damaging the plants. Also, the plants may flower later, which can lead to a lower yield in a short growing season. In the soil, nitrogen becomes available to the plants mostly as nitrate (NO^{3-}) and ammonium ($NH4^{+}$).

Phosphorus

Phosphorus plays an important role in breathing and in the energy supply. It promotes the development of roots in young plants. It has a positive effect on the number of grains per spike and the grain weight and for bulb crops on the bulb and root production. A phosphorus deficiency causes limited growth, especially in the root, which gives the plants a stocky appearance. The leaves turn a dark, blue-green colour. Some plants turn purplish, first on the stem base, and later on the underside of the main nerve of the leaves. Seed and fruit developments is plant, except that it can cause a shortage of zinc, copper and iron. Plants can absorb phosphorus in the form of phosphate ions (H_2PO^{4-}).

Potassium

Potassium is needed for the firmness of the plant. Potassium makes the crop strong, and ensures that the root system is large and widely branched. It regulates the opening and closing of stomata. It reduce water loss from the leaves and increase drought tolerance. It promotes the development of roots and bulbs, and it has a positive effect on the size of fruits and the weight of grains. Plants that have a potassium deficiency stay small and weak, and their leaves fall off. The leaves get pale-coloured spots, beginning on the edges. Later the whole leaf turns brown. A severe potassium deficiency makes the young leaves bumpy, because the nerves are too short. Grains fall over easier. Plants that have little potassium are less able to withstand drought, and will therefore wilt faster. Excess potassium makes also causes a shortage of magnesium and boron.

Sulphur

Surphur is needed as a building block of some organic compounds and vitamins and other compounds in the plant. A sulphur deficiency makes the leaves light green or yellowish (as does a nitrogen deficiency). The plant's growth is inhibited, and the stems are stiff, woody and thin. An excess of surphur seldom occurs. Plants adsorb Sulphur in the form of sulphate (SO_4^{2-}).

Calcium

As an important component of cell walls, calcium influences the growth and strength of the plant. It regulates transport of other nutrient and involve in the activation of certain plant enzymes. A deficiency of calcium appears first in the young leaves. They are often deformed, small and strikingly dark-green. Growth points die off. The leaves are wrinkled. Root growth is visibly inhibited, and rotting of the roots can occur. The stem is weak.

Magnesium

Magnesium is needed, among other things, for photosynthesis. With a deficiency of magnesium, coloured spots appear on the leaves, beginning with the older leaves. The nerves of the leaves sometimes stay green. In grains, yellow stripes appear lengthways on the leaves. A magnesium deficiency can retard the ripening of grain. An excess of magnesium occurs seldom.

Every nutrient thus has its own function in the plant. A shortage of one nutrient cannot be compensated by a higher dose of another. The element that is most lacking and yield of the plant.

Sulphur

Sulphur is a structural component of some amino acids and vitamins, and is essential in the manufacturing of chloroplasts. Sulphur deficiency is not common

Silicon

Silicon is deposited in cell walls and contributes to its mechanical properties including rigidity and elasticity

Boron (B)

Boron is necessary for calcium to perform its functions in the plant but too much boron is also harmful to the plant. Excess use of magnesium sulphate will also cause a boron imbalance. The symptoms of boron deficiency are poor development of the growing tip of the plant. It is more likely in soils with pH above 6.5.

Confirming boron deficiency is a job for laboratory analysis. Adding borax to the soil will correct the deficiency but borax is also a herbicide. For garden growers who are unlikely to want to pay for professional testing and recommendations the best advice is to avoid over use of magnesium sulphate. Crop rotation and use plenty of home made compost can correct boron defficiency.

Copper (Cu)

It is required for root formation. Copper deficiency is rare but can occur on sandy, peaty and chalky soils with their high pH levels. Once again it requires professional analyst to confirm and to determine a proper course of action to rectify. Usually the single use of a copper sulphate based fungicide (Bordeaux mixture) will re-stock the soil for as long as you are likely to grow on it. Excess copper is very toxic to plants and to people. In plants it causes reduced growth, yellowing of the foliage, and stunted root development

Iron (Fe)

Iron is necessary for photosynthesis and is present as an enzyme cofactor in plants. Iron deficiency can result in interveinal chlorosis and necrosis.

Iron deficiency causes yellowing of the leaves and a general lack of vigour. Use sulphate of iron fertilizer to correct Iron deficiency

Manganese (Mn)

Manganese deficiency is often caused by over liming and is most often found on peaty and sandy soils with a high pH. Symptoms are similar to iron deficiency and can be confirmed by laboratory analysis of the leaf. Susceptible crops include peas and beets.

Adding sulphur to the soil, which will increase the acidity (decreasing pH) will solve the problem.

The following micro-nutrients are rarely lacking and analysis and remedy are professional jobs. Normal additions of composts and manures will resolve deficiency problems. Excess in the soil will probably be due to industrial contamination.

Molybdenum (Mo)

Molybdenum is only required in minute amounts. Molybdenum is a cofactor to enzymes important in building amino acids. Excess of it is as harmful as molybdenum deficiency.

Zinc (Zn)

Zinc deficiency is more likely in soils with high pH than low. Crops most sensitive are tomatoes, onions and beans.

Boron

Boron is important in sugar transport, cell division, and synthesizing certain enzymes. Boron deficiency causes necrosis in young leaves and stunting of plants.

Copper

Copper is important for photosynthesis. Symptoms for copper deficiency include chlorosis. Involved in many enzyme processes. Necessary for proper photosythesis. Involved in the manufacture of lignin (cell walls). Involved in grain production.

Manganese

Manganese is necessary for building the chloroplasts. Manganese deficiency may result in coloration abnormalities, such as discolored spots on the foliage.

Sodium

Sodium is involved in the regeneration of phosphoenolpyruvate in CAM and C4 plants. It can also substitute for potassium in some circumstances.

Zinc

Zinc is required in a large number of enzymes and plays an essential role in DNA transcription. A typical symptom of zinc deficiency is the stunted growth of leaves, commonly known as "little leaf" and is caused by the oxidative degradation of the growth hormone auxin.

Nickel

In higher plants, Nickel is essential for activation of urease, an enzyme involved with nitrogen metabolism that is required to process urea. Without Nickel, toxic levels of urea accumulate, leading to the formation of necrotic lesions. In lower plants, Nickel activates several enzymes involved in a variety of processes, and can substitute for Zinc and Iron as a cofactor in some enzymes.[citation needed]

Chlorine

Chlorine is necessary for osmosis and ionic balance; it also plays a role in photosynthesis.

Cobalt has proven to be beneficial to at least some plants, but is essential in others, such as legumes where it is required for nitrogen fixation. Vanadium may be required by some plants, but at very low concentrations. It may also be substituting for molybdenum. Selenium and sodium may also be beneficial. Sodium can replace potassium's regulation of stomatal opening and closing.

Levels of nutrients in the soil

There are four levels
a. Deficiency level: low level of a particular nutrient leads to **DEFICIENCY SYMPTOMS**
Which is an indication or signs expressed by the appearance of crops especially in the leaves.
b. Sufficiency level: Plant requirement is met. Additional quantity will not bring about increases growth or yield.
c. Critical Level. This slightly above deficient level and below sufficient level. Addition of nutrient brings about additional yield increase.
d. Excessive: This also called the luxury consumption. Addition of extra nutrient can be injurious and can lead to plant death.

DIAGNOSIS OF NUTRIENT DEFICIENCY

1. Visual observation are generally the first indication of nutrient deficiency where it is not obvious or convincing leaf analysis
2. Leaf analysis is usually engaged.
3. Field diagnosis
   a) Soil sampling
   b) Plant sampling
   c) Analysis and dignosis
   d) Fertility management
   e) Tillage
   i) Conservation tillage
   ii) Legume in rotation

iii) Cover crop or green manuring
- Animal manure
- Sewage sludge

AGRONOMIC GROUPINGS OF CROP PLANTS

The agronomic grouping of crop plants is a system of nomenclature that identifies a plant's agricultural use. This system of classification indicates how a crop will be used.

The followings are the major agronomic groups:

1. Cereals: Rice, maize, wheat, barley, sorghum, millet e.t.c.
2. Legumes: Beans, cowpea, groundnut, soyabean.
3. Forage crop: Centrosema, alfalfa, lueceana. Pueraria, stylosanthis spp, e.t.c.
4. Root crops (Roots and Tubers): cassava, cocoyam, carrot, yam, potatoes, sugar beet e.t.c.
5. Fibre crop: Cotton, flax, hemp, kenaf, jute, sisal, roselle, sugar cane
6. Sugar: sugar beet, sugar cane
7. Stimulants: Tobacco, mint, pyrethrum, coffee, cocoa, tea, kola
8. Oil crop: Flax, soyabeans, groundnut, sunflower, safflower, castor bean, oil palm
9. Rubber: Rubber tree (*Havea brasilensis*)
10. Cover crops: Mucuna, sweet potatoes, egusi (melon) *cucumis melo*
11. Beverages: Cocoa

Characteristics of Agronomic groups

1. **Cereals or grain crops**

   A cereal is any grass grown for its edible grain from the family: Poaceae. The term may refer to either the plant as a whole or the grain itself. Examples: rice, wheat, maize (corn), oats, barley, millet, sorghum and acha. Grain is a collective term for the fruit of cereals. The leaf blade is lanceolate (boat shaped).

2. **Legumes**

   Refers to plants in the family fabaceae (former leguminoseae). It is used to refer to the pod of leguminous plant, consisting of one carpel and usually dehiscent on both sutures. Examples are the principal legumes raised carpel for their seeds: Field bean, peanuts (groundnuts) cowpea and soybeans.

3. **Forage crops**

   Forage refers to a vegetative matter, fresh or preserved, utilized as feeds for animals. Forage crops include all grasses cut for hay, legumes cut for forage or silage, sorghum and corn fodder. Examples among grasses are maize, sorghum, millet, oats, barley, millet and pasture plants like guinea grass, elephant grass. Examples of legumes forage are: pueraria, centrocema, stylosanthis, calopogonum, pigeon pea, cowpea and soybean are important annual hay.

4. **Root crops**

   One grown for its enlarged root. Examples are: cassava, sweet potato, carrot. These are true root crops (or root tubers) but the potato is not e.g. irish potato is stem tuber and yam.

5. **Fibre crops**

   Grown for their fibre use in making textiles ropes, twines and jute bags. The principal fibre plants include cotton, flax kenaf, and hemp. Cotton is the most important of fibre plants. Jute and sisal are also sources of fibre.

6. **Tubers**

   The tuber is much thickened underground stem developed on a slender leafless shoot or stem. The only tuber of important cultivation in Nigeria is the yam (Irish potato is also a stem tuber important in the temperate regions).

7. **Sugar crops**

   The principal plant grown for their sugar are sugar cane and sugar beets. The bulk of the sugar produced in the tropical world is from sugarcane while in the temperate, it is from sugar beet. In addition to these crops, the saccharine sorghums (sorgos) are used for making syrup.

8. **Stimulants**

   This group includes tobacco, tea and coffee. Tobacco is by far the most important of these crops in Nigeria.

9. **Oil crops**

Among these crops grown for their oil are: soybeans, peanuts, flax, sesame safflower, sunflower and cotton.

10. **Rubber crops**

    A good example is *Havea brasilensis*

11. **Beverages**

    A good example is cocoa.

    There are other crops such as fruits, vegetables and tuber crops which are commonly classified as field crops.

Cereals

Member of grass family called (poaceae). They have many important features in common. The edible seed of a cereal plant is a fruit. It is a simple, dry, indehiscent structure called a caryopsis popularly referred to as a grain, kernel or a seed. It is composed of several water layers and of at least two components: the endosperm and embryo. The entire pericarp, and the testa, and usually the aleurone layer (fused together) collectively termed bran are removed in milling along with the embryo.

Bran that includes the embryo has higher protein content than the carbohydrate rich endosperm between the embryo, or germ contains more protein than any other part of the seed. This is because of the concentration of enzymes (proteins) in the embryo which are essential for germination, growth and development. Flour made from the entire wheat kernel is of greater nutritive value than white flour from which both bran and the germ are removed during processing.

All of the cereal crops species are annuals (cool season species are wheat, barley, oats and rye). The worm season species are corn, sorghum, millet and rice cultivated during rains or by irrigation in the tropics.

* Study maize seed parts diagram and master the functions of the parts.

- Plumule forms the shoot
- Radical gives rise to the roots
- Embryo (Rudimentary plant)
- Monocot seed has one single cotyledon = scutellum
- It mobilize and absorbs nutrients during germination cereals
- Endosperm consist of non-living cells filled with starch, protein and small lipids = it is surrounded by one or more layers of living cells distinguished by numerous protein bodies.
- Surrounding the seed is a hard coat = Testa covered with heavy walled cells with a thick waxy curticle = Testa, often resist uptake of water and O_2. Regulates the hydration of seed.

Growth stages: The pattern of growth and development of all cereals are similar.

At germination the seed coat is penetrated or broken to allow the plumule and the radical to emerge from which the shoot and root development starts. The primary root system develops and the seminal root is established. This root system is not extensive and does not support the plant throughout most of its life. So a secondary root system composed of adventitious roots developments early in the life of the crop. This fibrous root system becomes the permanent root system.

Germination is completed when the coleoptiles break through the soil surface and the primary culm emerges. It elongate and develop the leaves and tillering is initiated (maize does not tiller).

A crop makes its greatest demand on soil moisture and mineral during the vegetative stage of development. At this stage the culm elongates rapidly. As the vegetative stage is completed the inflorescence is pushed through, the sheath of the upper most leaf (called the flag) just after booting (swelling of the flag leaf sheath).

In most cereals flowering occurs between the time the inflorescence is in the boot and the time of emergence from the boot, or shortly thereafter.

Elongation of the upper internode (peduncle) and flowering are temperature sensitive, even moderate change in temperature can disrupt the flowering, pollination and fertilization process. Cool weather at the boot stage delays flowering and micro-spores or pollen may be rendered sterile by both low and high temperatures (the temperature that limit flowering fertilization vary from species to species even among cultivars of a particular species.

Maize differs from other cereals in that each flower is imperfect i.e. either male of female but not both. The plants are monoecious, that is a single plant bears both male flower (tassel) and female flowers (ear, including silks). The tassel emerges just as the inflorescence of other grasses do. The silks are the stigmas, one from each female flower (on the ear or cob). The cob is the woody central part of a spike, thus the ear is a spike with only female flowers. Each female flowers can become a maize kernel in the floral developemnt of a single plant, pollens tends to mature slightly before the silks of the same plant are receptive. Maize and rye are the only cereals that are cross pollinated, the other species are largely, although not exclusively, self pollinated. Following pollination and fertilization the fruit develops, lower leaves dries, assimilate partitioning is about 18% or below.

Common Cultural Practices

For barley, oats, rye and wheat the cultural practices are similar from seed bed preparation all through harvesting.

- Site selection: well drained fertile soil, level topography and previous history of crop cultivation.
- Seed bed preparation: requires a moderately time, well aggregated soil particle, void of weed.

- Seeding: seedling depth for cereals ranges from 2.5 - 7.6 cm. Shallow seeding subjects the seeds and seedlings to the danger of inadequate moisture. Smaller seeded cereals are all seeded in close pacing from as little as 15.2 - 30.55 -33.60 cm.
- Weed control: followed by proper seed bed preparation and the use of herbicides. Both pre-emergence and post-emergence. Common pre-emergence herbicides include triazine e.g. atrazine and simazine, premature (gramozone – post-emergence)
- Fertilizer application: A cereal requires adequate moisture and balanced mineral contribution. However, the critical requirement and response to deficiencies differ from each species. Cereals requires large amount of nitrogen for high yields (40-200 kg/ha), P & K ranges from 6 kg-50-60 kg/ha and about 45-90 kg/ha respectively. Other mineral nutrients are applied according to needs of the plant. Lodging is a problem common to all cereals as a result of excessively high rates of nitrogen fertilizer and heavy seeding rates which may lead to tall, weak stemed plants.
- Harvesting: Methods and equipment are similar for all cereals except maize. on a large scale, it could be mechanized using combined harvester
- Storage: Requirement for all cereals is generally uniform. The grains must be dried to 15% moisture content or less is highly desirable.

Ecological Distribution of Cereals

Cereals are most widely distributed crops in that they can grow in different ecologies where other crops cannot grow = (high rainfall (rice and maize), low rainfall (maize, rice, sorghum and millet), semi arid regions of the world (millet and sorghum). They are adapted to a wide range of soil types.

LEGUMES

Belongs to the family Fabaceae (formally leguminosae). The seeds are called beans or peas. When dried, falls under the general term pulses. The legumes are unique group among plants because they have special ability to trap atmosphere nitrogen and convert it to organic nitrogenous substance in the plant. They also have additional ability to make use of soil nitrogen.

A group of bacteria of the genus Rhizobium are able to trap this atmospheric nitrogen in association with the root cells of the leguminous plants and synthesize organic materials from it. A few weeks after the legume has germinated, these rhizobia enter and infect the plants root hairs.

Rhizobia come in contact with plant root through:

- Air
- Dust on the surface of the planted seeds

- Cultured strains of the bacteria are now and needed to maculate the soil in which the plants are grown or the root of the leguminous plant.

The presence of the bacteria in the root stimulates the rapid growth of the adjoining tissue forming a "nodule" which can be seen with the naked eye. The nodule bacteria can trap and fix atmosphere nitrogen which may become available to the host leguminous plant besides fertilizing the soil in which the plant grows. It may also become available on the disintegration of the nodules after death of leguminous plant and are plowed into the soil as green leguminous plant, thereby increasing the content of soil nitrogen without the application of N-fertilizers. Series of biochemical reactions produced hydroxylamine as the first intermediate product when Rhizobium spp reacts with the trapped atmospheric N (Virtanen, 1940). This then react with oxaloacetic acid to produce oximinosuccinic acid.

The rhizobia derive the energy in the form of glucose for this reaction from the host plant which in return, receives fixed nitrogen from the bacteria.

The fixation is aerobic, and it has been found that an iron containing pigment similar to haemoglobin combines reversibility with CO^{+2} and helps to accelerate O^{+2} thereafter to the N fixing system. Glutamic acid followed by aspartic acid and lysine are the amino acids produced from symbolic N fixation (Buris and Wisdom, 1945, 1953: Burns, 1956). Legumes are sources of protein (18-30 percent) with 25%. They are also good source of oil e.g. groundnut and soybean. Cowpea, bambara and pigeon pea have small amount of oil.

Legumes protein is higher than cereal grains. Legumes are rich in lysine but low in methionine which is found adequate in cereals. (Groundnut contains high level of methionine than soybean which has also higher lysine content). Common legumes in Nigeria are; soybean (*Glycine max* L. Merr.), Groundnut (*Arachis hypogaea)*, Lima bean (*Phaseolus lunatus* L.), Mucuna bean (*Mucuna mucunoides*), pigeon pea (*Cajanus cajan)* and cowpea (*Vigna unguiculata*).

Inoculation

This affects legumes only; adding the proper strain of rhizobia to legume seed or soil so that the plant can better use atmospheric N. This enhances the benefit of the plant/bacteria association.

Inoculation is necessary because some soils may not contain sufficient number of the bacteria.

Some types or strain disappear rapidly in very acidic soils (below 6.0 pH). Soil that lack aeration, water logged soils, soil poor in essential nutrient elements e.g. K, Ca, P also account for their absence or fewer number. Rhizobium is host specific; low yield or crop failure may be due to the nodulation of legume by poor types of rhizobia. But, effective strains of rhizobia cause formation of large, pink nodules on the central tap root system, and cause the fixation of large amounts of free N. These are desirable ones that are added in inoculation practices, they use little soil N thereby conserving much of the soil N for the subsequent cereals which will later follow.

Timing of inoculation

- When the legumes to be planted has not been grown previously on the land to be used.
- If legume previously grown were poorly nodulated.
- When the land has been abuse by lack of care or in favourable nature conditions.
- When land is uncropped or grown to non-legumes. It will contain relatively few rhizobia.

Advantage of inoculation

- Prevents N starvation in the current crop.
- Provides residual N for the subsequent crop.

Production practices

- Site selection: well drained fertile level or flat surface field.
- Seed bed preparation, similar to that of maize and small seeded cereals.
- Seeding: The seeds of most legumes are layer than the kernels of most cereals (except maize).
- Seeding depth is generally deeper than that for cereals: 2 seeds per hole at a depth of 4-5 cm. 75 cm x 20 cm spacing [or 60 cm x 30 cm(forest) 30 cm x 30 cm]

Seed rate: 25 – 30 kg = 60 x 30 for soybean 50-60 kg wider spacing and 95 – 112 kg; narrow spacing 50 – 55 kg = 30 x 30.

Pest and diseases control: - flower trips, pod borers and pod bugs infect cowpea on the field at pod filling stage. Use cypermethrin (Cymbush at 20 m/s/10 l or Nuvacron at 5 ml/10 l of water).

Weed control: (5 weeks after planting, then repeat weekly –noon 4 spray).

Maximum of two weedings – first at 2-3 WAP and at 4-5 WAP. Chemicals weed control can be effected on cowpea by applying Galex (Pentoran and Metolachor) on well prepared (seedbed at the rate 3.5 kg/ha a.i (1200-150 ml/10 litres of water as pre-emergence not later than the second day after planting. For minimum tillage, paraquat at 3 kg/ai/ha (100 ml/10 litres of water and Galex at 120 ml/10 wt of water 3.5 kg a.i.

Fertilizer application: 20 kg N/ha and 30-60 kg P_2O_5/ha with 45-90 kg K_2O/ha.

Harvesting Storage

Harvesting is done for most legumes when the pods are dry before they begin to shatter. It is then threshed manually, winnowed and bags at about 15% moisture content or 14% Moisture content like any other grains using two to three tablets of phostoxin in 100 kg bag (Jute bag with good aeration) in dry and well ventilated store.

Cowpea (*Vigna ungiuculata* (L) Walp)

Cowpea is the most important grain crop cultivated widely so the tropical region of the world (Asia, Africa (East and West) and America (central and south). It provides a major source of protein in human diet.

West Africa accounts for about three-quarter of the world cowpea production with Nigeria, Niger and Burkina Faso as the major producers. Cowpea is an annual crop which could be erect prostrate or climbing in nature. It has a distinct tap root system which developed from the radicle. It also nodulates well with a number of rhizobium strains. The leaves are trifoliate and the inflorescence is axiliary. The size of the seed varies as well as the coat colour, while the shape could be globular or kidney shaped.

It is a warm crop which does well under temperature between 20% and 35%. Well distributed and steady rains over a period of three months are needed.

Climatic requirements

Cowpea can be grown on a wide range of soils from sandy to clay and acidic to basic soils with pH ranging between 4.5-8.0.

Best yields are obtained on well-drained sandy loam to clay loam soil of pH range 4.5-8.0. Cowpea does not tolerate water logging but could rather tolerate moisture stress than maize and other legumes.

Fertilizer application

Cowpea has the ability to make use of atmospheric N_2 through biological nitrogen fixation. Rhizobia root nodules fix molecular N_2, while in tropical soils natural rhizobia could be said to be present to a number good enough to effect nodulation. Artificial inoculation may also be beneficial. Experiments have shown that excessive N-fertilization reduces inoculation, and causes excessive vegetative growth, hence reduced yield but a starter dose of N is appreciable based on soil test result especially on poor soil. Cowpea like other legumes requires P and K in reasonable quantities mostly on poor soils. A good yield of cowpea will require P and K in the following quantities.

200 kg of NPK 0:15:15 or 30-40 kg P_2O_5/ha and 25-30 kg K_2O/ha apply before planting

Planting could be done on ridges or flat depend on field drainage with spacing of

70 cm x 20 cm (medium maturing varieties)

50 cm x 10-20 cm (Early maturing varieties)

With 2 plants/hill for vegetable cowpea, 50-160 cm x 15-25 cm with row is recommended. Seed rate is 20-25 kg/ha. But for the early maturing varieties could be 40-50 kg/ha.

Planting is done when there is enough moisture to allow germination and could be adjusted such that the crop matures at the end of the rainy season depending on variety.

Early Maturing varieties

Varieties	**Seed Type**	**Amation (Days)**
IT 82E – 9	Black smooth	60 – 65
IT 82 E - 18	Brown smooth	65 – 70
IT 82E – 60	White rough	60 – 65
IT 52E – 442	Brown smooth	55 – 60

Medium Maturing varieties

Varieties	**Seed Type**	**Duration (Days)**

Ife Brown	Brown wrinkle	75 – 85
IAR 48	Light Brown to (large seed)	
(sampea 7)	dark brown rough	90 – 100
Vita 7	Brown wrinkle	75 – 80
TVx323b	Cream rough	75 – 80
IT 81D – 994	White rough	80 – 85
IT 90k 277-2	White smooth	75 – 80
Vegetable Cowpea		
IT 81D – 1228 – 14	White	55 days
IT 81D – 380-5	White	45 days.

Pest Control

Cowpea is attacked by pests such as flower thrips (*Maruca testulalis*, pod bearers and pod bugs (pod sucking), leaf hoppers and beetles.

1st spray - 15 – 20 DAP Cymbush + Nuvacron or Dual + Dimethoate + cymbush

2nd spray - 30 – 35 DAP At flower bud unitation (To control thrips).

3rd spray - 40 – 45 DAP pod initation

4th spray - 55 – 60 DAP pod filling stage with the attach of maruca and sucking bugs.

5th spray - 65 – 70 DAP In case of medium maturing varieties (To control pod bugs).

Weed Control

Hand weeding, 2 – 3 pre-emergence herbicides Galex. Dual, codal lasso, stomp combined with paraquat.

Harvesting, Storage and Utilization

Stored in air tight containers using phostoxin tablets (2-3 tablets per 100 kg bag).

FIBRES

Fibres: Fibre crops are grown for fibres, which is used in making textiles, ropes, twines etc. Fibres of commercial importance occur from many families on the plant kingdom. Thus, many species and varieties of plants yield fibres from the stems, leaves, leaf sheaths, fruits and seeds. Vegetable fibres can be classified in two ways:

(i) Morphologically, according to the part of plant from which fibres are obtained

(ii) According to the practical uses to which they are put.

i. Morphological Classification

A. Hair fibres: Hairs are borne on the seeds or inner walls of the fruit e.g. cotton (*Gossypium hirsutum*, *G. barbadense*); Kapok (*Ceiba petandra*) or silk cotton.

B. Stem, Bast (inner bark) or Phloem fibres: Fibres are obtained from stem e.g. Kenaf (*Hibiscus cannabinus*); Flax (*Phormium tenax*); Jute (*Corchorus capsulairis*); hemp (Indian hemp) (*Canabis sativa*); ramie (*Boehmeria nivea*); roselle (*Hibiscus sabdariffa*). These are sometimes referred to as "soft" fibres as distinguished from leaf fibres sometimes called hard fibres.

C. Leaf fibres: Fibres are obtained from the fibro-vascular system of the leaves e.g. sisal (*Agave sisalana*), Manila hemp (*Musa textilis*).

D. Woody fibres: These consist of the various elements of trees which make up the fibro-vascullar tissue of wood. These fibres are used in very large quantities for pulp and paper making e.g. Coniferous softwoods like pine (*Pinus sylvestris*).

E. Miscellaneous fibres: These are obtained from other parts of the plant. Two of the most important are piassava (surface fibres of palm leaves and stem) and similar brush making fibres obtained from the sheathing leaf stalks of palm trees, and coir fibre obtained from the fibrous husk of mesocarp surrounds the coconut (*Cocos nucifera).*

ii. Classification based on usage of the fibres

Fibres such as cotton, flax, hemp, ramie, manila etc. are generally produced for use in textiles and their use in paper making is secondary. They are also used for specialty papers; cotton for bank and bond papers to give them higher strength; sunn hemp (*Crotalaria juncea*) is used in making cigarette paper.

Cotton (*Gossypium hirsutum*)

Belongs to the family malvacea. Various types grown in West Africa are of members of the genus Gossypium.

VARIETIES:

The most important ones are *Gossypium hirsutum, Gossypium vitifolium* and *Gossypium peruvianum.* Their cotton has short fibres and is called upland cotton, sealand cotton – *Gossypium barbadense.*

BOTANY:

Cotton is a shrub growing 1-2m tall. It is a perennial but normally cultivated as an annual (builds up pest if left in the field so normally replanted every year). It has a tap root system. The stem is woody when mature. Leaves occur spirally on the stem. Each leaf consists of a long petiole and a palmate lamina, divided into 3-5 lobes. Hairs and oil glands are present on the leaf and two small stipules occur at the junction of the petiole with the stem. Flowers are borne on specialized branches which occur on the upper part of the plant. Each of such branches terminates in a flower. Flower is surrounded by 3 or 4 bracts which protect the flower before it opens. Petals are white or yellowish in colour. Each flower is open for only one day and self pollination is common. The cotton fruit (called the cotton boll) is a capsule. At maturity, the fruit wall splits along 3-5 sutures to expose the fruit contents. The seeds are black in colour. Two types of hairs arise from the seed testa, long white hairs (lint) and short hairs (fuzz). Economic part is the lint. Seeds are embedded in lint and fuzz.

ENVIRONMENTAL REQUIREMENT

Cotton grows well in areas of moderate rainfall, 600-700 mm/year very dry weather during flowering can cause shedding of leaves and young cotton bolls. It can be grow on many soils ranging from moderate sandy to very heavy clay soils with pH value varying from 5.2-8.

PLANTING:

Planting is done at the beginning of the rainy season. Cotton planted late will have a much reduced yield. Later heavy rains will affect flowering; the incidence as pests also increases later in the season. Cotton is spaced at 90 cm x 30-45 cm. 5-6 seeds is planted per hole at a depth of 2-3cm and later thinned to two plants/hole when they are 10 cm high but not later than 6 WAG (weeks after germination). Plant on ridges in high rainfall areas to prevent waterlogging. Crop rotation should be practiced to control pests and maintain fertility. It can be intercropped with cowpea, sweet potatoes, maize, groundnut or beans.

WEEDING

Weed when seedlings emerge because cotton is slow growing in its early stages and cannot stand too much weed competition.

FERTILIZER APPLICATION

For poor soils, apply 100 kg/ha of double superphosphate and 100 kg/ha of CAN (1 large spoonful for every two spaces).

SPRAYING

Crop yields are halved with chemical pest and spray when plants flower, 9-10 WAG (germination). In areas with two rainy seasons, if the crop is planted at the beginning of the short rains, spraying should start at the beginning of the long rains.

HARVESTING:

Harvesting commonly called hand-picking is done by hand in Africa. Harvesting is done at weekly intervals to prevent discoloration of lint in the field. Cotton as it is picked from plant is called seed cotton, composed of seed, lint and fuzz, care must be taken to avoid breaking off piece of dried plant material during picking because these can become easily mixed with the cotton. Do not over-pack to avoid damaging the lint.

PROCESSING AND STORAGE

Processing starts with ginning: a machine (gin) which separates the lint from the seed. The cotton seeds are dried artificially before ginning. Refuse and immature bolls are removed in the ginning process, the fibres are separated from the seed with a circular saw that catches and cuts the fibres from seed held on a screen. The lint is brushed from the blade and blown to a condenser and finally baled. The seed is further processed to yield cotton-seed oil.

GRADING

Graded into A and B. Grade A should be free from insect damage, clean and white, not spoilt by rain and without any foreign matter such as stem or leaves.

PESTS

PESTS	DAMAGE	CONTROL
Cotton aphids or leaf suckers or *Aphis gossippii*	The leaves are cupped or distorted with clusters of soft, greenish or blackish aphids on young shoots and on underside of young leaves – drops of sticky honey or patches of sooty mound on the upperside of leaves	Spray with Diazinon, Formothion
Cotton strainers (*Dysderus spp)*	Bugs sulk sap from bolls and seed small green bolls may turn brown due to death of seeds. Damaged bolls are partly opened and lint is stained and stick to the boll wall – pest also carries diseases from one plant to another	1) Spray with carbaryl cypermethrin 2) Sow early
Pink bollworm (*Pectinophora gossyprells)*	Caterpillars feed inside the bolls which open prematurely partly exposing discoloured and rotting lint	1) Uproot and burn old cotton crop 2) Use seeds fumigated with methyl bromide
American bollworm (*Heliothis arroigera)*	Larva bore clean circular holes in flower buds and bolls of all sizes	Spray with cypermethrin
Cotton jassid (*Empoasca spp)*	Attacks leave which curl downwards at the edges. The leaves turn yellow and then red and may dry up and be shed	Plant resistant varieties

DISEASES

Diseases	Symptoms	Control
Bacterial wilt or blight (*Xantomonas malvacearum)*	Attacks young seedling causing small, water soaked pacthes. Turn brown and dry up. Young bolls may rot.	Clear all crop residues after harvest, deep plough and use resistant varieties.
Alternaria spot (*Alternaria gossypina*)	Brown spots on leaves	Practice crop rotation and farm hygiene
Anthracnose (*Colletotrichum gossypii)*	Causes reddish spots on stem, leaves and bolls. Bolls may rot.	Dress seed with Thiram or captan. Use resistant varieties.
Fusarium wilt (*Fusarium spp*)	Plants wilt though soil is wet. (Soil-borne)	Practice crop rotation. Dress seed with captan or Thiram. Use resistant var.
Leaf curl (Viral)	All parts of plants are distorted. Transmitted by whitefly	1) Resistant cultivars 2) Clean cultivation

E.g. of fiber crops: Jute (Corchorus spp), Hemp (*Cannabis sativa*), Kenaf (*Hibiscus cannabinus*), Ramie (*Boehmeria nivea*), Roselle (*Hibiscus sabdariffa)*, Sisal (*Agave sisalana*).

KENAF (*Hibiscus cannabinus*)

Belongs to the malvaceae family. The numerous local names: gambo hemp, deccan (dekkan)hemp.

Varieties: Depends on maturity dates. There are 140-160 days or early maturing variety and the 160-180 days or late maturing variety.

BOTANY

Kenaf is an annual with straight thin stems reaching 4m in height. The leaves are oval (heart shape) or lobed. The flowers are red or yellow yielding round and pointed fruits. About 16-20% fibre is in the stem before flowering.

Environmental requirement:

It is grown throughout the tropics. Temperature ranges from 15-25^oC and rainfall of at least 600-800 mm per annum. Well-drained sandy loams, rich in humus with soil pH of 6-6.8 are suitable.

Planting

Seeds are planted at 25-35 kg per hectare at spacing of 20-30 cm by 5-10 cm. Wider spacing is necessary for seed production. They can be sown broadcast, and in mechanized agriculture they are drilled with the accurate spacings. One hoeing after germination may be necessary as stands develops so quickly that weed control is no problem. Fertilizer is similar to that of jute but N should not be less than 40-50 kg. 90 kg N, 60 kg P_2O_5 and 60 kg K_2O.

HARVESTING AND PROCESSING

When plants attain 50% flowering, harvesting should commence in 3-5 months either by hand or mechanical. The fibre is then still easy to separate from wood; also the fibre content does not increase significantly after this point. A substantially better fibre is obtained if a retting process (soaked in water) for 5-14 days to remove non-fibrous tissue. It is advantageous that the separated fibres can first be dried (shade) and then later retted at any convenient time. The fibre content of fresh stems is 5-6%, and 18-22% of the dry weight. Fibres are used for sacks, cordage (cords and ropes). The leaves are used as food, and oil is derived from the seed. Also used in paper making.

PESTS AND DISEASES

Diseases include dry rot, leaf spot, leaf blight, stem rot and anthracnose. These are caused by fungi and can be controlled by fungicide sprays and the use of resistant varieties.

Pests include damage by leaf-eating insects and can be controlled by contact insecticides. Root-knot nematodes and stem borers are also included.

COVER CROPS

Are crops grown to provide ground cover between widely-spaced tree crops or arables. They should be a fast growing species. They protect the soil from the impact of raindrops, and from the scorching effects of direct sunlight, and also prevent the development of an unwanted weed flora [e.g. *Imperata cylindrical* (L)]. Legumes are most suitable, as they simultaneously contribute on N supply to the main crop due to their N_2 fixing. Ground cover crops should be efficient in the acquisition of mineral elements or nutrients, so that they themselves demand little or no fertilizers, while at the same time mobilizing the mineral resources of the soil for the main crop. They should be deep rooted, so as not to compete with the main crop for water and nutrients. They should also remain green through several months of low rainfall in order to reduce the risk of fires, and should tolerate certain amount of shade. The choice of species depends not only on the local soil and climatic conditions, but also on the growth habit of the main crop.

Ground cover plants can have a decisive role as a means of controlling weeds. If a quick growing ground cover crop is soon immediately after harvesting, the possibility of weed propagation is reduced. Quick growing legumes such as *Lablab purpureus, Vigna phaseolus* are also suitable for keeping down weeds in the short term. However, vigorously growing ground cover crops are not only used to hinder the appearance of unwanted weeds, but also to suppress existing populations of weeds e.g. include *Pueraria spp, Centrosema pubescens, Mucuna spp*, Cowpea, sweet potato, melon, *Calopogonium mucunoides*, etc.

FORAGE CROPS

Are plants used essentially in their entirety as feed for animals. The condition or form of the forage when fed varies tremendously. When forage is grazed, animals feed directly on fresh plants in the pasture or on the range. Forages can also be fed fresh after being harvested mechanically. Forages include grasses and legumes e.g. of grasses are *Cynodon dactylon* (Bahama or Bermuda grass), *Panicum maximum* (guinea grass), *Pennisetum purpureum* (elephant grass), *Digitaria decumbens* (Pangola grass) while the legumes include: *Calapogonium mucunoides* (Calapo), *Centrosema pubescens* (Centro), *Lablab purpureus* (Lablab), *Stizolobium spp* (Mucuna), *Pueraria spp, Cajanus cajan* (Pigeon pea).

Citrus spp

The most important species in the sweet orange (*Citrus sinensis*). Citrus fruits are borne on large evergreen trees reaching heights of 4.5m-8m. (1) *Citrus sinensis* are classified as common or navel ('Washington', 'Thomson') etc. Other species include: (2)Tangerine or Mandarin (*Citrus recticulata)* is a type of citrus which has a loose skin, peels easily and has attractive orange-red flesh.

(3) Lemon (*C. limon*), (4) Lime (*C. aurantifolia*), (5) Sweet lime (*C. limetta*), (6) grape fruit (*C. paradise*), (7) Pummelo or shaddock (*C. maxima*), (8) sour orange (*C. aurantium*), (9) Tangelos (Tangerine x grapefruit) and (10) temples (tangerine x orange).

Most citrus species are propagated by grafting on rootstocks which has been grown from the seed. The stock has a definite influence on the disease resistance and fruit quality. The choice of stock depends on the local conditions: resistance against phytophthora on heavy soils, resistance against tristeza in places where no virus-free close material is available.

Planting distances depend on the cultivar and stock (growing vigour); for oranges, 7.5-9m, for mandarins, 4.5-6m.

The soil is kept free of weeds. Cover crops and arables can be planted. In large scale cultivation, soil herbicides are used (diuron or biomacil).

Pest and Control

	Pest	Damage	Control
1.	Citrus aphid	Suck plant sap and cause	Diazinon, Malathion,

	Toxoptera citricidus	distortion of the leaves	Dinethoate
2.	Citrus black fly Aleurocanthus	Groups of shiny black, scale-like insects underneath leaves. The leaves drop	As above
3.	False codling moth Coyplophebia leucotreta	Moths lay eggs on fruits, caterpillars bore into pulp. Yellow patch on skin of fruit	Spray Fenthion on malathion once a week starting when fruit measure 4cm across Bury infested fruits
4.	Mealybugs	Causes injuries to the growing points of citrus	Spray with Parathion or Malathion

Diseases and Control

	Disease	Symptoms	Control
1.	Tristeza (viral)	Trees do not grow well, leaves become bronzed in colour and fall off and twigs die	-No chemical control -Use resistant root stalks such as rough lemon, sweet orange
2.	Anthracnose	Leaf blight, twig blight and fruit staining	-Spray with copper fungicide -Farm sanitation -Use of tolerant/resistant varieties
3.	Scab	Whitish scabs on leaves, twigs and fruits	-Farm sanitation -Use of tolerant/resistant varieties -Use of fungicide e.g. captan, Bordeaux mixture
4.	Foot rot or brown rot (gummosis)	Kills the bare on trunks and roots resulting in the death of plant	-Use fungicide -Suitable growing rootstocks
5.	Citrus canker (*Xanthomonas citri*)		-Use of tetracylines -Use of disease-free grafting materials

Citrus Herbicides

Dalapon	2-4 kg/ha active ingredient	Annual and perennial grasses	Pre-emergence
Diuron	1.6-3.2kg/ha a.i.	Annuals	Pre-emergence
Simazine	4-9kg/ha a.i.	Annuals	Pre-emergence
Bromacil	1.6-6.4kg/ha a.i.	Annuals Perennials grasses	Used for orchards established more than 4 years(pre-emergence).

SPINACH (*Amaranthus curentus)*

It belongs to the family Amaranthaceae and has the following common names: African spinach, Indian spinach, Amaranth, Green leaf etc. Many species probably originated from South America or Mexico and are now widely distributed throughout most tropical areas.

BOTANY

It is usually a short-lived annual, up to 1m in height. The stems are erect, often thick and fleshy and sometimes grooved. The leaves vary in shape depending on variety and are green or purple, normally alternate, petiolate and entire, tips often obtuse. The inflorescence is racemose spikes, either axillary or terminal. Flowers are small, numerous, regular and unisexual with a super-ovary. The seeds are small with shiny testa and are usually black or brown.

VARIETIES

These include: Amarante rouge, Amarante verte etc. Fotete, Fotete Rouge, Fortete vert-rouge etc., *A. blitum, A. lividus*, *A. curentus*.

ENVIRONMENTAL REQUIREMENT

Soils with a high organic content, with adequate mineral reserves are required for optimum yields although some species are tolerant to fairly wide ranges of soil condition. The optimum pH range is 5.5-7.5 but some cultivars tolerate alkaline soils. Most species are tolerant of relatively high temperature and generally thrive within temperature range of 22-30^{o}C. It is grown in both wet and dry seasons although irrigation is normally acquired for dry season crops.

PLANTING: Seeds are sown broadcast on prepared beds at a rate of 3-10g/m^2 (1.5-2kg/ha). They may be sown on nursery beds and the seedlings transplanted to rows 20-30cm apart and 10-15cm between plants. Vigorous species can be transplanted to 30-40m x 30-40cm square spacing. Broadcast sown seedlings may be thinned to15-22cm apart each way. A grass mulch is sometimes used for covering freshly sown seeds protect them from heavy rain and removed when seeds germinate.

WEEDING

This is done by hand-picking the beds and hoe weeding the furrows.

FERTILIZER APPLICATION

Most cultivars or species have a high rate of nitrogen absorption and surface dressings of nitrogenous fertilizers are normally required during the period of active growth. Additional application of potassium may be also necessary or established plants may be cut back to within 15cm of the base to encourage lateral growths which will provide successive harvests. Yield entire plant harvest: 20-25t/ha; shoots only (successional harvesting) 30-60t/ha.

STORAGE AND PROCESSING

If harvested whole, roots are trimmed and the plants may be washed before being tied into bundles where available, crushed ice or water may be scattered over the top layers of the basket or container to prevent wilting. Care should be taken to avoid over-packing of the container.

PESTS

PESTS	DAMAGE	CONTROL
Hymenia recurvalis, F (leaf caterpillar)	Feeds on the leaves which it may roll up within a web	-Use of chemicals e.g. Lindane. Malathion (taints leaves) -Biological control
Lixus trunculatus, F (stem borer)	Larvae bore tunnels in the basal part of stalk, weakening the plant and reducing yield	-Burn crop debris -Use insecticides e.g. lindane, carbaryl
Zonocerus variegatus variegated or stink locust	Eats leaves of seedlings	Use Dieldriin or carbaryl sprays or aldrin or BHC baits

DISEASES

DISEASE	SYMPTOMS	CONTROL
Choanephora cucurbitarum (leaf and stem wet rot)	Saprophytic moulds, soft rot of leaves and young stems is covered with grey sporangiosphores with black heads. Young or weak plants may die. Attacks weaker plant	-Promote vigorous growth -Use resistant varieties
Pythium aphanidermatum (damping off)	Seedlings appear water soaked at ground level and topple over often with the leaves still green.	-Use quality seeds. -Plant under optimum conditions for rapid growth. -Avoid overwatering of plants. -Seed dressing e.g. captan, thiram.

FACTORS AFFECTING CROP PRODUCTION

The factors include: environmental, economic and sociological.

1. Ecological or Environmental Factors: These include: rainfall, humidity, and temperature, length of the growing season and soil factors.

   Rainfall is one of the most important environmental factors affecting crop production. Rainfall varies in its efficiency, in some sections a considerable part falls during months when crops are dormant. Different crops require different amount of rainfall/annum for optimum yield, and also in term of humidity. The loss of water by evaporation has considerable effect on the efficiency with which water is used by growing plants. Loss of water (moisture) by evaporation and transpiration is high when the relative humidity is low. **Temperature** is important in crop distribution. The date at which crops are planted relates directly to air temperature as this affects soil temperature. Crops that are grown when temperature is low is classed as cool-season crops.

   Soil factor: In some areas, much of the land may be broken and rough with many stones at or on the surface, or poorly drained or lacking in fertility. The topography of the land tells sometimes of the soil. Rough, hilly land is not likely to be fertile compared to soil with equal rainfall. The fertility of the soil is lost both by leaching and by erosion.

2. Economic Factors: These include: land value and choice of crops, labour requirement and transportation and other factors (population).

   Population:

- Perishable products raised near centres of high population.
- Non-perishable are produced at great distances from the centres of consumption.
- High demand for food in the market and urban centres.
- Agrobased industries like livestock feedmills, manufacturing plants for pharmaceuticals, soft drinks, textiles and etc. are sited in urban centres.
- High population in these areas provides ready market for products, apart from those produced for export market.

- Large quantities of food produced are consumed in the centres.
- Demand for most of these commodities often dictates the scale of production.

- Oil Boom – recession in economy (shortage of foreign exchange,
- importation): Exchange – reduction, followed by a total ban on importation – led to increasing demand (maize, rice, wheat and sorghum) to sustain local industries – led to increase in the production (large scale) of these commodities.

Land value and choice of crops: Land that is high in price must be made to produce crops with relatively higher unit value and with a higher production rate than cheaper land.

Labour requirement: The requirement of a given crop for labour at a particular time affects the crop choice to be made and the crop combinations used. Most farmers will plant crops that will increase their economic returns even after labour and other expenses.

Transportation and other factors: Transportation cost is a factor that influences the crops that farmers in certain sections will grow; it also affects other crop products needed to be transported from other sections. Changes in demand for different crops, as measured by prices they bring to the market and in the amounts exported to other parts of the world in response to different needs there will influence the hectarage of the different crops grown.

3. Sociological Factors: Some farmers regard some crops as lesser crops and will not cultivate these crops. Also cultural taboos prevent farmers from growing some crops even when these crops are of economic importance in some areas. This can affect the production of such crops.

DEFINITION OF CROPPING SYSTEM AND FARMING SYSTEM

Cropping system: refers to the scheduling and cultivation of various crops within a farm enterprise in a given agricultural year. It refers to the way and manner in which the farmer actually organizes the growing of various crops and how he arranges them in his field.

Farming system: refers to a system which is influenced by environmental, technical, economic, and human factors. It considers the farmer, his farm operations and the biological and socio-economic environment in which he operates. It incorporates cropping system. The farming system that results is determined by how he produces, uses, market or consumes his farm products, both crops and livestock.

CROPPING SYSTEM COMPONENTS

The components of the environment of crops consist of the soil, sunlight, water and temperature.

Soil: The characteristics of soil for crop production include:

1. Ease of cultivation with conventional tools
2. Ability of roots to penetrate, develop and anchor in the soil
3. Good nutrient content, nutrient-holding capacity and availability to growing crops
4. Absence of a permanent water-table near the surface of the soil
5. Depth of rooting zone
6. Satisfactory rate of acceptance of rainfall and resistance to erosion
7. The soil must be porous enough to permit free circulation of air for the benefit of the roots of growing crops

These characteristics are usually influenced by such factors as choice of soil for specific crops, cultivation practices, irrigation, drainage, manuring, mulching and planting patterns and distances between plants.

4. Air
5. Sunlight
6. Water

7. Temperature

(b) Human preferences (Exogenous factors)

(1) Government policy

(2) Market poll

(3) Institution (ADP etc.)

(4) Politics

(5) Religion

(6) Infrastructure

(2) Air: The O_2 of the air is required for respiration and the carbon dioxide for photosynthesis. The conc. of CO_2 determines in part, the rate of photosynthesis and thereby affects crop yields. High concentration of CO_2 in the rooting zone of crops are harmful to all crops, it is only the green, aerial parts that can benefit.

(3) Sunlight: The techniques used to obtain maximum utilization of sunlight in crop production include the choice of location, type of plant, distribution and density of planting, weeding, shading and time of planting. Control of the distribution and density of plants through spacing, pruning or training ensures maximum utilization of sunlight. Generally, close rather than wide spacing is the most efficient but the optimum spacing is often determined by the quality of yield desired. Competition for light between different parts of the same crop stand can be modified by pruning and training of the canopy of the crop. The intensity and duration of sunlight is controlled by shading i.e. growing companion crops or shade plants with a crop. One of the best ways of utilizing sunlight in crop production is to adjust the time of planting so that the crop grows through a period when sunlight is brightest and longest in duration.

(4) Water: Water is required for the process of photosynthesis and for all metabolic reactions. In fruit and leafy vegetables, water can limit yield. Although crops absorb water from the soil, all the water required for crop growth and yield come from rainfall which in the tropics is cyclic and fairly

dependable. The intensity and duration of rainfall varies. Humidity also affects crop production by influencing evapo-transpiration. Most tropical crops are adapted to intermediate moisture supply conditions and their growth and yield are severely affected by excess or reduced moisture availability. Certain stages of reproductive growth are very sensitive to moisture stress. Perennial tropical crops respond imperceptibly to moisture stress and the effects on yield may not be obvious until one year or more after the occurrence of the stress.

(5) Temperature: Optimum temperatures for crop growth lie between 5 and 34^{o}C. Different parts of plants, respond differently to the same temperature conditions. Temperature fluctuation is only important for crop growth and yield when moisture supply is limiting.

DEFINITION OF SHIFTING CULTIVATION

1) Shifting Cultivation

Farmers cultivate a plot of land large enough to supply their family's needs until soil fertility declined with continuous cropping. The farmers tend to move on to another plot leaving the first plot to return to bush through regeneration of the natural vegetation. The soil would recover its fertility during this fallow period. The land is planted with crops with high fertility requirements and ending with crops whose fertility is low. It is linked with low levels of inputs of technology and management. Most of the operations are carried out with simple hand tools and the labour requirements are high. Bush burning constitutes a technological easy answer to the problem of cleaning plant debris from the field prior to cropping. Bush left to fallow can stay up to 10yrs where land is abundant. Apart from soil fertility, pests and diseases can also cause a farmer to abandon his land. It requires a great deal of land to maintain the system. Shifting cultivation has low efficiency of labour utilization.

TYPES OF SHIFTING CULTIVATION

Two types of shifting cultivation are recognized under subsistence farming systems in the tropics.

1. The people build temporary villages and practice shifting cultivation in the immediate vicinity for several years until crop yields fall significantly. The whole community then migrates elsewhere to build a new village and open up new land. This practice is a common feature in Africa and Malaysia. The land is usually reopened only after a prolonged period of fallow.
2. The people live in permanent villages or towns with their cultivated land covering a large area. The prolonged use of a relatively limited amount of land naturally results in a more rapid rotation of the cultivated farms and so fallow periods tend to become gradually shorter and as the productivity of the immediate vicinity of the village declines, the distance from dwellings to the farms may continue to increase. The fertility restoration during the period of rest is dependent on the length of the fallow vegetation, the nature of the vegetation and the rate at which soil nutrients are taken up by the fallow vegetation from the subsoil.

CHARACTERISTICS OF CROPPING SYSTEM

(a) Shifting cultivation:

In the practice of shifting cultivation, the farm is not a permanent location. Instead, a piece of land is cleared, farmed for a few years and then abandoned in preference for a new site. While the new site is being farmed, natural vegetation (bush fallow) is allowed to grow on the old site. Eventually, after several years of bush fallow, the farmer returns to the original location. Shifting cultivation involves the moving of the home along with the farm, but this form exists in only a few places today. Shifting cultivation as practiced in the tropics is linked with low levels of inputs of technology and management.

There is no incentive to invest in permanent structures such as strong shed and irrigation facilities. Yields are usually low as inputs are also very low.

(b) **Mixed Cropping**:

The practice involves growing two or more crops simultaneously on the same piece of land. For example, sorghum and millet or cassava and maize are grown as mixed crops. Millet or maize is usually planted first and, about four weeks later, the sorghum or cassava is sown between the millet or maize stands. It is associated with under-developed farm technology. The system complicated the interpretation of crop performance while making mechanization difficult.

(c) Continuous Cropping:

This implies the cultivation of the same piece of land year after year. Fallowing may occur, but it never occurs for more than a season or two. The absence of a protracted fallow period means that other soil management procedures must be used to maintain high soil fertility. Continuous cropping is usually associated with a higher level of technology and management. In clearing, tree stumps and woody roots are removed from field. The operation is imperative if mechanical tilling devices (ploughs, harrow and ridgers) are to be used with ease in the field.

Continuous cropping relies on fertilizers and other soil amendments to boost fertility and also a good selection of crops and crop combinations. Lastly soil fertility is maintained by introducing short term fallow periods into the cropping cycle.

Land utilization under continuous cropping is extremely efficient. A high percentage of the land is under crops at any given time. It is possible to erect permanent structures on the farm site. Good access roads, irrigation facilities and store houses can be built.

(d) Crop rotation

The practice of growing different crops, one at a time, in a definite sequence on the same piece of land is referred to as crop rotation. The design of a good crop rotation is by no means an easy task. The farmer must decide what crops to have in rotation, in what sequence the crops should occur, and for how many years or seasons each cycle of the rotation must run. Economic considerations are a major factor in deciding on what crops to have in the rotation. Usually there is one main crop (sometimes two) which is the farmer's primary target, and around which he builds the rotation. He designs his rotation so as to obtain the maximum yields of the target crop, while tolerating whatever yields may result from the other crop. Alternatively, the rotation may be designed to maximize the total economic yield from all crops in the cycle, without giving particular favour to one crop. Invariably, a legume crop is included in the rotation, whether or not it is the target crop. A fallow period is sometimes also included in the rotation although a forage or green manure crop may be grown on the field during the fallow.

Several factors have to be considered in deciding the sequence of crops. Usually the target crop comes immediately after the legume or the fallow period. At this time the fertility of the soil is at its peak. Crops which are known to have a high demand for nutrients are also planted first for the first or second season after the fallow. Crops which are deep feeders should alternate shallow feeders. Crop sequence is also influenced by disease and pests including weeds. E.g. yams should not follow cowpeas if the root-knot nematode is prevalent. The number of years for which each cycle of the rotation should run is determined by the number of crops in the rotation, the length of their growing seasons and how frequently the farmer can grow the target crop without running into problems of disease and soil fertility. In practice each cycle of crop rotation may last from 3-8 years, sometimes with one crop occurring more than once in each cycle. The farmer may consider his entire field as one plot. He then rotates the crops in sequence on the field or divides his field into as many plots as there are years in the rotation. The farmer then starts with a different crop on each plot and progresses through the rotation. In this scheme, all the crops are present on the farm at any given time e.g.

	Year I	Year II	Year III
Plot A	Cotton	Guinea corn	Groundnuts
Plot B	Guinea corn	Groundnuts	Cotton
Plot C	Groundnuts	Cotton	Guinea corn

(e) Mixed farming

Mixed farming is the integration of animal and crop production on the same farm. It provides for the combination of crop production and livestock in a single enterprise, such that the farmer is able to feed his animals or poultry with his own crops. Farmyard manure produced by livestock is also used on the crops. Crop farms are used as livestock feeding grounds once the crop has been harvested. Cattle feed on the crop residues and leave their dung in the field, thus increasing the fertility of the soil. It provides insurance against failure of any farm enterprise. Bulls are used in the cultivation of crops, thus increasing the total land area available for cropping.

(f) **Ley farming**: This system alternates pastures with crop production. The pasture usually selected for ley farming is of sufficient nutritional and morphological quality to enable it to fit into a crop rotation system. After the arable crop (a cereal) is harvested, the field is sown to pasture and grazed for one or two seasons before it is ploughed again for arable cropping. The planted pasture is usually a mixture of grasses and legumes. It involves a planted fallow which many farmers are unable to justify in economic terms.

(g) Alley Cropping System:

Is a system of growing small tree or shrub which recycles plant nutrients and at the same time provides material for mulch with an arable crop. The concept of alley cropping retains the basic features of bush fallowing, but has the following modifications:

1) Selected species of fast-growing small trees and shrubs usually legumes with the ability to fix nitrogen are used.
2) The small trees or shrubs are planted in rows with inter-row spacing wide enough to allow the use of mechanized equipment.
3) The trees or shrubs are cut back and kept pruned during the cropping period and the leaves and twigs are applied to the soil as mulch, providing a source of nutrients and organic matter. Bigger branches are used as stakes or fire wood.
4) The height to which the trees or shrubs are cut back depends on the shade tolerance of the associated crops.
5) The land is periodically ploughed in order to cut tree roots to reduce competition with crops.
6) The trees or shrubs are allowed to recover during the dry season, when they develop new growth ready to be used on the next crop.

TYPES OF CROPPING SYSTEMS

1. CROPPING PATTERN IN RELATION TO TIME:

a) **Relay cropping**: Involves following one crop with another immediately before harvesting the former crop. In practice, the seedlings of the second crop are established within the maturity field of the first crop. Usually the later crop makes little growth until the early crop begins to mature and then fully utilizes the soil and air environment after the early crop has been harvested. Has similar advantage to phased planting.

b) **Phased planting**: Is a type of mixed cropping in which planting dates are systematically arranged to ensure continuous sequence of growth and harvesting. This method has the following advantages:

1) Permits the phasing of labour operations.

2) Saves labour costs by combining weeding and planting so that fresh tillage is not necessary.

3) Reduces risk of crop failure from unfavourable weather, pests and disease damage.

4) Leads to phased harvesting thus ensuring continuous food supplies with reduced storage losses.

5) Ensures that the soil is continuously covered and protected from wind and water erosion.

c) **Monocropping** (monoculture or sole cropping) is the growing of a single crop on a piece of land within a growing season. The practice has the following disadvantages:

1) The practice carries with it the risk that the farmer could lose his entire crop in the event of drought, pests or disease attack.

2) Encourages pest and disease build-up.

3) It creates an imbalance in nutrient removal from the soil.

The advantage is that it encourages specialization in the techniques of production.

d) **Double cropping**: Is the growing of two crops in a year in sequence.

2. CROPPING PATTERN IN RELATION TO SPACE

a) **Sole cropping**: The practice of growing one crop variety alone in pure stands on a field is referred to as sole cropping. In this practice, only one crop variety occupies the land at any one time.

b) **Mixed cropping**: Is the simultaneous growing of two or more crops on the same piece of land. It is the most common of farming systems in the tropics usually associated with under-developed farm technology.

c) **Row cropping**: This is a type of intercropping system based on the exact spatial arrangement of crops on the field. When the various crops are grown is separate rows, it is called row cropping.

d) **Alley cropping**: Is the growing of small trees or shrubs which recycles plant nutrients and at the same time provides materials for mulch. It provides support for such twining crops as yam, green leaf for enriching the soil organic matter and increased nitrogen levels in the soil. Apart from tree or shrub species, legumes and non-legumes have been evaluated for use in alley cropping system. Desirable species are those that can be established easily and which can be maintained from basal sprouts and coppices when periodically cut back.

e) **Taungya system**: Is a system whereby trees are first planted then followed by crops till the trees form their shape.

Features:

1. Crops are planted together with trees.
2. Permanent crops are not planted together with trees.
3. It helps to stop erosion.

ADVANTAGES AND DISADVANTAGES OF CROPPING PATTERNS

(1) Mixed cropping

Advantages

1. Makes better use of the environment in terms of space, water and nutrient.
2. Permits higher plant population.
3. Reduces the risk of total crop failure resulting from pests and diseases.
4. Gives a good soil structure which in turn minimizes erosion.
5. When legumes are included, they may have some residual nitrogen in the soil which may benefit subsequent crop.
6. The return per unit of labour is higher as a result of greater total yields and more dependable returns can be secured from year to year.
7. Pests and diseases do not spread as quickly in crop mixtures as they do in monoculture.

Disadvantages

1. It complicates the interpretation of crop performance.
2. It makes mechanization difficult.
3. Most fertilizer recommendations are based on monocropping.

(2) Taungya System

Advantages

1. It reduces sunshine intensity on the soil surface.
2. Virgin lands are always put into use.

Disadvantages

1. Continuous cropping is not encourage
2. Use of mechanization is not possible in some cases.

(3) Alley Cropping

Advantages

1. It provides support for twinning crops such as yams, and green leaf for enriching the soil organic matter.
2. It increases nitrogen levels in the soil.

Disadvantages

1. It makes mechanization difficult.
2. It can result in substantial decrease in crop yield.

(4) Sole Cropping

Advantages

1. Mechanization can be practiced.
2. It encourages specialization in crop production.

Disadvantages

1. Failure of the planted crop leads to total loss for the farmer.
2. Encourages pest and disease build-up.

(5) Crop rotation

Advantages

1. It is an effective means of controlling pests and diseases.

2. Is a device for maintaining high soil productivity over several years of continuous cropping.
3. Offers the farmer some insurance against crop failure if field is divided into several plots.

Disadvantages

1. The growing of one crop means that the demand for labour occurs in peaks. Labour demand is more evenly spread if many crops are grown simultaneously.
2. The risk of crop failure is ever present.
3. Facilities for target crops are only utilized once in several years.

(6) **Shifting Cultivation**

Disadvantages

1. It wastes land because of large area of land is left fallow.
2. It does not encourage long term planning e.g. erection of a homestead, irrigation facilities.
3. It requires a great deal of labour and money in cleaning new land every time a farmer moves to another land.

CACAO (*Theobroma cacao*)

1.0 The Origin of Cacao

Cacao developed in the upper amazon region of Latin America. It was first discovered and grown in Mexico. The word cacao refers to the tree while cocoa refers to a drink made from its seed. Cacao has been cultivated in America for 2000 to 4000 years. The crop was discovered by Christopher Columbus during his fourth voyage to the new world. The specific centre of origin of cacao has been accepted as the area from the forests of the Amazon to Orinoco and Tabasco in South Mexico.

Spain introduced cacao to Africa around 1840. Cacao was introduced into Nigeria in 1974. Other sources of introduction of the crop to West Africa include: trading companies, Christian missionaries, soldiers, chiefs, farmers' associations, cooperatives, various departments of agriculture and more recently the West African Cocoa Research Institute (WACRI), the Cocoa Research Institute of Ghana (CRIG), the Cocoa Research Institute of Nigeria (CRIN) and the Institute Francaise du Cacao et du Café (IFCC). The first cultivation of cacao was at Ibadan; other cacao producing countries include: Ghana, Ivory Coast, Sierra Leone, Togo and Republic of Benin.

TAXONOMY

Cacao belongs to the genus Theobroma in the family steruliocene. Over 20 species of Theobroma are recognised. All cacao cultivated belong to a single species *Theobroma cacao* (L). There are three large and distinct groups within the species T. cacao. These are Criollo, Trinitario and the Forastero Amazon.

1. Criollo: The trees are slender, green pods or pod coloured by anthocyanin pigments, warty, thin, soft pericarp, lignified mesocarp, beans plump and embedded in pulpy mucilage, white cotyledons. On fermentation and drying the cotyledon colour turns light brown.
2. Trinitario: Is a hybrid of mainly: Forastero Amazon and Criollo. Pods are green or pigmented. The beans vary in colour from very light to very dark purple.
3. Forastero: Is characterized by green pods, absence of anthocyanin pigmentation, thick pericarp, strongly lignified mesocarp, plump but slightly flattened beans, and deep purple cotyledons when fresh. Large scale cultivation is dominated by the Forasteros (80%) especially the Amelonados which are the form almost exclusively cultivated in West Africa.

MORPHOLOGY

The tree is low, reaching an average height of 5 to 10m. The main trunk is short, branching (jorquetting) in whorls of five branches: branches are dimorphic.

1. Verticals or chupons growing from the trunk have leaves arranged in 5/8 phyllotaxy.
2. Lateral branches (fans) with ½ phyllotaxy.

Cacao is naturally outbreeding. Various insects have been associated with pollination in cacao. The main pollinators are thrips, midges, ants and aphids. After successful pollination, fertilization takes place within 36 hours; the sepals, petals and staminodes drop away, the stamens and the pistil wither. The young pod known as cherelle, commences development by longitudinal elongation, followed by increase in girth. The period between fertilization and pod maturation varies from 150-180 days depending on the variety. The pods turn light yellow when ripe in all varieties. Pods are ready for harvest.

CLIMATIC FACTORS

Cacao is a low-altitude crop. It can grow from sea level up to an altitude of 700m. It has a wide range of rainfall from 1500-3000mm per annum or more. In selecting a site for planting cacao, it is desirable to ensure that the site enjoys rainfall averaging 150mm per month, 1500mm-2000mm optimal/year for at least 9 months of the year distributed evenly. It is susceptible to damage by strong winds. Different winds such as the harmattan, also can dehydrate of floral organs rendering them incapable of opening, thus resulting in failure of pollination. Cacao is a tap-rooted plant and requires deep well-drained soils, free from non concretions, high in nutrient content and a topsoil rich in organic matter. Cacao soils should have adequate clay content.

NURSERY PREPARATION

Seeds do not pass through a dormancy period. They lose viability on extraction from pod within 5-7 days unless specially treated. Seeds are mixed with moist fine sand, moist sawdust or moist ground charcoal for storage, and should be stored in a cool place. Wooden boxes are preferable to closed jars because the permit aeration for the respiration of seeds. Storage of this type lasts for 2-3 weeks as some already germinated seeds will be noticed within this period.

In nursery beds single seeds are planted per hole which is usually 15 to 20 mm deep and 15-16 cm apart. Seeds should be watered lightly every day. Germination of seeds will be noticed within 7-10 days. After germination, amount of water should be increased, depending on the quantity of raw water in the mornings or evenings.

Seeds can also be sown in poly bags. These should measure 20 x 12 cm and have drainage holes. The poly bags are filled with fertile sifted topsoil. Bags are watered heavily the night before the seeds are sown. Seed are sown one per bag. Light watering is done after sowing daily until germination. Adequate water should be provided after germination. Seeds should be provided with shade after germination. Examination for pests and diseases should be done regularly and once noticed should be uprooted and burnt for viral bacterial diseases. For fungal and insect attacks, it should be controlled with chemicals. No need for fertilizer application of cacao seedlings in the nursery.

About a week before transplanting the seedlings in to the field, seedlings which are raised in nursery beds should be partially dug in situ to stimulate new roots before transplanting in the field. It also ensures that fragile young roots are not damages. Seedlings should be planted with a ball of earth or with clay slurry. Seedlings should be sprayed against diseases and pests prior to transplanting in the field.

ROLES FOR SEEDLINGS IN NURSERIES

1. Site nursery on clear-felled land near a permanent water supply and provide seedlings with artificial shade of palm fronds.
2. Use forest topsoil for seeds to be sown ports, actual sowing should not be done at the hottest time of the day. Sow in Dec-Feb. to allow the seedlings a period of four months of growth in the nursery.

3. Water thoroughly when seeds are sown, thereafter lightly every second day for the remainder of the dry season except during harmattan periods when watering everyday may be necessary.
4. Fronds should be removed in stages (2-3), all shade being removed after a week before transplanting.
5. Seedlings should be no more than 4-5 months old when transplanting, care must be taken not to damage seedlings from the nursery to the field.

Cacao can easily be vegetatively propagated by leaf bud cuttings, multiple bud cuttings, marcotting, budding, grafting and layering.

TRANSPLANTING

Field should be well-prepared before transplanting and transplanting should be done when the rains are steady and regular. Accepted spacing in cacao is 3m x 3m. Plant seedlings immediately on arrival at the planting site. For polybag seedlings, a period of 7 days should be allowed for rest. Small, badly-shaped seedlings must be discarded. Seedlings with new flesh of growth should not be transplanted. In transplanting, seedlings are held in position and seedling roots are arranged in position, fill in the soil and consolidated.

WEEDING

Weeding is a problem involving the removal of annual plants and shrubs mainly in the first 3-4 years after establishing cacao in the field when canopy is not yet closed. Weeds compete for water and nutrients and cause poor growth of the cacao trees. Frequency of weeding will depend on the overhead shade and rainfall. In plantations, row weeding thrice a year, supplemented by at least 4-6 slashings of the avenues per year is considered adequate. Weeding may reduce the incidence of black pod disease as it allows for a better circulation of air thus reducing the humidity within the farm. It also helps to control insects especially leaf-eating caterpillars. Herbicides could also be used because of the increasing cost of labour. Herbicides to be used include:

Aminotriazole (2) Simazine (3) Aminotriazone + Simazine (4) Paraquat (apply before weeds blossom).

MULCHING

Mulch before the onset of the first dry season to assist in conserving moisture in the soil. Each plant should be given a 15cm deep layer of mulch towards the end of the rains. A small area around the base of each seedling should be left clear to reduce termite attack on the stem. Grasses serve as good mulching material.

PRUNING

Pruning is done to remove unwanted growth and thus maintain regularly shaped trees. Unskillful pruning may lead to injuries to tree with consequent reduction in yield. Frequency of pruning depends on growth of the trees. Pruning should be done as close as possible to the stem on which they have grown. A lightweight cutlass is suitable for pruning operations. Pruned surfaces bigger than 20 mm in diameter should be painted with ordinary paint or a tar sealing compound.

SHADE

Temporary shade (nurse shade) is beneficial during the early years before the cocoa canopy closes. Nurse shade should be easy to establish, it should compete at little as possible for moisture and soil nutrients. E.g. of nurse shade is plantain. Banana should be avoided as it competes for moisture during the dry season with cocoa. Thinning and removal of nurse shade should be at the end of the dry season.

FERTILIZER APPLICATION

Important fertilizers needed are N, P, K. and B (boron) 100 kgN, 20 kgP and 70 kgK per ha per year. The fertilizer is given in installments: at the beginning of the main foliage growth period, main flowering time and the time of the main growing of the fruit.

CACAO DISEASES AND CONTROL

	DISEASES	SYMPTOMS	CAUSATIVE AGENT	EFFECTS	CONTROL
1.	Swollen shoot	1)Network of red vein banding which soon develops into vien clearing or chlorosis 2)Swellings in stem and root.	(Mealybug)	Growth reduced	Cut all infected trees
2.	Black pod	1)Small brown spot on pods with an irregular water-soaked margin 2)Wilting on the flush leaves of cacao	Fungi (*Phytophthora palmivora*)		1)Removed infected pods 2)weeding Chemical 3)Use of lime Bordeaux mixture
3.	Charcoal rot	Pods have a dark brown colour initially	Fungi (*Botryodiplodia theobromae*)		
4.	Fusarium pod rot		Fungi (*Fusarium species)*		

CACAO PESTS AND CONTROL

	PEST	CONTROL	DAMAGE
1.	Cacao mirids	insecticide	Suck up the juices causing dual circular black patches on dry tissue called lesions
2.	Mealybugs	Biological control Chemical control	Piercing and sucking injury reduce plant growth and crop yield
3.	Pod-husk borer	Insecticide	Eat pods and beans
4.	Termites	Spray with Aldrex 40 or Agrothion	Eats branches and roots

HARVESTING

It takes 150-180 days depending on variety from pollination to pod ripening. Only mature and ripe pods are harvested and processed promptly. Harvesting should be done twice a month. Has two main season of pod production: September – March and the light season April to August. Tools for harvesting include:

1. Sharp cutlass for plucking pods within reach
2. Harvesting knife with short handle for ripe pods above ground level
3. Harvesting knife attached to long poles for pods on topmost part of cacao
4. Basket or any convenient container for packing pods.

PROCESSING

Pods are broken by knocking them against blunt objects. The beans and the pulp are removed from the pods. The extracted beans are collected in a container for fermentation. Fermentation is done so as to get the proper taste, colour and flavor, kill the embryo and stop germination, remove pulp and to loosen the skin from the cotyledon thereby allowing easy de-shelling. There are four ways to ferment:

1. Heap fermentation (2) basket fermentation (3) sweat box fermentation (4) tray fermentation

The pods are dried after fermentation, production of good quality seeds will also depend on proper drying method. Moisture content should be 7 percent or within the range 6-8%. Drying could be sun drying or artificial drying. Well dried beans will crack when squeezed between the fingers.

Store dry beans in clean baskets or new sacks and keep off the ground and walls. Do not store near maize, tobacco or other foodstuffs or smoke.

GRADING

To grade cacao, representative samples are taken at random from bulk. Only 300 beans are selected and these should not weigh less than 300g. There are two grades:

Grade I cocoa: Less than 3% slaty beans (result of non fermentation of beans),

Less than 3% mouldy beans (under-driedand poor storage),

Less than 3% other defectives.

Grade II cocoa: Less than 5% slaty beans,

Less than 4% mouldy beans,

Less than 5% other defectives.

Defectives lower the price being paid or render beans unsaleable if found too many.

OIL PALM [*Elaeis guineensis* (Jacq.)]

ORIGIN

Originated from Latin America. Malaysia is one of the major producers of the oil palm, the crop was introduced to that part of the world from West Africa, especially Nigeria.

TAXONOMY

There are three basic varieties. These are as follows:

1. Dura: characterized by thin mesocarp, thick endocarp (shell) with generally large kernels.
2. Tenera: possesses thick mesocarp, thin endocarp with reasonably sized kernel. Used for production of mesocarp oil and kernel.
3. Pisifera: has thick mesocarp (with little oil content), no endocarp with small kernel. The female flowers are often sterile.

MORPHOLOGY

It grows to a height of 9 m or more, with a stout stem, covered with semi-persistent leaf bases on which epiphytes often grow. It is a **monocotyledoneous** and **monoecious** plant. The stem may be 30-38 cm in diameter with progressive thickening towards the base.

Selected palms flower in 2-3 years and an average mature tree may produce up to 12 bunches of fruit/year. The inflorescence is enclosed in a **spathe**, the whole structure is a **spadix**. When fully grown, the spadix splits in two or more parts longitudinally to expose the flowers. Both male and female flowers are borne on thick **penduncles**. The oil palm is naturally cross-pollinated.

CLIMATIC FACTORS

Grows best where rainfall is not less than 1500mm, evenly distributed throughout the year. Ideal temperatures are $27^{o}c$ - $35^{o}c$. Thrives under conditions of high relative humidity, yields are adversely influenced when the crop is exposed to dry harmattan winds. Roots benefit from deep soils which are fertile, free from iron concretions and well drained. It can tolerate a fair range of soil pH although neutral soils are most favoured.

PRE-NURSERY

Seeds issued to farmers for planting are derived from hand pollination of **Dura x Pisifera** palms which give 100% **Tenera**. Seeds are de-pulped by subjecting the fruits to heat. Seeds for planting should not be subjected to high temperature. Matured seeds are extracted from the bunch, collected in a cool place till the mesocarp softens on its own, then the kernels are washed clean in cold water, air dried and stored or germinated. Seeds are subjected to high temperature under controlled conditions to induce germination (21 days). Reheat seeds that do not germinate for 20 days (dry method).

NURSERY

Black poly bags measuring 40cm wide x 35cm deep are used. The bags are filled with topsoil and placed at $45cm^2$ spacing. The germinated seeds are planted in to the poly bags and thickly mulched with partially decomposed oil palm bunch refuse. Watering is done especially during the dry season. NPK Mg fertilizer in the ratio of 1:1:1:1 using sulphate of ammonia, murate of potash, SSP and magnesium sulphate should be applied twice when the seedlings are 2 and 8 months old respectively at 56g/seedling. Dithane M45 is used to spray against diseases at two weeks interval. Seedlings are transplanted into the field in April/May or when the early rains are regular and when seedlings reach 10-12 months old.

TRANSPLANTING

Land for planting should be level, well drained, fertile and deep. Clear-felling is obtained. The field is blocked and each block is lined out and the planting holes dug. Standard spacing is 8.7m triangular. Poly bag seedlings are transplanted with the entire soil but with the polybag removed. The base of the seedling should be above surrounding soil. Deep planting leads to failure of seedling to develop properly or even death. After planting, young palms should be protected from damage by animals such as rodents, grasscutter with a wire netting around each seedling and pegging it down. The netting should be cut 45cm high x 12cm long. It should be placed 15cm away from the base of the palm.

Establishment of a leguminous cover crop is desirable. Weeding, supply of vacant or dead stands, mulching and removal of undecomposed mulch during the early rains can be arranged.

FERTILIZER APPLICATION

N, K and Mg are very important to the palm. N and K should be applied 6 weeks after planting at the rate of 0.25kg/palm each and Mg at 0.2kg. There is no general recommendation for P.

DISEASE AND CONTROL

DISEASE	CAUSAL ORGANISM	SYMPTOM	CONTROL
Brown germ	*Aspergillus* spp	Brown spots on emerging bottom, spreading, coalescing and the tissue becomes shiny and rotten.	Dry heated germination seeds should be used.
Anthracnose	Fungi: *Botryodiplodia*	Dark necrotic lesion on leaves of seedling usually at pre-nursery and nursery stages	Fungicides should be applied e.g. Captan, Ziram, etc.
Freckle		Nursery disease	Dithane M45 or captan
Blast		Root disease causing wilting and death.	Use ammonium sulphate, organic matter, $MgSO_4$ and super phosphate to nursery bed.

PESTS AND CONTROL

PEST	DAMAGE	CONTROL
Mites	Damage during germination especially if charcoal boxes are used.	Spray with Roger
Termites	Attack unhealthy plant. Damage roots and senescent leaves.	Treat with Roger 40
Aphids	Feed on young shoots (mainly in the nursery)	
Rodents, Monkey, flying bats	Feed on ripe fruits	Harvest ripe fruits early, Shooting and trapping.
Weaver birds	Nests in swarms on the palms completely defoliating them.	Aerial spray with avicides, Shooting to scare them

		away.

HARVESTING

The palm bunch is ready for harvest when it has just a few loose frits. Inspect every two weeks for ripe bunches as over-ripe fruits produce lower quality palm oil. There are three methods of harvesting. Leaves that hinder removal of bunch should be cut.

1. Chisel method: The chisel consists of a piece of flat iron 23cm long, one end of which is rounded of and well sharpened. This method is used from the time the palms come into being until the palms become too tall.
2. The pole-knife method or the harvesting hook: Used for palms which have become too tall to be harvested with the chisel. The knife which is sickle-shaped is tied to a pole. The length depends on the height of the palms to be harvested.
3. Climbing ropes: Palm bunches are harvested by climbing with ropes.

PROCESSING

Processing of palm fruits to palm oil and kernel involves the following steps:

Sterilization ----- stripping ---- Milling ---- separation ---- pressing ---- clarification ---- storage or sale of palm oil

1. Sterilization: This is boiling of the fruits to soften them. It disinfects the fruits by killing the pathogen. Sterilization can be carried out in pots, drums or in sterilization chambers.
2. Stripping: Removal of fruits from sterilized or quartered bunches. The stripped fruits are re-sterilized for 30-45 minutes. Fruits pound easily when hot.
3. Milling: Pounding of the fruits for the purpose of separating the mesocarp from the kernel. After separation the mesocarp is pounded until no streak of coloured outer skin is distinguishable.

4. Pressing: The pounded mass is loaded into a press for the extracting of oil. Water may be added. There are screw hand press, hydraulic press and centrifugal press.
5. Clarification: The crude oil extracted is clarified by boiling and skimming. This is the traditional method. With the use of press, constructed double jacketed drum are used. Drums are mounted over open fire and water (45 litres) poured into each of the outer drum and is bought to boil. The crude oil is introduced. This will flow through the boiling water and deposit the sludge while the oil floats on top of the water. Boiling should be avoided at this stage. Clean oil is withdrawn from the inner drum. Hot water should be used to bring up the level of oil in both drums until the oil is completely swept off. The oil is then simmered over low fire to remove traces of water. The refined oil is then stored in drums, tankers, tins etc. ready for sale.

THE PALM KERNEL

After separation from the mesocarp, the kernels are washed, dried in the sun, cracked by hand or with a mechanical cracker, picked and packed for sale.

KOLA

ORIGIN

Cola nitida originated from the forests of Ivory Coast and Ghana, while Southern Nigeria is regarded as the centre of origin of *Cola acuminata.*

TAXONOMY

There are five subgenera. The *C. nitida* and *C. acuminata* are of economic importance.

MORPHOLOGY

	C. nitida	*C. acuminata*
1.	Tree is robust and usually 9-12m high but may reach 24m	Tree is slender and up to 12m high, but usually 6-9m Branches are slender, crooked and markedly ascending
2.	Foliage is dense and not confined to the tips of branches	Foliage is often sparse and confined to the tips of the branches
3.	Hermaphrodite flower is 3cm long and may be up to 5cm across	Hermaphrodite flower may be up to 25cm across
4.	Surface are shining green and are often rugose or tuberculate	Surface is rough to touch,russet or olive brown
5.	Each fruiting carpel contains up to 10 seeds in two rows	Seeds are 14 in each follicle
6.	Two or three cotyledons	3 – 5 to 6 cotyledons
7.	Cotyledons may be white, pink or red in colour	Pink, red or sometimes white
8.	Matures during Nov-Dec.	Matures from April – June

CLIMATIC FACTORS

Kola trees react to moisture changes by shedding their leaves. Kola grows well in tropical lowland rain forest areas with temperature around 25^oc, 1250mm rainfall or more. Kola requires well to fertile soils with high organic matter content. It demands a deep, well-drained soil. Kolanuts germinate best at 32-34^oc.

NURSERY PREPARATION

Seeds are first pre-germinated. Seeds are sown in the pre-germination medium at a depth of 3-5 cm. Watering is done often. *C. nitida* completes germination in 80 days while *C. acuminata* takes 60 days. They are planted in polypots by placing the seeds horizontally in fertile topsoil. The planting depth is 5-10 cm. Bigger nuts usually give bigger and better developed seedlings. Shade is provided for better seedling growth.

Water Requirements in Plant

Learning Expectations:

1. Functions of water in crop plant
2. Physical and chemical properties of water
3. Thermodynamic description of water
4. Driving forces of water in SPAC
5. Soil-Plant-Atmosphere Continuum (SPAC)
6. Water deficit, water use strategy and crop yield

Functions of water in Crops:

1. Cell Enlargement: The growth process in plant is directly related to the uptake and transportation of water into the cell. Presence of water deficit would greatly compromise growth process
2. Structural support
3. Evaporative cooling
4. Substrate for biochemical process in crops
5. Transport of solutes in the crop plant

Physical and chemical properties of water

1. Bipolarity: The angular arrangement of oxygen and hydrogen in water molecule leads to the emergence of bipolarity. The covalent bond resulting from this bipolarity results in hydrogen bond when two water molecules are found together in a medium. All the properties the physical and chemical properties of water are as a result of this hydrogen bond between water molecules.
2. Liquid at physiological temperature: Because of the strength of this hydrogen bond, water remains a liquid at physiological temperature, despite this comparative smaller molecular weight with respect to other molecules.
3. Incompressibility: As a liquid, water is incompressible, observing all the laws of hydraulics.
4. High Latent heat of Evaporation: The amount of heat needed to transform 1 gram of water into vapour is high, owing to the strong hydrogen bond greater than Van der Waals force. This particular property is very important most especially during transpiration of water vapour leading to evaporative cooling.
5. Cohesion and adhesion: Attraction of similar molecules leads to cohesion. This property was presumed to explain the upward movement of water in the xylem. Adhesion is the attraction of dissimilar molecules between water and other polymers. This wetness property has important property has important implications in water relations.

Thermodynamic description of water

To better describe water quantitatively, it was observed that thermodynamic concepts could be used. In this case the property of water was described with respect to its potential energy, which is its capability to do work. Pure water was conventionally adopted as the standard water potential, above which it is impossible to obtain higher magnitude of value. The value for pure water is zero. The unit for expressing water potential is Mega Pascal.
The components of water potentials are as follows:

1. Solute potential
2. Turgor pressure potential
3. Matric potential
4. Gravitational potential

Solute water potential is determined by the concentration of the solute present. It decreases with increase in solute concentration, thus its negative value. Turgor pressure potential value could be positive or negative. In a flaccid cell, where there is a net outward movement of water molecule, the value for turgor pressure potential is negative, creating tension; conversely with net inward movement of water into the cell, leading to turgid cell, the value becomes positive or positive hydrostatic pressure. The balance between negative value of solute potential and positive value of Turgor Pressure potential creates a balance, leading to negative water potential, since it is a rarity to have pure water in a cell. Matric Potential is as a result of the adhesion property of water, it is most prominent during the movement of water in the soil. Gravitational potential increases when water is raised above a height above a reference point. Water flows down gravitational potential gradient, all things been equal. At the microscopic level of the plant vascular tissue one may omit the role of gravitational and matric potential components of water potential, though their relevance increases with the increase in organizational level of the plant.

1 Atmosphere = 760mmHg @ Sea level, 45^0 latitude
= 1.013 bar
= 0.1013MPa
= 1.013×10^5 Pa

Water potential components:

Φw = φs + φt +φm +φg

Where:
Φw – Water potential
Φs – Solute potential
Φt – Turgor potential
Φm – Matrix potential
Φg – Gravitational potential

Table 1: Driving forces of water in SPAC

Process	Driving forces
Diffusion	Concentration gradient **Fick's Law** $Js = -\Delta s \Delta c/ \Delta x$ Where; Js – Rate of solute diffusion Δs – Diffusion coefficient, measures ease of substance movement via a medium Δc/Δx – Concentration gradient Δc – Difference in concentration Δx – Difference in distance
Bulk Flow	Pressure gradient $Volume = \pi r^4 \Delta P/\Delta x/8\eta$ Where: Volume - Flow rate r – Radius π – Viscosity of liquid ΔP – Difference in pressure Δx – Difference in distance ΔP/Δx – Pressure gradient
Osmosis	Composite forces (Concentration and pressure gradient)

Table 2: Transport of water in plant (Soil-Plant-Atmosphere Continuum)

Medium/Interface	Process	Driving force	Pathway
Soil	Water movement in the soil/Bulk	Pressure gradient	Soil Particles

	Flow		
Soil-Plant Interface	Water uptake	Composite force $\varphi_w = \varphi_s + \varphi_p$	o Apoplast o Symplast o Trans-membrane
Plant	Long distance transport (Cohesion-tension)	Pressure gradient	Xylem
Plant-Atmosphere	Transpirational pull of water	Gradient of water vapour concentration (Diffusion)	o Stomata o Cuticle o Lenticle

Models of water uptake in plants

Cohesion-tension Model

This model proposes that transpiration of water from the plant leads to the emergence of cohesion among similar water molecules, leading to the build up of negative hydrostatic pressure or tension. The emergence of tension increase tensile strength, which is the ability of water molecule to resist pulling force and by capillary action, water is being pulled up along the xylem. Where gas bubble are trapped in the water column, with an indefinite expansion of this bubble, a collapse of tension in the liquid phase is been observed, thus leading to cavitations. This phenomenon breaks the water column, resulting in reduced water uptake by plant.

Check this URL for animated version of this model:
http://academic.kellogg.edu/herbrandsonc/bio111/animations/0031.swf

Other resources:
http://www.mm.helsinki.fi/mmeko/kurssit/ME325/kuljetusprosessitkertaus.pdf
http://www.uoguelph.ca/plant/courses/pbio-3110/
www.mm.helsinki.fi/mmeko/kurssit/.../kuljetusprosessitkertaus.pdf

Root Pressure Model

An alternative model for the uptake and transportation of water in the plant is the root pressure model. The mechanism is as follows; absorption of solute leads to a reduction of solute potential in the plant cell, by concentration gradient water is being transported along the xylem tissue creating increase in positive hydrostatic pressure or root pressure, thus facilitating water uptake. Excessive uptake of water could lead to guttation, a phenomenon whereby liquid droplets are formed at the edges of the leaf most especially in the morning.

Water deficit, water use strategy and crop yield

Disequilibrium experienced between water supply and demand creates water deficit in plants. Alternatively, the concept could be envisaged as a situation when water content in the cell/ tissue is less than highest water content exhibited at hydrated state. In fields, drought conditions leads to water deficit accompanied with high temperature. This is a climatic condition.

The response of plant to water stress, which is when water is limiting, is varied and physiological responses are observed at different levels of organisation of the crop. Strategically, plant could avoid or tolerate water deficit. In avoidance, the plant could synchronise his phenology with the growing season in other to optimise the available resources for proper growth and development. With tolerance there must be specific mechanism to ensure availability of water and water use efficiency. Tolerance or resistant strategy involves:

1. Desiccation tolerance at high water potential
    a. Water saver, use water conservatively; example succulent
    b. Water spender, aggressive consumption of water; example Ephemerals
2. Desiccation tolerance at low water potential, possess the ability to function while dehydrated; xeromorphic plants/ non-succulent. There are two strategy for desiccation tolerance at reduced water deficit:
    a. Acclimation, which is transient and phenotypic in nature
    b. Adaptation, which is constitutive and genotypic in nature

Dimension of acclimation are as follows:

- I. Osmoregulation – the process of accumulation of solutes in cells independent of cellular volume change. The implication is reduced water potential, osmotic potential and through water uptake increased cellular turgor. The solutes accumulated could be:
    - a. Compatible –
        - i. Nitrogen containing, e.g. Proline, glycine betaine
        - ii. Non-Nitrogen containing, e.g. sugar alcohol (Sorbitol, mannitol)
    - b. Non-compatible, e.g. Inorganic ions
- II. Reduced growth
- III. Phenological variability or phenotypic plasticity (Determinate and indeterminate growth)
- IV. Energy dissipation through
    - a. Reduced growth of leaf
    - b. Changes in leaf orientation (Para and diaheliotropism)
    - c. Leaf modification
        - i. Wilting
        - ii. Rolling
        - iii. Pubescence

Dimensions of adaptation:

1. Crassulacean Acid Metabolism (CAM)
2. Metabolic changes via gene expression; synthesis of new protein types such as aquaporin, Ubiquitin, Late Embryonic Abundant protein.

From the cellular level, emergence of water deficit results in the decrease in the cellular water content, leading to shrinkage of cell and the relaxation of cell wall. Decrease in volume leads to increase in solute concentration, favouring reduced turgor pressure. Experimental results indicated that there is a synthesis of endogenous growth inhibitors (ABA and C_2H_2), changes in pH value and inorganic ion distribution. The consequence of these changes is the reduction in the expansion of leaf or leaf growth as expressed in the number of leafs or other growth parameters of the shoot. In the case of severe water deficit, reduction in total leaf area, increase senescence and leaf abscission accompany water deficit. If water deficit is mild the plant experiences reduction in transpiration rate via stomata closure increased heat dissipation and increasing resistance to liquid phase water flow.

At the crop level, reduced crop growth through stomatal regulation, as a result of water stress is reflected in reduced Leaf Area Index, thus compromising the radiant energy absorption capacity and its utilization efficiency (Radiant Energy Utilisation Efficiency). What is eventually experienced is reduced internal concentration of Carbon Dioxide and reduced Transpiration rate through the stomata. With reduced internal concentration of $C0_2$, carbon assimilation is equally affected reflecting in reduced Harvest Index and ultimately yield.

Where water a limiting factor, crop performance is expressed as:

$$\mathbf{Y_E = W \times W_{Transp} \times WUE \times HI}$$

Where:

W: Amount of available water

W_{TRANSP}: Water Transpired

WUE: Water use efficiency

HI: Harvest Index

WUE: (Pa – Pi)/ 1.6 (VPi – VPa)

Where:

Pa: Partial Pressure Air

Pi: Partial Pressure Inside

VPi: Vapour Pressure Inside

VPa: Vapour Pressure Air

Total amount of water consists of the available and unavailable water in the soil. The available water in the soil is a function of the texture/structure and the volumetric water content. With soil water potential less than root water potential, the water content in the soil reaches the wilting point at which the water becomes unavailable to the plant. Conversely, with increasing wetting of the soil water, soil water potential increases, becoming more available to the plant. The volumetric water content increases up to a point at which drainage of water against gravity cannot be avoided, the field capacity. The colloidal contents of the soil predispose the water to be adhered to it, thus making water available to plants. Interrelationship between soil, plant and the atmosphere is expressed conceptually via Soil-Plant-Atmosphere Continuum.

Physiologically, water use efficiency is the ratio between assimilation of carbon and transpiration. Factors responsible for increasing water use efficiency could be deduced from the equation above; decreasing partial pressure of carbon dioxide inside the cell will increase the partial pressure gradient between the leaf plant and the atmosphere, increasing carbon assimilation, assuming carbon assimilatory capacity is non-limiting in the plant. Another option is to increase the vapour pressure in the atmosphere, by increasing ambient temperature. This will minimize transpiration flux from the plant since in most cases the vapour pressure in the plant is more than that of the ambient atmosphere. Increasing stomatal conductance linearly increases transpiration but response of carbon assimilation is curvilinear. Initially, carbon assimilation responds linearly, when carbon concentration is no more limiting the curve reaches a plateau.

Transpiration is constrained physically and physiologically. The physical forces at play in evaporation are expressed in the Ficks equation as indicated above.

Concentration of gases is better expressed as partial pressure, while the between gases is quite difficult to express, the whole equation is better expressed as changed in partial pressure of gases, while the distance and diffusion coefficient is both expressed as diffusion coefficient (g). Physiologically, evaporation is regulated by stomatal aperture, which is equally dependent on certain environmental factors. Light affects photosynthesis, which leads to reduction in partial pressure of carbon dioxide inside the cell, leading to negative feedback loop for the opening of the stomata. Increase temperature affects rate of photosynthesis, displaying the aforementioned reaction. Alternatively, with an increase in temperature the rate of transpiration increases, reducing leaf water potential and turgor, eventually resulting in stomatal closure. Reduced soil water potential equally result in reduction in leaf water potential, increasing formation of ABA and the eventual closure of stomata.