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	Spray with Diazinon, Formothion

	of young leaves – drops of sticky honey or patches of sooty mound on the upperside of leaves	
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 cypermethri n 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	Causes reddish spots on	Dress seed with Thiram

(*Colletotrichum gossypii)*	stem, leaves and bolls. Bolls may rot.	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^{o}C 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.