SOIL FERTILITY AND PLANT NUTRITION (SOS 511)

By:

Dr. C.O. Adejuyigbe

Dr. F. A. Olowokere

Dr. M. O. Dare

General Concept of Soil Fertility

The plant depends on soil not only for anchorage but required elements for its structural build-up and physiological processes. All the elements that have been identified as essential for crop-plant growth and yield are obtained from the soil with the exception of C which is obtained from the air through the stomata. Hydrogen and oxygen are obtained from water absorbed through plant roots. The remaining elements – N, P, K, Ca, Mg, S, and the micronutrients, which are referred to as plant nutrients, are obtained directly from the soil. Thus the plant depends on the soil for its nutrition.

All the plant nutrients are present in the soil. However, the mere presence of plant nutrients in the soil does not mean that such a soil is fertile. Plants absorb nutrients in ionic forms dissolved in soil solution. Also, for optimum performance of crop, there must be sufficient amount of all the nutrients enough to meet the minimum requirement of the crop. Thus the soil must be able to supply adequate amount of plant nutrients, in forms which can be absorbed by the crop, within its lifespan. Thus soil fertility is defined as the ability of the soil to supply plant nutrients in adequate quantity and in available forms

Available forms of plant nutrients are the forms (ionic) which can be absorbed by the growing plant.

FACTORS AFFECTING THE FERTILITY OF SOIL

The ability of soil to supply plant nutrients in the available forms is affected by many physical, chemical and biological factors, including management practices.

Soil water

Plants tend to get their nutrients from the water in the soil. This water is usually referred to as the soil solution because it contains dissolved materials (cations and ions) as well as suspended colloids of clay and organic matter.

Soil solution does not contain sufficient nutrients at any one time to last the life of the plant. It has to be replenished from the pool of nutrients adsorbed onto soil colloids (exchangeable nutrients) and those bound up in solid form as minerals or organic matter called the stable pool

Cation Exchange Capacity (CEC) and Base Saturation

Cation exchange capacity is generally defined as the ability of the soil to adsorb cations.

Many of these nutrients are absorbed in the form of cations. Most soils have at least some ability to hold onto these ions at negatively charged sites within the soil. The amount that they can hold is called the Cation Exchange Capacity. The cations are held to the edges of particles within the soil. This is referred to as adsorption. (Use magnets to demonstrate attraction of positive and negative.) The cations in the soil are divided into acids and bases. The acids are predominantly hydrogen and aluminum. The bases are primarily calcium, magnesium, sodium, and potassium.

CEC is technically defined as the sum of exchangeable bases plus total soil acidity at a specific pH value, usually 7.0 or 8.0.

When acidity is expressed as salt-extractable acidity, the cation exchange capacity is called the effective cation exchange capacity (ECEC) because this is considered to be the CEC of the soil at the native pH value. It is usually expressed in centimoles of charge per kilogram of soil (cmol kg-1) or millimoles of charge per kilogram of soil.

The CEC of the soil is dependent on the following:

Amount of clay: Higher amounts of clay mean higher CEC.

Type of clay: Certain kinds of clay (smectites, montmorillonite) have higher CEC than others (such as kaolinite).

Amount of organic matter: Higher amounts of organic matter mean higher CEC

pH dependent CEC: Amorphous clay minerals and organic matter have a CEC that varies with pH. As pH increases, so does the CEC. For every pH unit above 4.5 there is a 1 cmol kg-^{1} increase for each percent organic matter.

Base saturation

Base saturation refers to the percentage of exchange sites (negatively charged sites on clay and organic particles) that are occupied with bases (usually Ca^{2+}, Mg^{2+}, K^+ and Na^+) as opposed to ions that make the soil acid (H^+ or Al^{3+}). In technical terms it is the ratio of the quantity of exchangeable bases to the cation exchange capacity. The value of the base saturation varies according to whether the cation exchange capacity includes only the salt extractable acidity (see cation exchange capacity) or the total acidity determined at pH 7 or 8. It is often expressed as a percent.

Exchangeable bases: Charge sites on the surface of soil particles that can be readily replaced with a salt solution. In most soils, Ca^{2+}, Mg^{2+}, K^+ and Na^+ predominate. Historically, these are called bases because they are cations of strong bases. Many soil chemists object to this term because these cations are not bases by any modern definition of the term.

Soils with high base saturations are considered more fertile because many of the “bases” that contribute to it are plant nutrients. Usually the base saturation is 100 percent when the pH is above about 6.5. Since rainfall tends to leach bases out of the soil, areas with higher rainfall tend to have lower base saturations than areas with lower rainfall, unless the parent material is high in bases (such as limestone).

Soil Reaction

Soil reaction refers to the degree of acidity and alkalinity of the soil. It covers the attribute of the soil in terms of its being acid, acidic, alkaline, alkali, sodic or saline. The degree of acidity or alkalinity of a soil can be denoted by its pH

What is pH?

The pH of a soil is defined as the negative of the log of the concentration of hydrogen ions (moles per liter); it is a number between 0 and 14. (Water, H_20 or HOH is usually in equilibrium with its constituent ions, H^+ and OH^- and has a pH of 7.) In acid soils (pH < 7), H^+ ions predominate. In alkaline soils (pH > 7), OH^- ions predominate. Soils with pH of 7 are neutral.

Effect of pH on nutrient availability and uptake

pH does not directly affect plants. It does affect the availability of different nutrients and toxic elements to plants. This is mostly due to the fact that pH changes the form of many of the nutrients and many of the forms are relatively insoluble.

Low pH causes nutrient deficiency, especially calcium phosphorus, and nitrogen. Extreme pH reduces the population of some useful organisms, such as bacteria and earthworms.

Soil acidity

Acidity refers to the condition of the soil when the exchange complex is dominated by hydrogen and aluminum ions. There are two forms of soil acidity:

Exchangeable acidity (salt-replaceable acidity) - The aluminum and hydrogen that can be replaced from an acid soil by an unbuffered salt solution such as KCl or NaCl.

Total acidity, total - The total acidity including residual and exchangeable acidity. Often it is calculated by subtraction of exchangeable bases from the cation exchange capacity determined by ammonium exchange at pH 7.0. It can be determined directly using pH buffer-salt mixtures (e.g., $BaCl_2$ plus triethanolamine, pH 8.0 or 8.2) and titrating the basicity neutralized after reaction with a soil.

Factors which contributes to a soil becoming acidic include

Le*aching*: Refers to the washing down of plant nutrients below the soil beyond the reach of the plant roots leaving behind hydrogen ion.

Use of acid fertilizers: The use of acid fertilizers like ammonium sulphate and ammonium nitrate can easily cause acidity in the soil.

Nutrient uptake by plants: the absorption of soluble minerals by plants results in the accumulation of hydrogen ions which cause soil acidity.

Presence of acid parent materials: The presence of acid parEnt mateials results in the easy dissolution of the rocks, leaving behind minerals rich in hydrogen ions. .

Presence of sulphur in the soil: sulphur undergoes oxidation and dissolution to form acid in the soil.

Soil acidity can be ameliorated through liming and application of organic manure can also be used on the soil to remove acidity

Distribution of acid soils

Acid soils usually occur where there is sufficient rainfall or other sources of precipitation to leach the bases out of the soil. When this happens, the exchange complex becomes dominated by hydrogen (lowers pH) and aluminum (toxic). In the U.S. there is a fairly strong correlation between precipitation and pH, with soils receiving more than about 30 inches of annual precipitation having a pH less than 6.

3. Problems associated with acidity

<u>Aluminum toxicity</u>: Aluminum is the third most common element in the earth's crust. It becomes more available at low pH's, and can be toxic to plants.

<u>Manganese toxicity:</u> This may occur in soil that are high in Mn and that have a pH less than 5

4. Acid soils and liming

Lime (calcium carbonate) is added to acid soils to raise the pH. Calcium replaces hydrogen and aluminum on exchange sites.

Alkalinity, Alkali, Salinity, and Sodic Soils

1. Definitions

Soil alkalinity: The degree or intensity of alkalinity in a soil, expressed by a value > 7.0 for the soil pH

<u>Alkali soil:</u> (i) A soil with a pH of 8.5 or higher or with an exchangeable sodium percentage greater than 0.15 (ESP>15). (ii) A soil that contains sufficient sodium to interfere with the growth of most crop plants. See also saline-sodic soil and sodic soil

Saline soil: A nonsodic soil containing sufficient soluble salt to adversely affect the growth of most crop plants. The lower limit of saturation extract electrical conductivity of such soils is conventionally set at 4 dS m^{-1}(at 25°C). Actually, sensitive plants are affected at half this salinity and highly tolerant ones at about twice this salinity.

Sodic soil: A nonsaline soil containing sufficient exchangeable sodium to adversely affect crop production and soil structure under most conditions of soil and plant type. The sodium adsorption ratio of the saturation extract is at least 13.

Saline-sodic soil*:* A soil containing sufficient exchangeable sodium to interfere with the growth of most crop plants and containing appreciable quantities of soluble salts. The exchangeable sodium ratio is greater than 0.15, conductivity of the soil solution, at saturated water content, of > 4 dS m^{-1}(at 25°C), and the pH is usually 8.5 or less in the saturated soil.

2. Some elements contributing to alkalinity

Calcium: Calcium is common in many soils in arid areas. It helps the soil to form aggregates. (Because it has a +2 charge (divalent), it can bind to two clay or organic particles).

Magnesium: Behaves similarly to calcium in helping to form aggregates.

Potassium: An important plant nutrient

Sodium: Toxic to plants at high levels

Soil Organic Matter

Soil organic matter (SOM) is that fraction of the soil composed of plant and animal remains in various stages of decomposition and synthesis. It includes cells and tissues of soil organisms, and substances from plant roots and soil microbes. Soil organic matter can be divided into two parts: the well-decomposed part in which the original precursor cannot be distinguished anymore known as humus. Humus is dark brown, porous, spongy in appearance with, earthy smell. The other part of SOM is referred to as the non-humic substances and contains fragments of the original substances as identifiable in the original plant and animal remains. Humus also referred to as humic substances consist of three major chemical fractions: fulvic acid, humic acid and humin.

Plants produce organic compounds by using the energy of sunlight to combine carbon dioxide from the atmosphere with water from the soil. Soil organic matter is created by the cycling of these organic compounds in plants, animals, and microorganisms into the soil. In most soils, the organic matter accounts for less than about 5% of the volume.

Soil organic matter is a dynamic entity. It can be lost through natural processes such as erosion, ecological processes such as decomposition, and human activities that promote the processes. Soil organic matter is utilized by soil microorganisms as source of energy and nutrients to support their own life processes. Some of the material is incorporated into the microbes, but most is released as carbon dioxide and water. Some nitrogen is released in gaseous form, but some is retained, along with most of the phosphorus and sulphur.

Importance of organic matter to soil fertility and plant nutrition

Stabilizes and holds soil particles together. Thus reducing the hazard of erosion. Aids the growth of crops by improving the soil's ability to store and transmit air and water;

stores and supplies such nutrients as nitrogen, phosphorus, and sulphur, which are needed

retains nutrients by providing cation-exchange and anion-exchange capacities;

maintains soil in an uncompacted condition for easy growth of root

Factor influencing level of soil organic matter

The amount of soil organic matter is controlled by a balance between additions of plant and animal materials and losses by decomposition. Both additions and losses are very strongly controlled by management activities. The amount of water available for plant growth is the primary factor controlling the production of plant materials. Other major controls are air temperature and soil fertility. Salinity and chemical toxicities can also limit the production of plant biomass. Other controls are the intensity of sunlight, the content of carbon dioxide in the atmosphere, and relative humidity.

The proportion of the total plant biomass that reaches the soil as a source of organic matter depends largely on the amounts consumed by mammals and insects, destroyed by fire. or produced and harvested for human use.

When soils are tilled, organic matter is decomposed faster because of changes in water, aeration, and temperature conditions. The amount of organic matter lost after clearing a wooded area or tilling native grassland varies according to the kind of soil. but most organic matter is lost within the first 10 years.

Rates of decomposition are very low at temperatures below 38 °F (4°C) but rise steadily with increasing temperature to at least 102 or: (40°C) and with water content until air becomes limiting. Losses are higher with aerobic decomposition (with oxygen) than with anaerobic decomposition (under waterlogged conditions).

Available nitrogen either in the organic matter or from external sources (such as fertilizer application) also promotes organic matter decomposition.

Organic matter level in the soil can be decrease by such management and agricultural practices that leads to decrease the production of plant materials as

replacing perennial vegetation with short-season vegetation,

replacing mixed vegetation with monoculture crops,

introducing more aggressive but less productive species,

using cultivars with high harvest indices,

Increasing the use of bare fallow.

As well as those those that decrease the supply of organic materials such

burning forest, range, or crop residues,

over-grazing,

removing plant products

Maintenance of soil organic matter

Soil organic matter level can be maintained or build up through activities that lead to increase in primary production of plant materials, addition of organic materials to the soil, and reduction in the rate of organic matter decomposition or loss.

Activities that lead to increase in production of plant materials include:

irrigation,

judicious us of fertilizer to increase plant biomass production,
planting of cover crops
improved vegetative stands,
introduction of plants that produce more biomass,
reforestation,
restoration of grasslands.
Level of organic materials returned into the soil can be increased by
controlled grazing rather than by harvesting,
applying animal manure or other carbon-rich wastes,
applying plant materials from other areas.
Loss of soil organic matter in the soil can be reduced through
zero or minimum tillage,
keeping the soil saturated with water (although this may cause other problems),
keeping the soil cool with vegetative cover.
protecting from fire.

ESSENTIAL NUTRIENTS/ ELEMENTS

Definition: They are elements needed by plants for growth and reproduction without which plants cannot complete their life cycle (Vegetative, Flowering and seed production).

Criteria for nutrient essentiality:
Plant cannot complete its life cycle without it
The function of the element cannot be replaced by another element
. The element is directly involved in the plant's growth and reproduction

List of essential elements
Carbon (C)
Hydrogen (H)
Oxygen (O)

The above are considered to be non-mineral nutrients because they are derived from air and water

Nitrogen (N)
Phosphorus (P)
Potassium (K)
Calcium (Ca)
Magnesium (Mg)
Sulfur (S)
The above are considered as mineral elements because they are derived from soils and minerals, they are also known as macronutrients because they are required by plants in large quantity.

Iron (Fe)
Manganese (Mn)
Zinc (Zn)
Copper (Cu)
Nickel (Ni)
Boron (B)
Molybdenum (Mo)
Chlorine (Cl)
Cobalt (Co)
The above are mineral elements and known as micronutrients because they are required in minute quantities by plants

Element	Source of supply
C	Air
H	Air/Water
O	Air/Water
N	Air/Soil
P, K, Ca, Mg, S, B, Cl, Cu, Fe, Mn, Mo, Ni, Zn	Soil

Elements	Available forms
C	CO_2
H	H_2O
O	H_2O, CO_2, O_2
N	NO_3^-, NH_4^+
P	$H_2PO_4^-$, HPO_4^{2-}
K	K^+
S	$SO4^{2-}$
Ca	Ca^{2+}
Mg	Mg^{2+}
Fe	Fe^{2+}, Fe^{3+}

Mn	Mn^{2+}
B	BO_4^{2-}
Zn	Zn^{2+}
Cu	Cu^{2+}
Mo	MoO_4^{2+}
Cl	Cl^-
Ni	Ni^{2+}

Physiological roles and deficiency symptoms of essential nutrients

Element	Functions	Deficiency symptoms
Nitrogen	Amino acid formation, plant growth and dev. Enzymatic reactions, photosynthesis, component of vitamins, Improves quality and quantity of dry matter in leafy vegetables and protein in grain crops	Stunted growth, chlorosis, lowering of protein content of seeds and vegetables
Phosphorus	Photosynthesis, respiration, energy storage and transfer as ADP and ATP; DPN and TPN, increases resistant to diseases, part of RNA and DNA, aids roots dev., flower initiation , seed and fruit development	Dark to blue green coloration of leaves purpling of leaves and stems under severe deficiency, delayed maturity, poor seed and fruit development

Potassium	Enzyme activator, promotes metabolism, Regulates plants use of water, photosynthesis Regulates plants use of water, maintains the balance of electrical charges at the site of ATP production, promotes translocation of sugars	Chlorosis along the edges of leaves, slow and stunted plant growth, weak stems, lodging
Element	**Functions**	**Deficiency symptoms**
Calcium	Cell wall membrane formation, maintains cell integrity and membrane permeability. Acts as detoxifying agent by neutralizing organic acids in plants, reduces soil acidity when limed.	Growing tips of roots and leaves turn brown and die, sticking together of newly emerging leaves at the margins.
Magnesium	Major constituent of chlorophyll molecule, assists the movement of sugar within the plant	Interveinal chlorosis, premature leaf drop
Sulfur	Plant protein formation, metabolism of B vitamins, biotin and thiamine, seed production, aids in seed formation.	Chlorosis, stiff, thin and woody plant stems
Boron	Pollen germination and growth of pollen tube	Stunted growth, leaves tend to be thickened, may curl and become brittle
Copper	Photosynthesis, part of chloroplast protein, plastocyanin, which part of the electron transport chain	Distortion of younger leaves, necrosis of apical meristem, multiple sprouting at the growing tips of trees
Chlorine	Photosynthesis, increases cell osmotic pressure and water content of plant tissues	Chlorosis, plant wilting
Iron	Photosynthesis and respiration, nitrate and sulfate reduction	Interveinal chlorosis

Manganese	Involved in oxidation reduction processes, activates several metabolic functions	Marsh spots in legumes
Molybdenum	Required by some soil organisms for N fixation in soils	Chlorosis, stunted plant, leave margins roll inwards
Zinc	Protein and RNA synthesis	Interveinal chlorosis, dropping of dead tissue out of the chlorotic spots
Nickel	Nitrogen metabolism in legumes, stimulates nodule weight and seed yield of soybeans	Accumulation of toxic levels of urea in leaf tips

Fertilizers

Definition: Fertilizer is any material, organic or inorganic, natural or synthetic, that furnishes to plants one or more of chemical elements essential for normal growth.

Types of fertilizers:
Inorganic or chemical fertilizer: simple chemical compounds made in a factory
Organic fertilizer: Composed of wastes and residues from animal life
Organic fertilizers could be classified into Industrial and Non-Industrial organic fertilizers.

Industrial Organic fertilizers include waste from brewery factories e.g. molasses, waste From tobacco companies e. g. tobacco leaves, waste from fruit juice and meat canning industries e. g. orange or fruit peelings, bones hooves, blood. It also includes sawdust from sawmills.

Non- Industrial Organic Fertilizers: These include cocoa pods, rice brans, bean pod, sorted town refuse, sewage and city wastes. Animal dung, human feaces and urine are also included.
The difference between organic and inorganic fertilizers lies in the fact that inorganic fertilizers consist of relatively simple chemical compounds of known composition, they

are nutritionally more concentrated and they release their nutrients immediately they are applied to the soil provided there is adequate moisture while organic fertilizers are slowly mineralized, add organic matter to the soil, they are rich in water and carbon compounds.

Common fertilizer terms:

Fertilizer Grade; Nutrient content expressed in weight percentages of N, P_2O_5, and K_2O in the order: N-P-K

Straight Fertilizer: Fertilizer containing only one nutrient

Compound Fertilizer: Fertilizer containing two or more nutrients

Granular Fertilizer: Fertilizer in form of particles sized between an upper and lower limit

Nongranular (powdered) Fertilizer: Fertilizers containing fine particles, usually with some upper limits such as 3 mm but no lower limit.

Fillers: These are materials which may or may not possess any manorial value added to compound fertilizers to make up the weight required to get them conform to a predetermined Specification in terms of percentages of the active ingredient. Examples of materials used as fillers in the past were fine river sand, powdered charcoal and kaolin while gypsum, dolomite and dried poultry manure have been more recently used.

Bulk-Blend Fertilizer or Blended Fertilizer: This refers to two or more fertilizers of similar size mixed together to form a compound fertilizer.

Coated Fertilizer: Granular fertilizer coated with a thin layer of some substances such as clay to prevent caking or to control dissolution rate.

Liquid or fluid fertilizer: This term is used for fertilizers wholly or partially in solution that can be handled as a liquid. This includes clear liquid and liquids containing solids in suspension.

Examples of N supplying fertilizers:

Carrier	%N
Urea $[(NH_2)_2CO]$	46
Ammonium nitrate (NH_4NO_3)	32- 34.5

Examples of P supplying fertilizers:

Carrier	% P	% P_2O_5
Triple Super Phosphate $[Ca(H_2PO_4)_2$	20	45
Potassium Phosphate (K_2HPO_4)	18	41

Examples of K supplying fertilizers:

Carrier	% K_2O	% K
Muriate of Potash (KCl)	60	50
Potassium nitrate (KNO_3)	44	37

Conversion table for some fertilizer nutrients

To Convert	Multiply by
P to P_2O_5	2.2915
P_2O_5 to P	0.4364
K to K_2O	1.2047
K_2O to K	0.8301

Fertilizer rate: The quantity of fertilizer that should be applied per unit area of farm land for a given crop.

Example of fertilizer rate calculation:

Calculate the quantity of Urea, Triple Super _Phosphate (TSP) and Muriate of Potash (MOP) needed to supply 20 kg N/ha, 15 kg P/ha and 30 kg K/ha.

Urea: 46kg N would be supplied by 100 kg urea
20 kg N would be supplied by 100/46 x 20 = 43.48 kg Urea/ha

Triple Superphosphate: 20 kg P would be supplied by 100 kg TSP
15 kg P would be supplied by 100/20 x 15 = 75 kg TSP/ha

Muriate of Potash: 50 kg K would be supplied by 100 kg MOP
30 kg K would be supplied by 100/50 x 30 = 60 kg MOP/ha

Fertilizer Manufacture:

Ammonia production is the first step in the manufacture of most nitrogen fertilizers.

Ammonia manufacture

Chemical Characteristics: Ammonia contains 82% nitrogen by weight and is 99% NH_3, it is

N content	82%
NH3 content	99%

Urea

Urea is manufactured using calcium cyanamide according to the following reaction:

$$CO\,(NH_2)_2 + H_2O \longrightarrow CO\,(NH_2)_2 + Ca\,(OH)_2$$

Urea chemical characteristics

Color	white
Nitrogen content	46.6 %
Molecular weight	60.06
Melting point	0° C

Manufacture of phosphate fertilizers

Phosphate rock and sulfuric acid are the two major raw materials for the manufacture of phosphate fertilizers

Phosphate Rock: Commercial phosphate rock refers to any rock containing a high percentage of phosphate minerals that can be used for commercial purposes such as fertilizer manufacture and direct application to soil. The term usually applies to a product obtained by mining and beneficiation.

Phosphate rocks which contain fluoroapatite as the primary and usually the only source of phosphorus are known as Apatitic phosphates while deposits in which the principal phosphate minerals are aluminous are known as Aluminous Phosphates.

Triple Super Phosphate (TSP) manufacture)

The basic chemical reaction involved in the production of TSP is:

$$Ca_{10}F_2(PO_4)_6 + 14H_3PO_4 + 10H_2O \longrightarrow 10Ca(H_2PO_4)_2.H_2O) + 2HF$$

(Fluoroapatite) (Phosphoric acid) (Monocalcium phosphate) (Hydrofluoric acid)

Chemical Characteristics:

Color	Gray
Odor	Acid
P content	20 %

Potash Fertilizers

The principal potash evaporate minerals of commercial importance are:

Sylvinite , a mixture of potassium chloride and sodium chloride crystals. This is the easiest to process and is mined in very large quantities. Carnallite, a mixture of potassium chloride and magnesium chloride crystals. Kainite, a mixture of potassium chloride and magnesium. chloride crystals. About 95 % of all potash mined is used as fertilizers, the other 5 % is used in various industrial applications.

Potassium mineral deposits are usually the result of evaporation of water from landlocked seas that have become separated from the main oceanic body and from which the contained salts have gradually precipitated.

Potassium Chloride manufacture

Potash is very largely extracted or mined from underground deposits of sylvinite, primarily mixed crystals of potassium chloride and sodium chloride using either shaft or solution mining method. Mined sylvinite is later beneficiated or refined using any of the three principal methods namely: flotation, heavy-media separation and solution-crystallization methods.

Flotation is a method of floating off either the potassium chloride or the sodium chloride on a froth. Flotation of potassium chloride is the preferred commercial method.

Heavy media beneficiation utilizes the difference in specific gravity of sylvite (KCl) and halite (NaCl). Halite is denser, therefore, in a liquid of intermediate specific gravity, halite will sink and sylvite will float.

Solution-Crystallization-Dissolution process is based on the solubilities of NaCl and KCl in hot and cold water, the solubility of NaCl decreases slightly as temperature increases. Thus when a brine that is saturated with both NaCl and KCl at 20ºC is heated to 100ºC, it is capable of dissolving substantial amounts of KCl but no NaCl. The KCl is then dried and marketed in several grades.

Chemical Characteristics

Potassium content:	50 %
Solubility in water	High
Chlorine content:	47 %

Methods of fertilizer application

There are three general methods of fertilizer application;

Broadcasting – Uniform fertilizer application over the whole cropped field

Placement – Inserting, drilling or placing fertilizer below the soil surface

Row, band or side dressing- applied to the sides in a band, usually 5 to 10 cm to the side and about 5 cm deep

Ring application- applied round the plant in form of a ring

Spot application: Similar to ring application, but in addition, holes are made in a ring form round the crop

Top dressing- application of fertilizer after crop emergence

Foliar application: Application of fertilizer solution on leaves of growing plants by spraying

Crop growth

What is crop growth?

Growth can be defined as the progressive development of an organism. Crop growth is a complex process whereby different organs such as leaves, roots, stems, flower, fruits and grains develop, grow and die in overlapping sequences.

Is crop growth different from crop development?

Crop growth can be defined as the increase in size of a plant. The increase may be expressed in terms of dry weight or dimensions such as height or diameter.

Plant development is the progress of a plant from germination to maturity through a series of stages which in many crops are often well defined.

Exercise:

How is crop growth and development expressed?

Factors affecting crop growth and yield

Crop growth are affected by various factor which can be categorised into two

Genetic factors which concern primarily the inherent capability of a given crop to give high yield and desirable characteristics.

Environmental factors which concern all the external conditions that influence crop growth. It could be climatic, edaphic or human factors.

The major environmental factors affecting crop growth are

Sunlight/radiant energy

Adequate supply of plant nutrients

Adequate supply of moisture

Availability of oxygen and carbondioxide

Favourable temperature

Favourable soil reaction

Absence of toxic substances

Soil structure and composition of soil air

Biotic factors

Human factors

Crop growth response to soil nutrient

Plant growth is a function of various environmental or growth factors and may be expressed as

$$G = f(x_1, x_2, x_3 \ldots, x_n)$$

where G = measure of growth and x_1, x_2, x_3,……x_n = various growth factors

Understanding Liebig's Law of the minimum

A German scientist named Liebig proposed a *law of the minimum* stating that plant growth is proportional to the amount available of the most limiting plant nutrient. It means that the addition of each successive increment of a growth factor results in an increase in growth. Maximum yield is obtained when all factors are supplied in adequate or optimum amount.

…… And Mitscherlich's Law of diminishing return

Another German scientist, Eilhart Mitscherlich concluded that plant growth response to a limiting element is not proportional as Liebig proposed but rather follow a law of diminishing return.

He developed an equation to express this law mathematically:

$$dy/dx = k(Y - y)$$

where *dy* is the yield increase resulting from a small addition *dx* of the limiting factor, k is a constant for a particular crop and growth factor, Y is the maximum possible yield and y is the yield under the actual condition.

The simplest interpretation of this equation is that yield improvement resulting from any additional unit of fertilizer or nutrient is proportional to the remaining possible improvement. It means that each additional unit of fertilizer gives slightly smaller benefit than the previous unit.

Exercise

Compare Liebig's law of the minimum and Mitscherlich's law of diminishing return

Crop growth modelling

Models simulate or imitate the behaviour of a real crop by predicting the growth of its components, such as leaves, roots, stems and grains.

A crop growth simulation model not only predicts the final state of total biomass or harvestable yield, but also contains quantitative information about major processes involved in the growth and development of a plant.

Computer technology has made growth modelling easier

Some of the modern growth models like DSSAT, ORYZA, APSIM, are developed to simulate crop growth and yield responses to scenarios of field management changes

Some of these models are applied to specific crop e.g. ORYZA is used for only rice while APSIM is used mostly for legumes such as drybeans, cowpea, pigeon pea and g/nut and also sweetpotatoes.

Models are developed based on

the high-resolution sub-national agricultural statistics data

databases of region-wide field trials managed by agricultural research institutes, including CGIAR centers and FAO and NARs

Nutrient absorption for plant growth

Absorption of nutrients refers to the transfer of the nutrient ions across the soil root interfaces into the plant cell.

Crops take their nutrients in the form of inorganic ions from the solution that surrounds soil particle and roots.

Factors such as genetic make up of a plant, root morphology and the environment influence nutrient absorption and transport in plants.

The process of nutrient absorption starts from the release of nutrient ions from the soil solid phase to solution and their movement to the root surfaces. The ions move from the root surface through membranes into the root system and from the root system to the whole plant system.

Movement of ions from soil to root surfaces

Three mechanisms are recognized

Root interception (contact absorption):

Root interception occurs as the plant roots grow through the soil mass encountering ions in soil solution and adsorbed ions on soil surfaces.

Nutrient absorption through this mechanism is, however, insignificant as most of the plant nutrients occur in the soil solutions.

Mass flow

Mass flow occurs as nutrient ions are transported in the flow of water to the root surface that results from transpirational water uptake by the plant.

Mass flow prevails for nutrients that are present in relatively high concentration such as Ca and Mg, and mobile nutrients such as NO_3^- and SO_4^{2-} .

Movement of nutrient by mass flow is reduced at low temperature and low soil moisture content.

Diffusion:

Nutrient ions diffuse toward the roots when ion concentration at the root surfaces decreases as plant absorb nutrient, creating a nutrient concentration gradient.

Diffusion functions to alleviate the nutrient depletion that has occurred in the zone next to the root.

Most P and K moves to the root by diffusion.

Diffusion acts in reverse (back diffusion) when the other two mechanisms deliver more than needed and increase the concentration near the root to a level above that of the rest of the soil.

Movement of ions into the root system

The movement of nutrient ions from root surface into the root can be described by two processes:

Passive movement/transport

Active movement/transport

Passive movement or transport of ions

Passive transport of ions occurs in the outer or free spaces in the wall of epidermal and cortical cells of roots and is controlled by ion concentration (diffusion) and electrical (ion exchange) gradient.

The concentration of ions in the apparent free space is normally less than the bulk solution concentration and therefore, diffusion occurs with concentration gradient, from high to low concentration.

Passive transport is non-selective process and does not require energy from the metabolic activities of the plant.

Active movement or transport of ions

Active transport of ions is the movement of an ion against its concentration gradient using energy i.e. when the cell uses energy to pump a solute across the membrane against a concentration gradient.

The process of nutrient entry known as ion-carrier mechanism or carrier theory involves a metabolically produced substance (carriers) that combines with free ions. The ion-carrier complex can then cross membranes and other barriers not permeable to free ions and later dissociate to release ions into the inner space of the cell.

Active ion transport is selective process such that specific ions are transported across the plasmalemma by specific carrier mechanism.

Organic manures and wastes

Organic manures are materials largely of plant and animal origin in different states of decomposition that are added to soil to supply plant nutrients and improve soil physical properties. They are made from cattle dung, excreta of other animals, rural and urban composts, other animal wastes, crop residues, green manures and industrial organic wastes such as paper and sugar industries and sewage sludge. Organic manures are rich in water and C compounds but poorer in plant nutrients than inorganic manures.

Types of organic manures

Farm yard manure: This is the wastes from mixed arable and livestock farming used to fertilise crops. It consists of animal excreta (cattle, goat and sheep dung and urine, poultry litters) mixed with bedding materials such as straw, wood chips, crop residues etc. Farm yard manure supplies both macro and micronutrients to plants. It varies in composition from location to location. However, on the average, it contains about 2% N, 0.4% P and 1.7% K.

Crop residues: These include plant parts (straw, stovers, roots) that remain on land after crop harvest.

Compost manure: This is made by accelerating the rate of humification of plant and animal residues by microorganisms in well aerated condition.

Green manure: These are green plants used in fertilizing soil. Green manuring is the practice of ploughing in a quick-growing leafy crop before maturity. Leguminous plants are largely used as green manure due to their symbiotic N fixing capacity. Some non-leguminous plants may also used due to local availability, drought tolerance, quick growth and adaptation to adverse conditions e.g *Tithonia diversifolia*

Slurry: This is a suspension of dung in the urine and washing water coming from animal houses and milking parlours.

Sewage sludge: It is an end product of wastewater treatment process, consisting of solids separated from liquid raw sewage. Sewage sludges vary in condition from sticky materials containing half their weight of water to well dried powder, easy to handle and spread. Sludges are processed and transformed into biosolids using a number of complex treatments such as digestion, thickening, dewatering, drying, and lime/alkaline stabilisation. Digested sludges are fermented anaerobically to eliminate offensive odours and lower the count of pathogens and may safely be applied to the land. However, sustained heavy application of sludges may introduce pathogens into soil and/or raise heavy metals content such as Zn, Cu, Ni and Cd to levels that are detrimental to plants.

Benefits of organic manure to sustainable agriculture

It builds soil organic matter thus improving soil quality

It serves as nutrient reserves thus improving soil fertility

It improves soil physical properties like

Soil porosity

Water stable aggregates

Water holding capacity

Infiltration rate

Hydraulic conductivity

It buffers against rapid changes in acidity, alkalinity and salinity of soil

It improves soil structure and reduces soil crusting

It provides energy substrate for microbial transformations.

Composition of manures

Organic manures vary in composition of their nutrients. Variability in elemental and composition among and within organic fertilizer types is due to factors such as

Differences in source (whether animal or plant origin)

Animal species or breed

Population of animal

Feed ration and conversion rate of animal

Bedding material type and composition if present

Climatic condition during manure accumulation

Plant species or variety added as residues

Age of plant material

Environment of operation (industrial or domestic)