COURSE GUIDE

SLM 512
FERTILIZER TECHNOLOGY

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INTRODUCTION

The term fertilizers generally refer to chemically synthesized plant nutrient compounds, which are usually applied to the soil to supplement its natural fertility. Any natural or manufactured material, which contains at least 5% of one or more of the three primary nutrients (N, P_2O_5, K_2O) can be called fertilizer. Industrially manufactured fertilizers are called mineral fertilizers. Fertilizers may contain one or more of the essential nutrients. Those that contain one of the essential nutrients are called single, simple or straight fertilizers. While those that contain two or more of the essential nutrients are called mixed or compound fertilizers.

Fertilizers supply nutrients needed by crops. With fertilizers you can produce more food and cash crops of better quality. With fertilizers you can improve the low fertility of soils which have been over-exploited. All this will improve the well-being of villages, communities and the nation through the production of adequate food feed and fibre for the ever increasing human population. The nutrients needed by plants are taken from the air and from the soil. This course deals only with the nutrients taken from the soil. If the supply of nutrients in the soil is ample, crops will be more likely to grow well and produce high yields. If, however, even only one of the nutrients needed is in short supply, plant growth is limited and crop yields are reduced. Therefore, in order to obtain high yields, fertilizers are needed to supply the crops with the nutrients the soil is lacking. With fertilizers, crop yields can often be doubled or even tripled.

Mineral fertilizers vary in appearance, depending on the process of manufacture, the particles of mineral fertilizers can be of many different sizes and shapes: granules, pellets, „prills‟, crystals or coarse/ compacted or fine powder (dust). Other forms of fertilizer are in solid form. There also liquid and suspension fertilizers. Specific weight/density of a fertilizer important. Urea normally has a greater volume per unit of weight than most other fertilizers.

This course as conceived here has to do with understanding the basics of fertilizer technology. Terminologies and importance of fertilizers in agriculture. Previous utilization of fertilizer and compositions various sources of macro-and micro-nutrient fertilizer sources. How to calculate fertilizer rates and the different methods of application to fields. It also covers how fertilizers are produced as well as chemical and physical methods of assessing the quality of fertilizer materials.

WHAT YOU WILL LEARN IN THIS COURSE

This course carries two credit units.

This course guide tells you briefly what to expect from reading the course material. The study of fertilizers as a means of supplying nutrients to crops. These nutrients are usually adequate in fertile uncultivated soils. However, some soils may be naturally low in nutrients, or even the fertile ones may become deficient due to nutrient removal by crops over the years, or when high- yielding varieties (HYV) are grown, which are more demanding in nutrient requirements than local varieties.

Sixteen elements are essential for the growth of a great majority of plants and these are derived from the surrounding air and soil. In the soil the transport medium is the soil solution. Carbon (C) as CO_2 (carbon dioxide) are derived from the air, hydrogen (H) and oxygen (O) are derived from water, While the rest are derived from the soil, fertilizer and animal manure, which are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl). Other chemical elements are also taken up by plants. These may be beneficial nutrients for some plants, but they are not essential to growth for all. These include silicon (Si), vanadium (V), sodium (Na), cobalt (Co), which may be required by some plants for their special needs.

Apart from carbon (C), plants take up all nutrients from the soil solution. They are divided into two categories (based on quantitative classification): macronutrients, divided into "primary and secondary nutrients‟; and micronutrients or trace elements. Macronutrients are needed in large amounts, and large quantities have to be applied if the soil is deficient in one or more of them. Within the group of macronutrients, the primary nutrients are: nitrogen, phosphorus and potassium. In contrast with macronutrients, micronutrients or trace elements are required in only minute amounts for correct plant growth and have to be added in very small quantities when they cannot be provided by the soil.

These are the nutrients contend in fertilizers and the course introduces you to the basics of fertilizer technology in the modern world.

COURSE AIM

The course aims to provide good understanding of the basics of macro- and micronutrient fertilizers in agriculture, calculation and application, manufacture, as well as chemical and physical methods of assessing the quality of fertilizer materials.

COURSE OBJECTIVES

If you attend the course, you are expected to be able to:

- Define basic fertilizer terminologies and explain their meaning.
- State the importance of fertilizers in agriculture.
- Give an elaborate history of fertilizer consumption.
- State the compositions of the different macro-and micro-nutrient fertilizer sources
- Calculate of fertilizer rates for application to crops.
- State and explain the various methods of fertilizer application to crops.
- Describe how fertilizers are manufactured, especially phosphorus and potassium fertilizers.
- Ascertain the quality of fertilizers using chemical and physical methods.

You should able to clearly understand the concepts, importance, history, manufacture, calculations, application, manufacture and quality assessment of fertilizers.

WORKING THROUGH THIS COURSE

This course has been organized to provide you with basic introduction to fertilizer technology for the first time. Therefore, it has been designed with all simplicity for clear understanding of the rudimentary aspects of fertilizer technology, such as terminologies used to describe fertilizers and their components, sources of the different nutrients they contain, history of their consumption, how to calculate rates for application, how to apply, manufacturing methods and how to ascertain their quality using simple physical and chemical methods.

Tables, figures and plates have been used, where relevant to facilitate your understanding. Study the work carefully and also attend the tutorials, where you will interact with colleagues and tutors to socially learn what this document could not provide.

COURSE MATERIALS

You will be provided with; A Course guide and Study units.

A list of some text books are also provided at the end for your reference. Though not compulsory to buy, that could be very useful in enhancing your knowledge and understanding of various aspects of the soil ecosystem discussed.

STUDY UNITS

This course is divided into 15 units. The following the units are contained in the course.

Module 1

Unit 1 Fertilizer Terminologies
Unit 2 Importance of Inorganic Fertilizers in Agriculture
Unit 3 Importance of Organic Fertilizers in Agriculture
Unit 4 Role of Fertilizers in Integrated Soil Fertility Management

Module 2

Unit 1. History of fertilizer consumption
Unit 2. Compositions of Nitrogen fertilizer sources
Unit 3. Composition of phosphorus fertilizer sources
Unit 4. Composition of potassium fertilizers sources
Unit 5. Composition of micronutrient fertilizer sources

Module 3

Unit 1: Fertilizer calculations content
Unit 2 Factors effecting fertilizer use
Unit 3: Methods of fertilizer application content
Unit 4: Phosphorus fertilizer production and use content
Unit 5: Potassium fertilizer production and use content
Unit 6: Chemical and physical properties of fertilizers

Module 1

In unit 1, you will be taken through the definition of the various terms that are commonly used with fertilizers and fertilizer-related issues. Without a prior knowledge of these terms, one will seriously be disadvantaged in really appreciating the concept of the all-important contributors to food availability and, consequently, food security. In the next two units (2 and 3), however, you will be introduced through the importance of fertilizers, inorganic and organic alike. The former is captured in unit 2 and the latter in unit 3. In unit 4, the role of fertilizers, as an important component of Integrated Soil Fertility Management practice is discussed. Emphasis is, however, placed on the organic fertilizers here.

Module 2

You will be introduced to the history of fertilizer consumption in Unit 1. While Unit 2 will introduce you to nitrogen fertilizer sources, Unit 3 will guide you to phosphorus fertilizer sources and unit 4 to potassium fertilizer sources and finally Unit 5 discuss micronutrient fertilizers sources.

Module 3

Unit 1 will introduce you to fertilizer calculations, while Unit 2 will guide in understanding the factors effecting fertilizer use. The unit 3 will follow with details on the different mthods of fertilizer application and rationale behind each. Unit 4 will describe how phosphorus fertilizers are produced, followed by how potassium fertilizers are produced them finally unit 6 will teach the physical and chemical properties of fertilizers for easy identification.

TEXT BOOKS AND REFERENCES

S. O. Olaitan, G. Lombin and O. C. Onazi (1988). Introduction to tropical Soil Science. Macmillan Publishers Ltd. London and Basingstoke.

Tisdale S. L., Nelson W. L., Beaton J. D. and Havlin J. L. (1993). Soil fertility and fertilizers. 5th Edition.

Brady N. C. and Weil R. R. (2002). The nature and properties of soils. 13th Edition. James B. (1994). History. Essential fertilizer use Manual. mossico.com.

ASSESSMENT

There are two components of assessment for this course. They are the Tutor-Marked Assignment (TMA), and the end of course examination.

TUTOR-MARKED ASSIGNMENT

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. The TMAs will be given to you by your facilitator and you will return it after you have done the assignment.

FINAL EXAMINATION AND GRADING

This examination concludes the assessment for the course. It constitutes 70% of the whole course. You will be informed of the time for the examination.

SUMMARY

The course provides with knowledge about basics of fertilizer technology, mainly concerned with the study of the terminologies, history, sources, calculations, application, manufacture and quality assessment using chemical and physical methods. At the end of the course you will be able to answer the following questions:

1. State the various terminologies used in fertilizer technology and explain their meaning.
2. What is the significance fertilizers in agriculture?
3. Shade some light on the history of fertilizer consumption
4. State the composition of macronutrient locally available fertilizers sources
5. State the composition of micronutrient locally available fertilizer sources
6. Describe how fertilizer rates are calculated
7. State and explain the various methods of fertilizer application and explain their meaning.
8. How are phosphorus fertilizers manufactured?
9. How are potassium fertilizers manufactures?
10. Describe how to ascertain the quality of a given fertilizer, using physical and chemical methods.

We wish you a successful study of the course and proper understanding of fertilizer technology. Best of luck

MAIN COURSE

CONTENTS

MODULE 1

UNIT 1 FERTILIZER TERMINOLOGIES

CONTENTS

1.0 INTRODUCTION

A fertilizer is a substance that is used in agricultural productions in order to provide crops with the necessary vital nutrients for them to grow. Examples of fertilizer elements are nitrogen (N), phosphorus (P) and potassium (K). Fertilizers can broadly be divided into organic and inorganic fertilizers. The latter are also, alternatively, called mineral, synthetic or manufactured fertilizers, and are chemical mixtures produced by the fertilizer industry.

2.0 OBJECTIVES

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

- identify and explain meanings of the various fertilizer terminologies.

3.0 MAIN CONTENT

3.1 Fertilizers

Fertilizer is generally defined as any organic (natural) or inorganic (synthetic) material, which is used to supply one or more of the required chemical elements necessary for plant growth. Fertilizer is, therefore, a substance that is used in agricultural productions of crops in order to provide them with the necessary vital nutrients for their growth. Examples of fertilizer elements are nitrogen (N), phosphorus (P) and potassium (K). Fertilizers can broadly be divided into organic and inorganic. The latter are also, alternatively, called mineral, synthetic or manufactured fertilizers, and are chemical mixtures produced by the fertilizer industry. They can also include: simple mineral fertilizers, for example urea, ammonium nitrate, ammonium sulphate, *et cetera*; complex mineral fertilizers, examples: NP, NK and NPK mixtures and mineral-organic fertilizers like calcium cyanamide. Organic fertilizers include manure and such other organic fertilizers as compost, sewage sludge and industrial waste.

3.1.1 The Essential Nutrients

Sixteen, seventeen or eighteen elements, without or with cobalt (Co) and/or nickel (Ni), as listed on Table 1, are identified as essential elements for plant growth, of which nine are required in macro (large) and seven in micro (trace) quantities. Hence, they are traditionally divided into two main groups, macronutrients and micronutrients, according to the quantities required by plants. Carbon and O_2 are obtained from the gas CO_2 whereas H is obtained from water. As C, O and H are supplied by both air and water, they are therefore, not treated as nutrients by the fertilizer industry. These three elements (C, H and O) are, however, also required in large quantities for the production of such plant constituents as cellulose or starch. The other 13 are called mineral nutrients as they are absorbed in mineral (inorganic) forms. Regardless of the amount required, physiologically, all of them are equally important. The 13 mineral elements are taken up by plants in specific chemical forms as shown in Table 2 (below) regardless of their source. The major aim of fertilizer industry is to provide the primary and secondary nutrients which are required in macro quantities. When chlorophyll of plants is exposed to light, the three elements (C, H and O) are combined in a process of photosynthesis thereby making carbohydrates, with subsequent oxygen being released. The water is, on the hand, brought into the plant by root absorption from the soil system. Carbon dioxide (CO_2) enters plant through stomata, small leaf openings. The photosynthesis rate is directly controlled by the water and nutritional status of the plant. Maximum rates are ultimately, however, influenced by the plant genetics.

Table 1 Essential plant nutrients and their chemical (elemental) symbol

Nutrients Supplied by Air and Non-Mineral	Nutrients Supplied by the Soil System Primary Macronutrient	or Secondary	Micronutri ents
Carbon (C)	Nitrogen (N)	Calcium	Zinc (Zn)
Hydrogen	Phosphorus (P)	Magnesium	Chlorine
Oxygen	Potassium (K)	Sulphur (S)	Boron (B)
			Molybdenu
			Copper (Cu)
			Iron (Fe)
			Manganese (Mn)
			Cobalt
			Nickel (Ni)*

*These elements are among those regarded as beneficial, but not essential, by some authors. Others are Se, Si, Na and Al.

Table 2 Essentiality, forms absorbed by plants and concentrations of essential elements

Nutrient (symbol)	Essentiality established by	Forms absorbed	Typical concentration in plant dry matter
Macronutrients			
Nitrogen (N)	de Saussure (1804)	NH_4^+, NO_3^-	1.5 %
Phosphorus (P, P_2O [1])	Sprengel (1839)	$H_2PO_4^-$,	0.1 – 0.4 %
Potassium (K, K_2O[1])	Sprengel (1839)	K^+	1 – 5%
Sulphur (S)	Salm-	SO_4^{2-}	0.1– 0.4 %

	Horstmann (1851)		
Calcium (Ca)	Sprengel (1839)	Ca^{2+}	0.2 – 1.0 %
Magnesium (Mg)	Sprengel (1839)	Mg^{2+}	0.1 – 0.4 %
Micronutrients			
Boron (B)	Warington (1923)	H_3BO_3, $H_2BO_3^-$	6 – 60 µg/g (ppm[2])
Iron (Fe)	Gris (1943)	Fe^{2+}	50 – 250.µg/g (ppm)
Manganese (Mn)	McHargue (1922)	Mn^{2+}	20 – 500.µg/g (ppm)
Copper (Cu)	Sommer, Lipman (1931)	Cu^+, Cu^{2+}	5 – 20.µg/g (ppm)
Zinc (Zn)	Sommer, Lipman (1931)	Zn^{2+}	21 – 150.µg/g (ppm)
Molybdenum (Mo)	Arnon & Stout (1939)	MoO_4^{2-}	below 1.µg/g (ppm)
Chlorine (Cl)	Broyer *et al.*, (1954)	Cl^-	0.2 – 2 %

[1]Oxide forms are used in extension and trade, [2]ppm = parts per million = mg/kg
= µg/g; 10, 000 ppm = 1 percent. Source: Roy *et al.*, 2006.

Carbon, H and O make up to 95 % of plant biomass, and the remaining 5 % is made up of all other elements. The difference in plant concentration, between macronutrients and micronutrients, is very large. The relative contents of N and Mo in plants is in the ratio of 10,000:1. Plants need about 40 times more Mg than Fe. These examples indicate the significant difference between macronutrients and micronutrients.

3.1.2 Functions of Essential Nutrients in Plants

A briefly summarised description of the various functions of essential plant nutrients within the plant is provided in Table 3. It also lists the plant uptake form(s) of the nutrients. All the nutrients are, however, present in the soil solution complex as either positively charged cations or negatively charged anions.

3.1.3 Beneficial nutrients

Several elements, other than the essential nutrients, have certain beneficial functions to crop plants. Although not essential though, as plants can live without them, beneficial nutrients can readily improve the growth condition of some crops in certain ways. Some of these nutrients can be of great practical significance and may require external addition: Nickel (Ni): a part of enzyme urease for breaking urea in the soil, imparts useful role in disease resistance and seed development.

Sodium (Na): beneficial for beets and halophytes, partly capable of replacing K (uptake as Na^+).

Cobalt (Co): beneficial for N_2-fixation in legumes and for other plants (uptake as Co^{2+}). **Silicon (Si):** beneficial for stalk stability of cereals particularly rice (uptake as silicate anion). **Aluminium (Al):** beneficial for tea plants (uptake as Al^{3+} or similar forms).

3.2 The Fertilizer Terminologies Fertilizer materials

This term, fertilizer material, means a commercial fertilizer that contains one or more of the recognized plant nutrients, and which is primarily used for its plant nutrient content. A fertilizer that meets any of the following conditions: 1) contains important quantities of no more than one of the primary plant nutrients (N, P or K). 2) has ≥ 85 % of its plant nutrient content present in the form of a single chemical compound. 3) is derived from a plant or animal residue, by-product or natural material deposit, which has been processed in a way such that its plant nutrients content has not been changed materially, except by purification and concentration.

Fertilizer Label

The fertilizer guaranteed analysis or grade, is always stated on the bag, and refers to as how much of a fertilizer element is in the material. It is the guaranteed minimum quantity present based on a percentage by weight. All fertilizers are labelled with three numbers, which give the percentage by weight each of total N, citrate-soluble P expressed as oxide (P_2O_5) and water-soluble K also expressed as oxide (K_2O), respectively. Mostly, for simplification, these numbers are said to represent N, P and K (N, P, K). It should, however, be noted that it is actually not N-P-K but rather N-P_2O_5-K_2O.

Table 3 Showing the functions and plant-available forms of the nutrients

Nutrient Element	**Functions in Plants**	**F**	**Plant Available From Soil Solution Symbol(s)**
Nitrogen	Promotes rapid growth, chlorophyll	A n i	NO_3^- NH_4^+
Phosphorus	Stimulates early root growth. blooming	A n i	$H_2PO_4^-$ HPO_4^{--}
Potassium	Increases resistance to drought and strength.	C a t	K^+
Calcium	Improves root formation, stiffness of resistance to seedling diseases.	C a t	Ca^{++}
Magnesium	Aids chlorophyll formation and regulate uptake of other nutrients.	C a t	Mg^{++}
Sulphur	Amino acids, vitamins. Imparts dark production.	A n	SO_4^{--}
Boron	Aids carbohydrate transport and cell division.	A n i	H_3BO_3 $H_2BO_3^-$ HBO_3^{--} BO_3^{---} B
Copper	Enzymes, light reactions.	C	Cu^{++}
Iron	Chlorophyll formation.	C	Fe^{++} Fe^{+++}
Manganese	Oxidation-reduction reactions.	C a	Mn^{++}
Zinc	Auxins, enzymes.	C	Zn^{++}
Molybdenu	Aids nitrogen fixation and nitrate	A	MoO_4^{--}
Cobalt	Essential for nitrogen fixation.	C	Co^{++}
Nickel	Grain filling, seed viability.	C	Ni^{++} Ni^{+++}
Chlorine	Water use.	A	CI^-
Oxygen	Component of most plant		
Hydrogen	Component of most plant	Obtained from air and	

Carbon	Component of most plant	water.

* Also plant-available in chelate form (*i.e.* a nutrient form with the essential nutrient linked to an organic compound so that it stays plant-available within certain soil pH ranges). Source: Savoy (1999)
The first chemists who studied nutrition of plant expressed the P and K as their oxide form in their writings. This practice continued and was eventually adopted as an industry standard that continues to date.

Fertilizer Specifications
Specifications are the requirements with which a fertilizer should conform, as agreed upon between buyer and seller. Fertilizer specifications meet differing requirements depending on the use or intent of the specification **information**. Specifications are normally used in the contract between the buyer and seller of a fertilizer to ensure agreement on product characteristics or more often to define the product in sufficient detail to effect the satisfaction of both buyer and seller.

Complete and Incomplete Fertilizers Complete Fertilizers
A fertilizer is said referred to as complete (or mixed) fertilizer when it contains all the primary nutrients (*i.e.* N, P and K). Examples of some commonly available and used complete fertilizers are: N: P: K 6-12-12, 10-10-10, 15-15-15 and 20-10-10.

Incomplete Fertilizers
An incomplete fertilizer is, however, when one or more of these major components is missing. Examples of incomplete fertilizers are, therefore: ammonium nitrate (34-0-0), urea (46-0-0), diammonium phosphate - DAP (18-46-0), triple super phosphate – TSP (0-46-0) and muriate of potash - MOP (0-0-60). Incomplete fertilizers are blended to produce complete fertilizers.

Straight Fertilizer
This is a qualification that is generally given to a nitrogenous, phosphatic or potassic fertilizer that has a declarable content of only one of the primary plant nutrients, that is: N, P or K. Straight fertilizer is therefore an example of incomplete fertilizers.

Compound Fertilizer
This is the fertilizer type that has a declarable content of at least two of the primary plant nutrients (N, P and K) obtained chemically, by blending or both. Compound fertilizer can, therefore, be a complete or an incomplete fertilizer.

Fertilizer Ratio

The fertilizer ratio indicates the proportion of N, P_2O_5 and K_2O that are contained in any given fertilizer. The specific fertilizer ratio one will require depends largely on the soil inherent nutrient level. A ratio 1-1-1 (10-10-10 or 15-15-15) is, for example, widely used during planting time when both P and K are not adequate (*i.e.* low or medium soil tests). When soils are ranked high or very high in P and K, on another hand, a ratio 1-0-0 (34-0-0 or 46-0-0) may be more appropriately chosen during or prior to planting date.

Special Purpose Fertilizers

Special purpose fertilizers are those primarily used in small fruit and nursery industries. When shopping for fertilizer, one will find out that some are packaged for very specific uses, such as blueberry food. The blueberry, sometimes called rhododendron or azalea fertilizer, food is an example of these specialty materials and which belongs to an old established group, called the acid-plant foods. Some of the compounds ($(NH_4)_2SO_4$ is usually the acidifying ingredient) used in these fertilizers are chosen because of their acid reaction and may, therefore, benefit acid loving plants at a very high soil pH condition.

Slow-release Fertilizers

A slow-release fertilizer is the type of fertilizer that is designed to release its nutrients at rates that match specific plant nutrient requirements. It slowly releases its nutrients, sometimes throughout a growing season, compared to a commercial fertilizer that is quick releasing. Slow-release fertilizer strategies are becoming popular in public opinion. The contribution of N from slow-release fertilizer, however, varies by climate, field condition and cropping system. It will be advantageous to provide plants with a relatively steady nutrients supply throughout their most active growth periods since they can continuously assimilate nutrients. The most efficient way to achieve this is, perhaps, to apply a slow- release fertilizer. Slow-release fertilizers contain one or more essential nutrients. These elements are released or made available for plant use over an extended period. Slow-release materials are, usually, generally too costly for use.

Organic Fertilizers

The word organic, as applied to fertilizers, usually means that the nutrients contained therein are solely derived from a once-living organism remains. Some organic materials, especially composted sludges and manures, are usually registered and sold as soil conditioners instead of fertilizers. Soil conditioners do not have any nutrient guarantee, although various quantities of plant available nutrients are usually present.

Granular Fertilizer
This is a solid material that is formed into predetermined mean sized particles.

Coated Fertilizer
This is a granular fertilizer covered with a thin different material so as to improve the behaviour and/or modify the fertilizer characteristics.

Soil Conditioners
Soil conditioners are those materials that have properties capable of possibly improving physical and/or chemical properties and/or biological activity of soil. Those soil conditioners with substantial nutrient value have much higher potential for cost-effective use.

3.2.1 Other Related Fertilizer Terminologies Coated Slow-Release Fertilizer

This is a product that contains sources of water-soluble nutrients, the release in the soil of which is controlled by the coating applied to the fertilizer.

Polymer-Coated Fertilizer
This is a coated slow-release fertilizer that consists of fertilizer particles that are coated with a polymer (plastic) resin. It is a good source of slowly available plant nutrients.

Controlled-Release Fertilizers
These are, generally, fertilizers in which one or more of the nutrients contained have a limited solubility in the prevailing soil solution, so that they become available to the growing plant over a controlled period of time. The three fertilizer types above are a very good example of slow-release fertilizers earlier stated.

Nitrogen Stabilizer
This is a substance that is added to a fertilizer so as to extend the time that the N component of the fertilizer remains in the soil in the ammoniacal form.

Liquid Fertilizer
This is the term used for fertilizers in solution or suspension and for liquefied ammonia.

Solution Fertilizers
These are liquid fertilizers that are free from solid particles.

Suspension Fertilizer

This is a two-phase fertilizer in which solid particles are allowed in suspension in the aqueous phase. It (suspension fertilizer) is also defined as a fluid that contains dissolved and undissolved plant nutrients. The undissolved plant nutrients" suspension may be produced with the help of a suspending agent of non-fertilizer properties or may be inherent with the materials. Mechanical agitation may, sometimes, be necessary in certain situations, in order to facilitate for uniform suspension of the undissolved plant nutrients. Suspension fertilizer

may also be a liquid (fluid) fertilizer that contains solids that are held in suspension, by an addition of a small amount of clay, for example. The solids may, however, also be water- soluble in a saturated solution, insoluble or both.

Slurry Fertilizer

This is a fluid mixture containing dissolved and undissolved plant nutrient materials requiring a continuous mechanical agitation to ensure homogeneity.

Powder

This is a solid substance in very fine particles form. Powder is also at times referred called a non-granular fertilizer, and is sometimes defined as a fine particles containing fertilizer.

Formula

This is a term used in certain countries to express, by numbers, in the order N-P-K (nitrogen- phosphorus- potassium), the respective content of these nutrients in a compound fertilizer.

Bulk

This is a qualification given to a fertilizer or soil conditioner that is not packed in a container.

Guarantee (of Composition)

This is a quantitative and/or qualitative characteristic with which a market product must comply for legal or contractual requirements.

Declarable-Content

This is that content of an element (or an oxide) which, according to a given national legislation, may be given on a document or label associated with a soil conditioner or fertilizer.

Fertilizer unit

This is the unit mass of a fertilizer nutrient, in its elemental or oxide form.

Plant Food Ratio

This is the ratio of the numbers of fertilizer units present in a given fertilizer mass, expressed in the order N – P – K.

4.0 CONCLUSION

Fertilizers have several terminologies and are of many types, for specific and general purpose functions.

5.0 SUMMARY

1. Fertilizer terminologies are important in clearly understanding their functions.
2. User can best and specifically select and use the most desirable fertilizer nutrient needed.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the difference between organic and mineral fertilizers; and essential versus beneficial elements?
2. Differentiate simple from complex fertilizers.
3. What are the differences between fertilizer label, materials and specifications? Give at least one example in each case.
4. Briefly discuss on the functions of primary plant nutrients.

7.0 REFERENCES/FURTHER READING

Food and Agriculture Organization of the United Nations /International Fertilizer Industry Association FAO/IFA (1999). *Fertilizer Strategies*. Rome: FAO.

Roy, R.N., Finck, A., Blair, G.J. and Tandon, H.L.S. (2006). *Plant Nutrition for food security: A guide for integrated nutrient management.* Food and Agriculture Organization of the United Nations, Rome. 386 pp.

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UNIT 2 IMPORTANCE OF INORGANIC FERTILIZERS IN AGRICULTURE

CONTENTS

1.0 INTRODUCTION

2.0 OBJECTIVES

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

- State the various advantages and disadvantages of using chemical fertilizers.
- Give the future outlook on synthetic fertilizers.

3.0 MAIN CONTENT

3.1 Importance of fertilizers in agriculture

The use of agricultural fertilizer is one of the crucial land management practices that has lightened nutrient problem in cropland and considerably elevated soil fertility and consequent crop yields over the past century. Since the generation of the Haber–Bosch process, in the early 20th century, chemical N fertilizer production, for example, has changed a large quantity of unreactive N to its reactive forms. Chemical P fertilizer production was also enhanced along with the P acid. On the one hand, as a crucial constituent of the *green revolution*, the histrionic increase in fertilizer production and application has markedly contributed in global rise in agricultural productivity and, hence, reduced hunger. Disproportionate use of fertilizer, on the other hand, is proven to be causing a number of such environmental and ecological menaces, within and outside of farmlands, as eutrophication of water bodies, air pollution, soil acidification and degradation, reduction in crop yield, and attenuation of food and energy production sustainability from agricultural fields. Data obtained by Lu and Tian (2017) indicated that consumptions for fertilizer N has steadily increased from 11.3 Tg N yr^{-1} in 1961, to 107.6 Tg N yr^{-1} in 2013 and that of P increased from 4.6 to 17.5 Tg P yr^{-1} during the same period as indicated in Figure 1. Increase in world total fertilizer use is derived from both cropland expansion and elevated fertilizer application rate per unit cropping area.

While the biotech industry proffers solution to crop pests and diseases in the form of creating highly toxic pesticides and genetically altered forms of crops capable of resisting or tolerating these threats, the straight forward solution lies in getting back to the sole use of organic fertilizers or in combination with certain quantities of inorganic that will enhance a truly healthy plant growth to ensure greater natural resilience of crops. For the purpose of this unit, we would restrict the term fertilizers to inorganic (chemical/synthetic) fertilizers only.

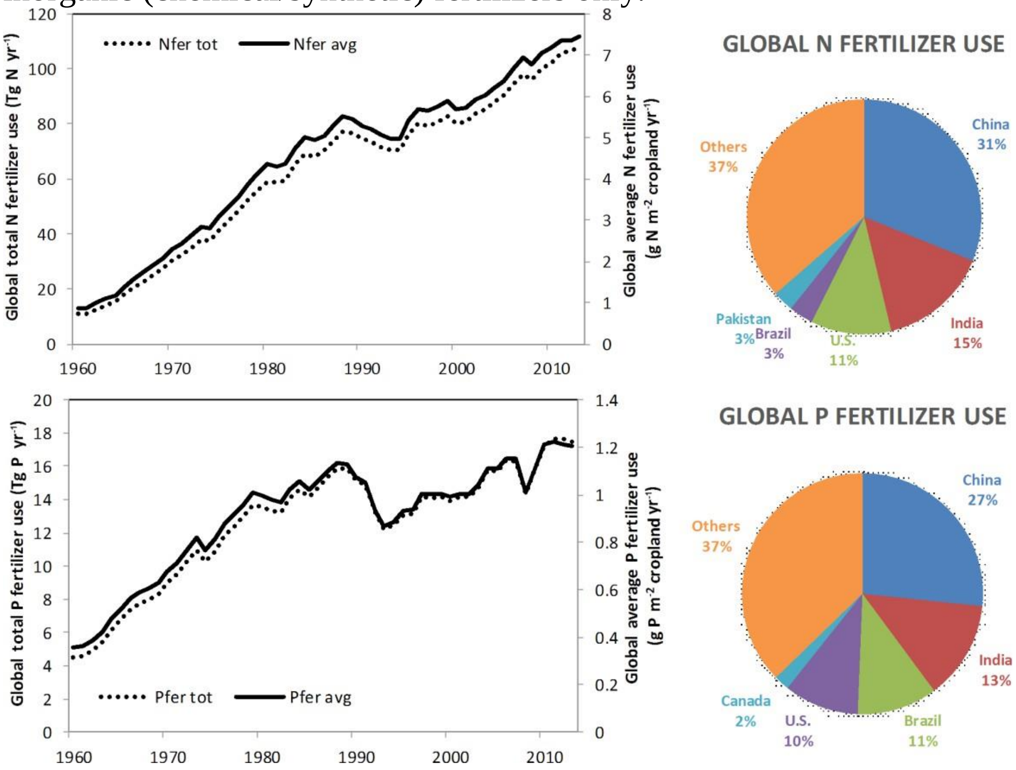

Figure 1. Temporal patterns of global N and P fertilizer use in terms of total amount (tot) and average rate on per unit of cropland area (avg) per year. Pie charts show the proportion of N and P fertilizer use in the top five fertilizer-consuming countries and others in the year 2013.
….... Nfert tot = total Nitrogen fertilizer Nfert avg = agerage N fertilizer
Source: Lu and Tian (2017).

3.1.1 Advantages of using fertilizers

There are various advantages of fertilizers to crop plants. Some examples of such benefits are given below for reference purpose, as follows:

Support to crop growth

Generally, chemical fertilizers contain the primary plant nutrients (N, P and K) in specifically predetermined ratios tailored towards specific growth needs of specific crop plants. These fertilizer‟s nutrients allow crops to grow even in depleted soils, as the basic nutritional requirements of the crop plants are met.

Provision of a predictable and efficient nutrients' source

Manufactured fertilizers contain a predictable ratio of N, P and K. These nutrients are dissolved in the soil water before quickly reaching plants‟ cells, where they are required. The nutrients consistency allow for efficient production of crop products.

Allow crops to grow faster and bigger

Crops are capable of growing faster and bigger, due to the nutrients being applied to them through fertilizer application, than those crops living in infertile and/or unproductive soils.

Allow for an increased harvest

A quick and efficient production increases harvest yields thereby making food relatively more available and, hence even, affordable through a reduced cost of production.

Their nature of easy transport

Chemical fertilizers are easier to transport than such organic soil amendments as animal manure. They are also cheap to produce, and hence cheap to purchase, depending of course upon the country.

3.1.2 Disadvantages of Using Fertilizers Possible burning effect

Synthetic fertilizers are composed of high amounts of acidic chemicals and can, therefore, have negative impact on soil quality and burning effect on crop plants and can even affect human skin negatively.

Fertilizers are potential pollutants

Nitrogenous fertilizers, through surface runoff from farmlands can enter into water bodies after rains, thereby causing toxic algal blooms in such water bodies as rivers, lakes, ponds, *et cetera* due eutrophication. Chemical fertilizers, depending on type and concentration, usually contain toxins that can be destructive to the soil, especially under poor management system. The chemicals can also be poisonous to humans, wildlife and aquatic lives. Fertilizers can also leach through soil into groundwater, making it very harmful to the surrounding environment.

Results in depleted soils

Synthetic fertilizers typically only supply N, P and K, but do not supply most other nutrients to the soil. Consequently, the soil that is continuously used for growing crops with given
chemical fertilizers is being depleted, over time, and the food crops may also be nutritionally deficient. This explains why, over the last century, some soils in many parts of the world, become so depleted that many food items became significantly deficient in many such vital nutrients as Mg, as the soil is mostly not been replenished any nutrient other than the N, P and K.

Interfering with natural soil ecology

In addition to the role of heavy tillage practice of agriculture in disrupting the delicately balanced soil ecosystem, consistent application of chemical fertilizers to crops can also retard the growth of many beneficial soil organisms and even kill others. Without a healthy soil ecology having appropriate texture and structure, soil moisture will not be well retained and this will lead to a reduced resilience to drought. Crop health will also be at stake as unhealthy soil always leads to plants to be more exposed to more pests and diseases.

Chemical fertilizers are like steroids for plants

Fertilizers provide plant-available nutrients for crops‟ growth; as a consequence, however, the crops can over grow to an extent that their roots cannot sustain. This can result in weaker plants that are further more vulnerable on their own to pests and diseases organisms.

3.2 Future Outlook on Fertilizers

3.2.1 Fertilizer Demand

Fertilizer demand in 2020 is estimated using three approaches: the first two are based on estimate fertilizer demand on the basis of food production requirements and nutrient removal (agronomic) needs. The third method aims at estimating effective demand on the basis of behavioural model by considering the role of such economic and noneconomic parameters, as availability of foreign exchange, exchange rate, the development of irrigation and other infrastructure, and crop and fertilizer prices; it also considers the impact of policy reforms on demand for fertilizer. Estimates resulting from econometric approaches under this method are modified based on qualitative information and reliable judgments. The agronomic needs are estimated using nutrient removal coefficients for diverse cereals and rates of nutrient uptake efficiency. These estimates indicate how much fertilizer will be needed if nutrient reserves in soils are maintained at their initial level. Also, fertilizer requirements based on food production needs indicate the amount of fertilizer nutrients required to meet food production needs in the year 2020.

Effective Fertilizer Demand

Global fertilizer demand is projected to increase to 1.2 % year^{-1} during the 1990 - 2020 periods. In absolute amounts, however, it is projected to increase from about 144 million tonnes in 1990 to 208 million tonnes in 2020. Global use of N, P_2O_5, and K20 is projected to increase from 79, 38 and 27 million tonnes, respectively, in 1990 to 115, 56 and 37 million tons in 2020. Little growth was, however, projected during the period of 1990 – 2000, for many reasons including: 1) policy reforms and environmental regulations
expected to have a negative bounce on fertilizer use, especially, in Western Europe; 2) economic and political reforms in Eastern Europe and Eurasia that would drastically reduce fertilizer use in the early to mid-1990s and these regions were also expected to have a slow to moderate recovery in the late 1990s. The expected decline in fertilizer use in these regions was barely to be compensated by the growth in fertilizer use in other regions including Asia and Latin America, 3) North America and Oceania were expected to experience a modest growth due to improved prospects for crop exports in the late 1990s and
4) structural adjustment programmes and policy reforms were expected to reduce growth in fertilizer use in many developing countries.

3.2.1 Future Challenges in using fertilizers

Fertilizer use will remain an essential component of future strategies for ensuring food security and protecting the natural resource base. In fulfilling that role, however, fertilizer should be approached differently in the future. In the past, the main focus was on promoting growth in fertilizer use, and therefore, all efforts - institutional, infrastructural, technical, organisational and policy-related - were geared towards that goal. Developing countries, mainly Asian, encouraged rapid growth in fertilizer use which reaped rich dividends in an increased food production and security. In many countries, however, this growth was associated with high energy use, low fertilizer use efficiency, increased fiscal burdens, inefficient parastatals and little environmental monitoring. All this will have to change because these costs are unsustainable. New strategies do a better job of promoting complementarities between economic and environmental goals and generating congruencies among efficiency, equity, fiscal prudence and environmental protection objectives.

In future, emphasis should be on growth and management rather than growth alone, per se. This implies not only the management of fertilizer nutrients on the farm, but also the management of all resources - physical, human, financial, organizational and policy - that go into the fertilizer sector.

Resource Use Efficiency

In contrast to developed countries, resource use efficiency in both the developing countries and the reforming economies is low in many areas. Inefficiencies in fertilizer use and energy consumption warrant special discussion.

Fertilizer Use Efficiency

Crop response to fertilizer use varies from one agro-ecological zone to another, and in the same agro-ecological zone, from one crop to another. On average, 1 tonne of fertilizer nutrients yields about 10 tonnes of grain in the developing countries (FAO 1987). This is, however, extremely low compared with the 15 to 20 tonnes of grain per tonne of fertilizer nutrients achieved elsewhere like in North America and Western Europe. Overall, fertilizer use efficiency (*i.e.* nutrient uptake by plants) in the developing countries may not exceed 40
%. This indicates that considerable amounts of applied fertilizer nutrients are lost to the atmosphere, which potentially damages the environment. Higher nutrient uptake by plants
would limit these nutrient losses to atmosphere and reduce the need for fertilizer subsidies by improving the profitability of applied fertilizer nutrients. Thus, improving nutrient uptake efficiency and/or fertilizer use efficiency and would promote both economic benefits and environmental protection. Proper timing, application and products can also reduce nutrient losses. Soil analyses can also help in matching nutrient applications with plant requirements. Many large-scale farmers in North America use computers to identify nutrient requirements of crops in different parts of their fields. In contrast to uniform broadcasting known as precision application, which results in considerable savings in applied plant nutrients. Although most small-scale farmers in developing countries cannot afford this information technology, governments can help them by providing better soil analyses and information facilities on nutrient needs.

Another means to improve nutrient use efficiency is to move from low- to high-analysis fertilizer products. Many farmers in the developing countries, especially in Sub-Saharan Africa, still depend on low-analysis fertilizer products such as ammonium sulphate (20.5
% N) and single superphosphate (SSP) (18 % P_2O_5) rather than such high-analysis fertilizer products as urea (46 % N), triple superphosphate (TSP) (46 % P_2O_5) and diammonium phosphate (DAP) (18 % N, 46 % P_2O_5). Additionally, over 8 million tonnes of N fertilizers used in China is

ammonium bicarbonate (ABC) – a highly unstable and low-efficiency product. Under a programme to convert its 1,000 or more small ABC plants into urea plants, China had converted about 75 of such plants by 1992. This process will help to improve N use efficiency, if the pace of conversion can be accelerated. Improvement in nutrient balances (the N: P2O5: K2O ratio) can enhance nutrient use efficiency. As indicated earlier on, N use in many developing countries, in relation to P_2O_5 and K_2O use, is excessive. This reduces the efficiency of N use. In some parts of China, K_2O and P_2O_5 deficiencies are so acute that farmers get only a little response from additional application of N. Many developing countries depend on importation of P_2O_5 and K_2O fertilizers. In addition to these technology-related improvements, both the developed and the developing countries can also improve fertilizer use efficiency by removing policy distortions.

4.0 CONCLUSION

The best approach to growing crops, using inorganic fertilizers, is to employ sustainable production methods, which nourish the soil and its critical ecology that supports all lives. The long-term sustainability of food production process depends upon how the soil is treated. Nourishing and treating the soil well, means the soil will reward us with healthy, nutrient-dense food. It will also maintain greater resilience in the face of drought, pests and disease while safeguarding our drinking waters.

5.0 SUMMARY

1. Chemical fertilizers, although very important for high yielding crop production, they are still related with some problems.
2. Synthetic fertilizer use has some global future outlooks.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the importance of fertilizers in crop production?
2. In your opinion, what is the future of chemical fertilizer use?

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UNIT 3 IMPORTANCE OF ORGANIC FERTILIZERS IN AGRICULTURE

CONTENTS

1.0 INTRODUCTION

2.0 OBJECTIVES

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

State the various advantages and disadvantages of using organic fertilizers.

3.0 MAIN CONTENT

3.1 Organic Fertilizers

It is necessary to clarify that organic fertilizers, in some countries, are those fertilizers that can be used in organic farming, and are derived from animal matter, animal excreta, human excreta and vegetable matter, according to some international standards. European Commission"s working groups gave a more generic definition of organic fertilizers as those whose nutrients are contained in organic materials of animal, vegetable or other natural organic origin constituted by compounds/materials, in which the main nutrients are chemically linked or are part of these organic matrices. The nutrients contained in organic fertilizers must be transformed in the soil by microorganisms before they are assimilated by the plants. Their incorporation into the crops is, however, more gradual than if they come from mineral fertilizers.

3.1.1 Importance of organic fertilizers in agriculture

Organic fertilizer, when available, can and should be part and parcel of soil fertility management strategies. Organic fertilizer alone will, however, not be sufficient to support the sustained high levels of

production and productivity necessary to feed Africa‟s rapidly growing population. This is due to space–time variability in production and utilization. Application of
organic fertilizers, as a component of sustainable agriculture apart from soil mineral provision, contribute to soil quality by improving the chemistry, biological and structural levels of soil. These shape the general agricultural soils‟ health. Its nutrients are also gradually released and reused. Because it is based, mostly on locally sourced materials with little or no dependence on external inputs, it is one of the eco-friendly infrastructures for sustainable rural development.

3.1.2 Advantages of using organic fertilizers

There is an array of advantages in using organic fertilizers for crops production. Some examples of such advantages are as stated below:

1. Soil Structure

Because of the organic matter present in organic fertilizer, soil structure is improved and as a result, the soil‟s water and nutrients holding capacity increases.

2. Microorganisms Thrive

Synthetic fertilizers consist of chemical molecules without carbon. These molecules can sometimes be disruptive and not accessible to microorganisms. Organic fertilizer, on the other hand, is rich in organic matter, which assists microbes to favourably thrive. Organic fertilizer also contains carbon as part of its chemical structure; and it is the C, along with N, P and K that nourishes microorganisms and enables them to make nutrients available for plants in a naturally occurring biological process.

3. Sustainable and Environmentally Friendly

Chemical fertilizers run off into waterways thereby harming aquatic life and water quality. Organic fertilizers, on the other hand, do not run off as easily, even if at all, and are associated with soil structure. According to the Organic Trade Association, organic fertilizers also increase species biodiversity by up to 30 % compared with artificial fertilizers.

4. Reduce Fertilizers and Pesticides

Although organic fertilizers can be costlier than synthetic, depending on certain factors and conditions, it can reduce the need for pesticides and the overall N, P and K requirements. This is due to reductions; organic fertilizer can be cost neutral and sometimes a cost savings.

5. Plant Damage Threat Avoided

Some synthetic fertilizers can cause plant damage to leaves and roots, due to their burning effects. This is a situation less likely with organic fertilizers.

6. Other advantage of inorganic fertilizers is that nutrient content is known and they release nutrient quickly so that timing of nutrient uptake can very well be predicted.

3.1.3 Disadvantages of using organic fertilizers

1. Not all Products are Created Equally

Not all products are created equally and many organic products produce inconsistent results. Make sure you are selecting a product that is industry vetted by reviewing any university studies or case studies.

2. Low Nutrient Levels

The level of nutrients present in organic fertilizer is usually low. Additionally, the nutrients are often complexed in organic chemical structure. Using an organic fertilizer is, therefore a process, not an event.

3. Compost making may be a Complicated Procedure to follow

While one can produce one"s own compost, it"s sometimes a messy and complicated process that may lead to an inconsistent product and end-result.

4. Another disadvantage is that, when organic matter decomposition is rapid, more nutrients are released but release of soil organic matter, on the other hand, is favoured by a slow decomposition process. Decomposition of organic matter, therefore, operates with moisture and temperature. These two vital factors can, however, not be controlled and hence nutrient may be released when the plants do not need them.

5. Potentially pathogenic

In addition, an organic fertilizer or incomplete/badly formed compost can leave some types of pathogens in organic matter. The pathogens can later enter water or food chains, thereby causing environmental and health problems.

4.0 CONCLUSION

The values of organic materials, being used as fertilizers, could be essential to sustained soil- crop productivity in diverse soils. The revitalization of crop production in these soils would be expected to yield some significant results. This is particularly true when organic materials and bioorganic fertilizers are considered as most imperative component of many agricultural systems.

5.0 SUMMARY

1. Unlike chemical fertilizers, organic fertilizers can be a ready - made solution to many of the problems of synthetic fertilizers.
2. Although highly advantageous, organic fertilizers are still known for some basic problems.

6.0 TUTOR-MARKED ASSIGNMENT

What are the advantages and disadvantages of using organic fertilizers in agricultural crop production?

7.0 REFERENCES/FURTHER READING

Bumb, B. and Baanante, C.A. (1996). The Role of Fertilizer in Sustaining Food Security and Protecting the Environment to 2020. USA: International Food Policy Research Institute.

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UNIT 4 ROLE OF FERTILIZERS IN INTEGRATED SOIL FERTILITY MANAGEMENT

CONTENTS

1.0 INTRODUCTION

2.0 OBJECTIVES

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

- Understand the various advantages and disadvantages of using chemical fertilizers.
- Have idea on the future outlook on synthetic fertilizers.

3.0 MAIN CONTENT

3.1 What is Integrated Soil Fertility Management (ISFM)?

Integrated Soil Fertility Management (ISFM) is defined as a set of soil fertility management practices that include, necessarily, organic and inorganic fertilizers and improved germplasm (seeds) combined with the knowledge on how to adapt these practices to local conditions, aimed at optimising agronomic use efficiency of the applied nutrients and improved crop production. The definition, thus, focuses on maximizing the use efficiency of organic and inorganic fertilizers since they are both scarce resources in areas of agricultural intensification need. The Figure 2 below depicts the relationship between the use efficiency of resources as one move from a current practice to a full ISFM.

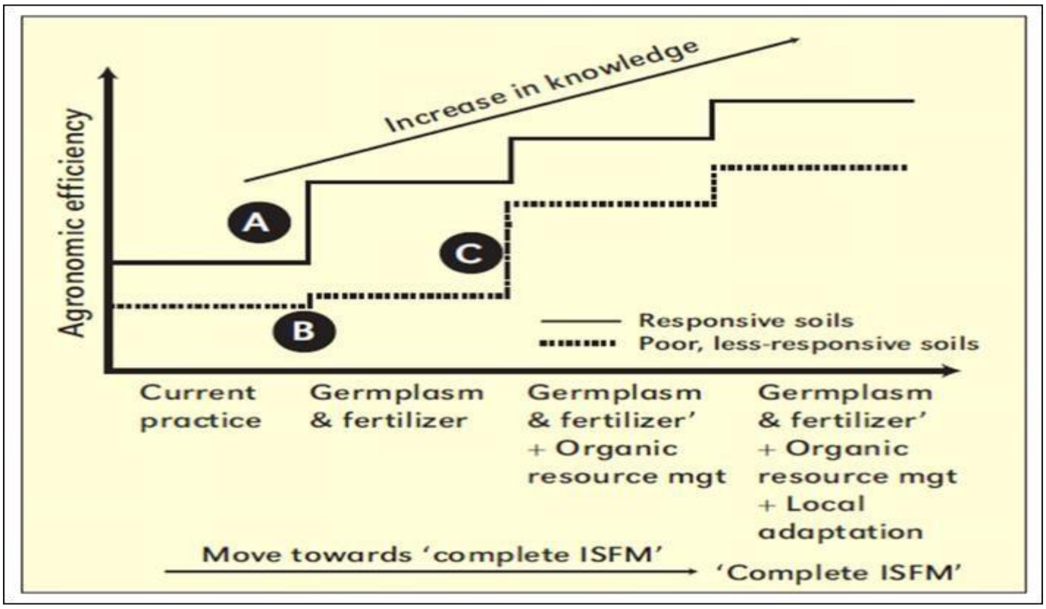

Figure 2: Conceptual relationship existing between the agronomic efficiency (AE) of organic and in organic fertilizers and the implementation of various components of ISFM, culminating in complete ISFM towards the right side of the graph. Source: Ruganzu et al. (2015) as Adapted from Vanlauwe et al. (2011).

The role of ISFM is to maximize the interactions resulting from the potential combination of organic and inorganic fertilizers, improved germplasm and farmer knowledge towards an improved productivity vis-à-vis efficient farm investments and field practices. It (ISFM) also offers environmental services by fostering soil biological diversity and sequestering additional soil C. In addition, use of ISFM offers a sustainable and cost-effective soil fertility management.

3.1.1 Organic resource management in the context of ISFM

3.1.1.1 Concepts Organic Matter (OM)

Organic matter or organic material is the material composed of organic compounds that has come from plants and animals remains and their waste products. It may be found in the atmosphere, in organisms, or in the water and soil.

Soil organic matter (SOM)

This is the OM in soil that is derived from plants and animals. After decaying, to form no longer recognizable, it is called soil organic matter (SOM). The sources of OM include compost, farm yard manure, green manure and bio-fertilizers.

3.1.1.2 Composting

Composting is the natural process of decomposition of organic matter by microorganisms under controlled conditions. It is an attractive practice for turning on-farm organic waste materials into a farm resource. It also enhances soil fertility, improves soil biodiversity, reduces ecological risks, increases agricultural productivity and provides a better environment. The materials that are required for compost preparation include:

- Twigs (branches of trees)

- High carbon materials - includes dry vegetative matter such as maize stalk, seed husks, dry grass *et cetera*.

- High N rich materials, including such green vegetative materials as weeds, grasses, leguminous crop residues, hedge cuttings; or such kitchen wastes as fruit and vegetable peelings.

- Animal dungs, slurry or old compost.

- Top soil, which adds decomposition microorganisms.

- Ash, which provides such minerals as potash, Ca, Mg and P. It also increases the pH due to the higher base cations in ash.

- Sharp-pointed stick of about 2 - 3 m long, in order to detect heat and water needs.

- Water, as moisture is the lifeblood of all metabolic processes of the microbes. Water provides the medium conducive for chemical reactions and nutrient transport. Biological activities are at their optimum when the materials are moisture saturated. Activity ceases entirely below 15 % moisture content. Water also rotten materials and regulates heat in the heap.

- Temperature in a compost pile can rise above 71 ^{0}C due to heat generated by microbial activity and insulating qualities of composting materials. Many of the microbes die or become dormant when the temperature reaches this level. Hence, the composting process effectively stops and does not recover until when the population of the microorganisms recovers. The temperatures should, therefore, be monitored and when the composting material becomes too hot, heat loss should be reduced through forced aeration and/or by turning.

- Wheelbarrow, watering can, hoe and machete are the most used tools.

Composting Methods

There are two basic methods of composting; i) Heap or pile composting and ii) Pit method. The former method is briefly summarised below.

(i) Heap or pile composting

This method is suitable for areas with higher rainfall.
- Make a pit 30 - 45 cm deep and 2 meters wide with any convenient length.
- Put a layer of 30 cm of dry vegetative matter; chop them into small pieces for a faster decomposition.

Add a 10 cm layer of old compost, animal manure or slurry. This will add extra bacterial and fungi to speed up decomposition.

Other organic approaches include the use of farm yard manure, green manure, use of bio-fertilizers and crop residues.

The aspect dealing with the role of synthetic fertilizers in ISFM is similar to what you will study in other units.

4.0 CONCLUSION

The adaptations of ISFM, to local conditions, would lead to specific management practices and wide array of investment choices, and are interactive in nature, which leads to better judgments by farmers about soil management, targeting of fertilizer in space and time and even choice of crop varieties.

5.0 SUMMARY

ISFM can serve the dual purpose of reaping the advantages enshrined both organic and chemical fertilizers, with even the additions of other advantages

6.0 TUTOR-MARKED ASSIGNMENT

Compare and contrast the use of ISFM, on one hand and fertilizers on the other in terms of crop productivity.

7.0 REFERENCES/FURTHER READING

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MODULE 2

UNIT 1 HISTORY OF FERTLIZER CONSUMPTION

1.0 INTRODUCTION

German chemist Justus von Liebig (1803-1873) is considered by many to be the father of agricultural chemistry and the fertilizer industry. He made many outstanding contributions are that he made several important conclusions regarding the source and role of plant nutrients, e.g. carbon in plants being derived from atmospheric carbon dioxide and the necessity of phosphorus for seed formation. He introduced the concept of developing fertilizer recommendations based on the chemical analysis of plants and interpretation of the analyses. He also introduced the principle that plant growth is proportional to the amount of mineral substances available in the fertilizer. He outlined the Law of the Minimum which essentially states that if one nutritive element is deficient, plant growth will be limited even though the supply of all other vital nutrient elements are adequate. Also, plant growth will be improved by increasing the amount of the deficient nutrient up to the point that it is no longer deficient. Liebig strongly believed that soil fertility could be maintained by the addition of mineral elements present in plant ashes and that nitrogenous manures were unnecessary because of the ammonia occurring in the atmosphere and supplied in rainfall. Benefits of manure were
attributed to the release of ammonia to the air in contact with plants. Although von Liebig showed that treatment of bones with a strong acid,

such as sulfuric acid, would increase the availability of phosphorus, he developed a fertilizer in which the phosphate and potash salts were fused with lime and as a result it was a failure.

Following closely on von Liebig‟s notable activities was the work of Lawes and Gilbert at England‟s Rothamsted Experiment Station founded in 1843. Twelve years after starting this research unit they settled a number of important issues including the facts that crops require both phosphorus and potassium and the amount of these elements in plant ash is not a measure of plant requirements. They also established that non-legume crops require a supply of nitrogen and the amount of ammonia provided by the atmosphere is insufficient for crop needs. Likewise, the established that soil fertility could be maintained for many years by using chemical fertilizers. Even though, some modifications were made to their work later.

Many of the sound agricultural practices of today, including manuring, liming, and crop rotations with legumes were also important in ancient times. Also, the value of silt deposits from flooding rivers in maintaining soil productivity was recognized over 5,000 years ago by the early Egyptians living along the Nile River and by the Mesopotamian civilization occupying the region between the Tigris and Euphrates Rivers, now present day Iraq.

2.0 OBJECTIVES

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

- State when and how fertilizer production and consumption started
- State the history of nitrogenous fertilizer sources
- State the history of phosphorus fertilizers Sources
- State the history of potassium fertilizer sources.

3.0 MAIN CONTENT

3.1 Beginning of fertilizer consumption in 1770s

Several famous French chemists conducted quantitative experiments and demonstrations to determine the benefits of chemical fertilization. Lavoisier began his studies in 1778 and found large yield increases on unproductive soils in his area of France. Boussingault established a farm at Alsace and from 1834 to 1871 conducted quantitative field plot experiments with manures, fertilizers and other materials. His inputs and the harvested crops were weighed and analyzed. Also, the numerous sound field experiments carried out between 1848 and 1863 by Georges Ville of Vincennes greatly advanced the practical understanding and use of chemical fertilizers.

The Highland and Agricultural Society of Scotland initiated farmer trials with salt in about 1818. Its programs were extended in 1823 to include farmyard manures, bone and fish compost. Sodium nitrate was introduced into the comparisons in 1831. The treatments were increased further in 1841 with the inclusion of ammonium sulfate, ammonium chloride, aqua ammonia, guano, urine, gypsum and other substances.

The renowned long-term field experiments at Rothamsted, England, deserve special mention. The first classical experiments involved wheat and turnips treated with farmyard manure, no manure and ammonium salts of sulfate or chloride. In 1852, the experiments were established in their final form on continuously cropped wheat, barley, roots, clover and shortly afterwards grass hay. Treatment with only minerals, including superphosphate and potassium, sodium and magnesium sulfates, nitrogen plus these same minerals, farm yard manure and no manure were compared on all the crops. These experiments have been conducted for many years and some are still continuing. Careful records have been maintained of weather, soil and crop conditions as well crop and soil samples were analyzed.

3.2 History of nitrogen fertilizers

1. **Sodium nitrate**: This is the world‟s first commercial nitrogen fertilizer was sodium nitrate mined from natural deposits in Chile. It was imported into Europe and North America from about 1830 onwards. During the 1920s sodium nitrate imports from Chile were still a very important source of nitrogen in the United States with consumption amounting to about 600,000 tons annually.

2. **Ammonium sulfate**: was the next commercial source of fertilizer nitrogen. It was originally a by-product of the manufacture of coal gas for use in illumination and later from the coke industry serving the steel industry in Europe and America in the late 1800s. The initial product in England in 1815 was of poor quality but by the 1830s substantial amounts were being used by farmers in that country.

3. **Calcium Cyanamide:** Nitric acid and calcium nitrate were being manufactured in Norway by 1905. Shortly before this time, German chemists discovered how to synthesize calcium cyanamide and its agronomic value was confirmed around 1901. Its manufacture was built in Italy in 1905. By 1918, there were 35 plants operating globally in such countries as Germany, Dalmatia, and Canada.

4. **Anhydrous ammonia:** After the discovery of the Haber and Bosch‟s 10 or more years of intensive research and development on the

synthesis of ammonia from its elements. The first commercial plant for production of ammonia opened in Germany in 1911.
Manufacturing of synthetic ammonia in the United States began in 1921 with water gas as the source of hydrogen. A second U.S. plant, utilizing by-product hydrogen from the electrolytic formation of chlorine came on stream in 1922. After so many developments, the use of natural gas as an ammonia feedstock became dominant in the 1950s. Due to the adaptability of ammonia to a wide variety of conditions and its price competitiveness, growth in consumption in the U.S. has been rapid, from just a few thousand pounds in 1934, to over 1.1 million tons in 1964 and 5.5 million tons in 1994. Anhydrous ammonia, excluding aqua ammonia, now accounts for 35.9 percent of the nitrogen applied to U.S. cropland.

5. **Ammonium nitrate:** The use of ammonium nitrate compound was first employed as a fertilizer in Europe following World War I when large stocks not utilized for explosives were released for agricultural use. Because of explosions in Germany in 1920 and 1921, it was usually dry-mixed with limestone, gypsum, chalk or ammonium sulfate to avoid such danger and to also serve as conditioning agents. The first use of ammonium nitrate in the United States occurred in 1926 with product imported from Germany. After some time, ammonium nitrate accounted for about one-third of all the nitrogen applied directly to U.S. cropland in 1955. By 1980, this use had declined to 10 percent. The tonnage of directly applied nitrogen as ammonium nitrate was exceeded by anhydrous ammonia in 1960, by nitrogen solutions in 1970 and by urea in 1978. Ammonium nitrate supplied 5.3 percent of the total 12.6 million tons of nitrogen consumed nationally in 1994.

6. **Urea:** The present commercial method of synthesizing urea through the reaction of ammonia and carbon dioxide was first introduced in Germany in 1920. In the U.S., commercial synthesis of urea was first achieved in 1932. After a long time, urea consumption in 1994 accounted for 14.7 percent of the 12.6 million tons of nitrogen applied to U.S. croplands.

7. **Poudrette or human excrement, cottonseed meal, fish scrap and slaughterhouse wastes:** These were major sources of fertilizer nitrogen in the United States from about 1850 to 1900. In 1910, 90 percent of the fertilizer nitrogen consumed in the U.S. was in the form of natural organic materials including cottonseed meal, dried blood, fish scrap and animal tankage. Two new natural organics, activated sewage sludge and digested sewage sludge were introduced in the 1950s.

3.3 History of phosphorus fertilizers

1. Phosphate rock: This is the only economical source of phosphorus for production of phosphate fertilizers and phosphate chemicals. Most of the world phosphate rock reserves are widely distributed marine phosphorite deposits. Phosphate ores were first mined in relatively small amounts in the mid-1840s in England, France and Spain and in the 1860s
in Norway and Germany. Between 1863 and 1895, phosphate rock was shipped from deposits in Ontario and Quebec to England for processing. The leading countries in the mining of phosphate rock are the U.S.A., Morocco and Algeria, People"s Republic of China, Tunisia, Jordan, Republic of South Africa, Brazil, Togo, Israel, Nauru, Senegal and Syria. Morocco has the greatest reserves, followed by South Africa.

2. Phosphoric acid: Phosphate in the naturally occurring phosphorite ores exists in several variations of the very stable apatite compound. In the manufacture of the common phosphate fertilizers, the strong bonding in the apatites is broken by chemical or thermal processes to render the phosphate more soluble. Treatment with sulfuric acid to produce phosphoric acid is the most widely used method of accomplishing this breakdown. The first phosphoric acid plant was built in Germany in about 1870. In the U.S., phosphoric acid was first manufactured in 1890.

3. Phosphatic fertilizers: Animal and human bones were not always effective in improving or sustaining crop yields and the superphosphate industry came into being as a result of attempts to increase the effectiveness of bones and also to find a more plentiful and secure source of phosphate. As early as 2,000 years ago, Chinese farmers applied calcined or lime-treated bones to their fields. Several individuals, including von Liebig, in Europe during the early 1800s to 1842 acidulated bones, usually with sulfuric acid, to improve the solubility of phosphorus.

3.4 History of potassium fertilizers

Potash (K_2O): Virtually all of the economic sources of potassium occur in sedimentary salt beds remaining after the evaporation of ancient seas and lakes. World reserves of such potassium-bearing deposits are immense and total about 250 billion tons of K_2O, of which 9.4 billion tons are considered commercially exploitable. With global consumption of about 25 million tons of K_2O annually both economical reserves and total resources are sufficient to satisfy world demand for centuries.

The potassium fertilizer industry originated in Western Europe where significant ores exist in several countries including Germany, France, Italy, Spain and the United Kingdom. Capacity for production of potassium fertilizer salts is currently much in excess of world demand.

At least 95 percent of world production of potassium fertilizers is in the form of potassium chloride. Potassium sulfate is the next most important source followed by much smaller quantities of specialty materials such as potassium magnesium sulfate, potassium nitrate, potassium thiosulfate, potassium polysulfide, potassium carbonate and potassium bicarbonate.

Reserves of potassium salts are modest in South America where production of small amounts of potassium fertilizer began about 1986 in Brazil"s Sergipe Basin. Chile"s current production of specialty potassium fertilizers is based on its nitrate deposits.

4.0 CONCLUSION

Production and consumption of fertilizer started since 1770s, which include nitrogenous, phosphorus and potassium fertilizers, among other essential nutrients.

5.0 SUMMARY

1. Several famous French chemists initiated quantitative experiments and demonstrations to determine the benefits of chemical fertilization since 1778.
2. By 1852, the experiments were established in their final form on continuously cropped wheat, barley, roots, clover and shortly afterwards grass hay, with adequate records keeping.
3. The fertilizers used contain nitrogenous, phosphorus and potassium and other nutrients and of different formulations.

6.0 TUTOR MARKED ASSIGNMENT

Give a brief biography of the production and consumption of nitrogenous, phosphorus and potassium fertilizers, using suitable formulations.

7.0 REFERENCES/FURTHER READINGS

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UNIT 2 COMPOSITION OF NITROGEN FERTILIZER SOURCES

CONTENT

1.0 INTRODUCTION

Nitrogen (N) is the main nutrient promoting of plant growth. It makes up 1 to 4 percent of dry matter of the plant. It is taken up from the soil in the form of nitrate (NO_3^-) or ammonium (NH_4^+). In the plant it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins. It is the essential constituent of proteins, hence involved in all the major processes of plant development and yield formation. A good supply of nitrogen for the plant is important also for the uptake of the other nutrients.

All commercial nitrogenous fertilizers are produced from ammonia. The latter is obtained by combining atmospheric nitrogen and hydrogen at high temperature (400 - 500^oC) and pressure (500 - 1000 atmospheres). The hydrogen is obtained by hydrolyzing water, burning coke or distilling coal, petroleum or natural gas. There are many different types of nitrogenous fertilizers, some of which we shall discuss in this unit.

2.0 OBJECTIVES

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

- The role of nitrogen fertilizers in enhancing plant growth
- What nitrogenous fertilizers are
- Give example of nitrogen fertilizers and their individual nature

3.0 MAIN CONTENT

3.1 Nitrogenous fertilizer sources.

3.1.1 Urea: Urea ($CO(NH_2)_2$) is prepared by combining liquid ammonia with carbon dioxide. It has 45-46 percent N and is the world‟s major source of nitrogen due to its high concentration of the nutrient. It a white, fine crystalline material. It is very soluble in water and highly deliquescent. The particles are usually coated with dry powders. It readily undergoes hydrolysis in the soil to produce ammonium carbonate.

$CO(NH2)2 + 2H2O \rightarrow (NH4)_2\ CO_3$

This is then converted to into nitrate by nitrifying bacteria. Urea thus ultimately produces both $NH4^+$ and $NO3^-$ ions for absorption by plants and so it acts as a similar way to ammonium fertilizers.

However, its application requires exceptionally good agricultural practices to avoid, in particular, evaporation losses of ammonia to the air. Urea should be applied only when it is possible either to incorporate it into the soil immediately after spreading or when rain is expected within the few hours following the application. Application of urea leads to a small loss of calcium from the soil. While it can be utilized directly by plants from foliar spray and it is used on wheat, rice, potato and fruit crops, among others.

3.1.2 Ammonium sulphate $(NH_4)_2SO_2$ has with 21% N (in the form of ammonia) and is obtained by distilling ammonia. It is not as concentrated as urea. It is a fine crystalline salt, which is generally white or sometimes faintly blue or yellow. It is very soluble in water and it acts almost as quickly as nitrate in the soil. However, it contains 23% Sulphur, in addition to N. Sulphur is a plant nutrient that is growing in importance in some soils. It is used by preference on irrigated crops and where sulphur has to be applied. The same holds true for ammonium sulphate nitrate with 26% N (about ammonia and 1/3 in the form of nitrate) and 13 to 15% of sulphur.

3.1.3 Calcium ammonium nitrate (CAN) or nitrochalk with up to 27% N (equal parts of ammonia and nitrate nitrogen) is a fertilizer of preference on crops in semi-arid regions of the subtropics. It contains a mixture of ammonium nitrate (NH4NO3) and finely precipitated carbonate of lime ($Ca\ CO_3$). It is highly hygroscopic and tend to form hard lumps, which makes it difficult to distribute in the field. It requires careful storage and handling.

4.0 CONCLUSION

Nitrogen fertilizer sources vary from each other in production nature and nitrogen content.

5.0 SUMMARY

1. Nitrogen (N) is the main nutrient promoting of plant growth.
2. All commercial nitrogenous fertilizers are produced from

ammonia.
3. They vary from each other in nature and nitrogen content.
4. They include urea, ammonium sulphate and calcium ammonium nitrate, among others.

6.0 TUTOR MARKED ASSIGNMENT

Describe the nature of nitrogenous fertilizers with their varying nitrogen contents using suitable examples.

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 COMPOSITION OF PHOSPHORUS FERTILIZER SOURCES

CONTENT

1.0 INTRODUCTION

Phosphorus (P), which makes up 0.1 to 0.4 percent of the dry matter of the plant, plays a key role in the transfer of energy. Thus it is essential for photosynthesis and other chemico - physiological processes in the plant. It is indispensable for cell differentiation and for the development of the tissues, which form the growing points of the plant. Low crop production is more often due to lack of phosphorus than to the deficiency of any other nutrient, except nitrogen.

Phosphorus fertilizers are produced from phosphate rock and sulphuric acid and vary from one another in phosphorus and other nutrients content. Customarily, the phosphorus content of phosphate fertilizers is expressed as phosphoric acid or phosphoric oxide. Chemically these two terms are not synonymous, but they are both indicated by the formula P_2O_5. Phosphorus is deficient in most natural or agricultural soils or where fixation, as a result of acidity or alkalinity limits its availability. International standards governing the sale of fertilizers recognize three grades of phosphate solubility; water soluble, citrate soluble (not soluble in water) and phosphates that are only soluble in strong mineral acids such as sulphuric, nitric or hydrochloric acids. This solubility depends on largely on the chemical composition of the phosphate, but the particle size is also important, since the finer the particle size, the more soluble the fertilizers are. Almost all commercial fertilizers are essentially calcium phosphates. Water soluble form of phosphate is the most valuable from the agricultural point of view.

2.0 OBJECTIVES

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

- Describe the nature of phosphorus fertilizers.
- Differentiate among the different fertilizers containing phosphorus based on the amount of phosphorus and other nutrients in them.

3.0 MAIN CONTENT

3.1 Single superphosphate: This is a greyish-white granular fertilizer with an acid odour. It has 16 to 20% P_2O_5, additional 12% sulphur and more than 20% calcium (CaO). It is prepared from concentrated sulphuric acid and finely ground rock phosphate. Good quality phosphate rock, which is high in calcium phosphate (not less than 60%) and low and iron and aluminium are used in the production of single super phosphate. The phosphate is in water-soluble, plant-available form.

3.2 Concentrated superphosphate: This contains 42 - 45% available P_2O_5 and is manufactured from rock phosphate with higher ratio of sulphuric acid than is used in the case of single superphosphate. The phosphoric (v) acid is thus combined with more rock phosphate to produce a more concentrated superphosphate fertilizer. It contains more phosphate and no gypsum, compared to the ordinary superphosphate. The phosphate is also in water-soluble, plant-available form.

3.3 Triple superphosphate: This contains 46% P_2O_5 contains no sulphur and less calcium. The phosphate is also in water-soluble, plant-available form.

3.4 Ammonium phosphate: Mono and di-ammonium phosphate are the two important fetilizers prepared by neutralizing phosphoric (v) acid with liquid ammonia. Mono- ammonium phosphate with 21% N and 48% P_2O_5 is more common than di-ammonium phosphate (21% N and 53% P_2O_5). A substantial amount of phosphate is applied in form of NP- (nitro-, monoammonium- (MAP) and diammonium (DAP) phosphate) and NPK fertilizers.

3.5 Rock phosphate: This is the raw material used for the manufacture of superphosphate. It may contain up to 80% apatite and it is found mostly in Morocco, Algeria, USA, for USSR and middle east and smaller quantities in Togo, Senegal and west Africa, including Nigeria, in Sokoto, Ogun and some other places.

Rock phosphate is used directly as fertilizer material in most parts of the world, although its rate of release of phosphorus is slow. Therefore, it must be finely ground to react easily and readily when applied to the soil. Ground phosphate is usually effective, where there is adequate rainfall and the soil is acid, especially when applied in large amount to balance the in solubility. It may not even be applied annually. The availability of phosphorus is increased when the rock phosphate is applied with farm yard manure, which contains organic acids that facilitates the availability. About 90% of phosphorus fertilizers are rock phosphate.

4.0 CONCLUSION

Fertilizers are produced from rock phosphate and sulphuric acid and vary in their production and phosphorus content.

5.0 SUMMARY

1. Phosphorus plays a key role in the transfer of energy in plants.
2. Phosphorus fertilizers are produced from phosphate rock and sulphuric acid and vary from one another in phosphorus and other nutrients content.
3. These include; single superphosphate, concentrated superphosphate, triple superphosphate and ammonium phosphate, among others.

6.0 TUTOR MARKED ASSIGNMENT

Describe the nature and phosphorus content of phosphorus fertilizer sources using suitable examples.

7.0 REFERENCES/FURTHER READINGS

S. O. Olaitan, G. Lombin and O. C. Onazi (1988). Introduction to tropical Soil Science. Macmillan Publishers Ltd. London and Basingstoke.

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UNIT 4 COMPOSITION OF POTASSIUM FERTILIZERS SOURCES

CONTENT

1.0 INTRODUCTION

Potassium (K), which makes up 1 to 4 percent of the dry matter of the plant, has many functions. It activates more than 60 enzymes (chemical substances which govern life). Thus it plays a vital part in carbohydrate and protein synthesis. Potassium improves the water regime of the plant and increases its tolerance to drought, frost and salinity. Plants well supplied with K are also less affected by disease. Potassium fertilizers are mainly potassium chloride and potassium sulphate.

Most potassic fertilizers are materials refined from natural deposits of potassium found in various parts of the world, notably France, Germany, USA and Canada. The crude potash minerals are dissolved in water and the salts are separated by fractional distillation. All potash salts used as fertilizers are water soluble and the potassium content is considered available to plants. Unlike the nitrogenous fertilizers, most potassic fertilizers have no effect on soil pH.

2.0 OBJECTIVES

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

- State the role of potassium fertilizer sources
- State the nature and composition of potassium fertilizer sources

3.0 MAIN CONTENT

3.1 Muriate of potash (MOP)

This is a coarse or fine salt closely resembling ordinary domestic salt, but with a bitter and somewhat acid taste. Its chemical symbol is KCl. It is primarily mined as sylvinite ore containing KCl and NaCl. Milling and a floatation agent used to separate salts. It is in
different colors and sizes available. Sometimes traces of iron oxide give some particles a reddish tint. It contains 60 to 63% K_2O (50 to 52% K)

and 46%Cl. It is very soluble and quick acting and so it is best applied to the soil at planting.

3.2 Potassium sulphate

A close type of potassium fertilizer is sulphate of potash-magnesia, which a double salt carrying 25% potash and 25% of magnesium sulphate, mainly in tobacco production.

3.3 Sulphate of potash

It is a fine yellowish salt which contains 50 to 53% K2O (40-42% K). It has one important advantage over muriate of potash in that it can also supply sulphur for the crop. It has a formula of K_2SO_4 containing 48 to 53% K_2O 17 to 18% S. It is rarely found in pure form in nature and generally produced by manipulating potash ores to remove other materials. It is highly valued when both K and S are needed for plant nutrition.

4.0 CONCLUSION

Potassium fertilizer sources are mainly muriate of potash (potassium chloride) and potassium sulphate with varying poatassium and other nutrient content such as sulphur.

5.0 SUMMARY

1. Potassium improves the water regime of the plant and increases its tolerance to drought, frost and salinity.
2. Muriate of potash and potassium sulphate are the mail potassium fertilizers, containing varying potassium and other nutrient contents such as sulphur.

6.0 TUTOR MARKED ASSIGNMENT

State the role of potassium in plant growth and describe the content of the two main potassium fertilizer sources.

7.0 REFERENCES/FURTHER READINGS

FAO (2000). Fertilizers and their use. Food and Agriculture Organization of the United Nations International Fertilizer Industry Association. Rome.
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UNIT 5 COMPOSITION OF MICRONUTRIENT FERTILIZER SOURCES

CONTENT

1.0 INTRODUCTION

The micronutrients or trace elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B). They are part of the key substances in plant growth and are comparable with the vitamins in human nutrition. They are taken up in minute amounts, hence their range of optimal supply is very small. Their plant availability depends primarily on the soil reaction. Oversupply with boron can have an adverse effect on the succeeding crop.

Hence, for a number of micronutrients, there is only a small difference between the level at which deficiency occurs and the level that it becomes toxic to plants. Therefore, it is important that micronutrients should only be applied when they are certainly deficient and that the application should be carefully controlled. Sometimes chelates facilitate the supply of micronutrients to plants.

2.0 OBJECTIVES

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

- State the nature and role of micronutrient fertilizers.
- State the causes of micronutrient deficiencies and describe the forms of micronutrient fertilizer sources.
- Describe chelates and their role in the supply of micronutrients to plants.

3.0 MAIN CONTENT

3.1 Requirements and nature of micronutrient fertilizer sources

Micronutrients require special attention and care because there is a narrow margin between excess and deficiency in the microelement needs of the plants. Since They are needed only in small amounts, if too much of a given microelement (e.g. boron) is applied, it may have a harmful effect on the crop and/or the succeeding crop. Special compound fertilizers can be prepared containing micronutrients along with the NPK grades for soils and crops where deficiencies are known to exist.

3.2 Causes micronutrient deficiencies in plants and forms of micronutrient fertilizer sources

Microelement deficiencies are usually caused through a soil pH which is too low (acid), or more often, through a soil pH which is too high (neutral to alkaline), thus a change in soil pH may make microelements plant-available. A more exact rate of application and usually also a greater efficiency are made possible through the use of spray or seed treatments with micronutrients (formulated as powders or liquids). Complex organic compounds of iron, zinc, manganese and copper chelates - will significantly increase the efficiency of the applied micronutrients, particularly that of iron, which is hardly taken up in non-chelated form.

Table 1 shows micronutrient salts commonly used as fertilizers. Some of these are incorporated into macronutrient fertilizers. Even though, this goes with disadvantage that the amount of micronutrient depends on the amount of the macronutrient fertilizer applied. Sometimes the trace elements are applied as solutions in water, to which wettable powders are being added, which is more preferable.

3.3 Chelates

Chelates are complex organic compounds that can be used to correct trace or micronutrient elements deficiencies because they will become attached to certain cations such as iron, copper, manganese and zinc. Chelates are applied directly to the soil or as foliar sprays. Plants absorb chelates along with any cation to which they are attached.

4.0 CONCLUSION

Spray or seed treatments with micronutrients (formulated as powders or liquids) and Complex organic compounds of iron, zinc, manganese and copper chelates are used as micronutrient fertilizer sources.

5.0 SUMMARY

1. Micronutrients are part of the key substances in plant growth and are comparable with the vitamins in human nutrition.
2. Micronutrients require special attention and care because there is a narrow margin between excess and deficiency.
3. Spray or seed treatments with micronutrients, formulated as powders or liquids are used as micronutrient fertilizer sources.
4. Complex organic compounds of iron, zinc, manganese and copper chelates are also used as micronutrient fertilizer sources.

6.0 TUTOR MARKED ASSIGNMENT

State the cause for micronutrient fertilizers need and describe the sources of micronutrients usually applied to crops

7.0 REFERENCES/FURTHER READINGS

S. O. Olaitan, G. Lombin and O. C. Onazi (1988). Introduction to tropical Soil Science. Macmillan Publishers Ltd. London and Basingstoke.

FAO (2000). Fertilizers and their use. Food and Agriculture Organization of the United Nations International Fertilizer Industry Association. Rome.
Table 1. Salts of micronutrients commonly used in fertilizers

S/No.	Compound	Formula	Nutrient content
1.	Copper sulphate	$CuSO_4$	25 - 35% Cu
2.	Basic copper sulphate	$CuSO_4.Cu(OH)_2$	13 - 53% Cu
3.	Copper carbonate (basic)	$CuCO_3.Cu(OH)_2$	57% Cu
4.	Zinc sulphate	$ZnSO_4$	23 - 35% Zn
5.	Zinc sulphate (basic)	$ZnSO_4.4Zn(OH)_2$	55% Zn
6.	Manganese sulphate	$MnSO_4$	23% Mn
7.	Manganese sulphate (basic)	$2MnSO_4.MnO$	40 - 49% Mn
8.	Sodium borate	$Na_2B_4O_7$	34 - 44% B_2O_3
9.	Ferrous(II) sulphate	$FeSO_4$	20% Fe
10.	Ferrous (III) sulphate	$Fe_2(SO_4)_3$	17% Fe
11.	Sodium molybdate	$NaMoO_4$	37 - 39% Mo

MODULE 3

UNIT 1 FERTILIZER CONTENT CALCULATIONS

CONTENT

1.0 INTRODUCTION

Fertilizers are any natural or manufactured materials, which contain at least 5% of one or more of the primary nutrients (N, P_2O_5 or K_2O). Industrially manufactured fertilizers are called mineral fertilizers. Fertilizers that contain only one nutrient are called straight or simple fertilizers. Those containing two or more nutrients are called multinutrient fertilizers. Examples of some straight fertilizers are: urea (46% N), ammonium sulphates (21% N), calcium ammonium nitrate (27% N). Others include: single super phosphates (16 to 18% P_2O_5), triple super phosphates (46% P_2O_5), Muriate of Potash (60% K_2O). Examples of multinutrient fertilizers are NPK 15:15:15, NPK 20:10:10 etc.
Generally, there are three distinct types of multinutrient fertilizers

- **Complex fertilizers**: manufactured through processes involving a chemical reaction between the constituents containing the primary plant nutrients.
- **Compound fertilizers**: granulated straight fertilizers or intermediates, the granules containing the nutrients in varying ratios.
- **Mixed fertilizers or blends**: simple mechanical mixtures of straight fertilizers

2.0 OBJECTIVES

- To know different types of fertilizers formulations.
- To know how to calculate fertilizer amount involving single fertilizers.
- To know how to calculate fertilizer amount involving multinutrient

fertilizers.

3.0 MAIN CONTENT

3.1 Calculating fertilizer rates

In calculating the exact amount of nutrient in fertilizers, the followings are necessary information.

1. Know the recommended rates.
2. Area to be fertilized.
3. Guaranteed analysis.
4. Calculate the amount of fertilizers needed to supply the nutrient in 1 above.
5. If fertilizer is compound or mixed, find out of how much of the other nutrients have also been supplied
6. If the quantity supplied by the compound has not met the specified recommended rate, make up with straight fertilizers by employing steps 1 and 2 above.

3.2 Calculation involving single or straight fertilizers

Here, the amount of each nutrient source can be calculated to satisfy the recommended application rate. The following relationship is used to calculate amount of fertilizer to be applied.
A = (R x 100) / C
Where A = fertilizer material required (kg/ha) R = recommended rate (kg/ha)
C = Guaranteed analysis (%)
If area is specified, the relationship becomes A = (R x 100 x area) / C x ha
Where ha = hectare = 10000m^2

Example 1:

1. Calculate the amount of urea (46% N) required to fertilize a hectare of land if the recommended rate is 60 kg /ha.

Solution:
A = (R x 100) / C. A= ?
R = 60 kg/ha C = 46%
Therefore, A = (60 x100)/ 46 = 130.43 kg urea. To convert this to bags, divide by 50
= 130.43/50 = 2.61 bags of urea.
In the example 1 above, if the area given is less than a hectare, e.g. 2500m^2, the amount will be:
A = (R x 100 x area) / C x ha.

A= (60 x 100 x 2500)/ 46 x 10000
A= 32.61 kg urea
In a bag, it will be 32.61/50 = 0.65 bags.

Example 2:

Calculate the amount of urea (46%), single superphosphate (18% P_2O_5) and muriate of potash (60% K2O) to meet the recommended rate of 80 N – 30 P_2O_5 – 30 K_2O.

Solution:

Using the formula:

A = (R x 100)/C,

Urea = (80 x 100) / 46 = 173 kg / ha = 173/50 = 3.46 bags of urea
SSP = (30 x 100) / 18 = 166.67 kg / ha = 166.67/50 = 3.33 bags of SSP
MOP = (30 x 100) / 60 = 50 kg / ha = 50/50 = 1 bag of MOP.

These fertilizers can then be applied separately or mixed to produce multinutrient fertilizer or blends. It should be noted however, not all fertilizers are can be mixed together. Fertilizers that are mixed together must be compatible both chemically and physically. When for example, fertilizers containing ammonia are mixed with rock phosphate or lime, evaporation losses of ammonia occur. Similarly, water soluble phosphate fertilizers (SSP and TSP) should not be mixed with fertilizers containing calcium (e.g. Calcium nitrate) since the calcium will revert the water soluble phosphates into insoluble forms. As a general rule, mixtures and blends should be be spread as soon as possible after mixing to avoid hygroscopicity.

3.2 Calculation involving multinutrient fertilizers Example 3:
Given that an application rate of 120 – 60 – 60 kg/ha, how can you use both single and multinutrient to achieve this.

Solution:

A fertilizer grade like 15:15:15 and urea (46%) can be used to achieve the application rate. The recommended rate shows that less amount of P and K are required. They should therefore be calculated first. Using the formula:

A = (R x 100)/ C,

To meet the need for P and K, we need

A = (60 x 100)/15 = 400 kg 15:15:15.
Now, how much N has 400 kg of 15:15:15 supplied? Using the same formula: A = (R x 100)/ C,
A = 400kg R =?
C = 15%.
Therefore, 400 = (R x 100)/15.
R = (400 x 15)/100 = 60kg N from the 15:15:15.
A simple fertilizer like urea is needed to supply the balance. Hence A = (60 x 100)/46 = 130.43 kg urea.

4.0 CONCLUSION

In calculating fertilizer rates, the type of fertilizer should be considered i.e. whether the fertilizer is single or multinutrient fertilizer. What is very important is the recommendation. Also when multinutrient fertilizers are used, the recommendation has to be checked to know how much nutrient the multinutrient fertilizer supplied and how much of the single should be applied to supplant the required amount. Care should be taken when making fertilizer blends because some fertilizers are not compatible with another chemically or physically. Failure to do so may lead to loss of nutrient from the when blends are made.

5.0 SUMMARY

At end of this unit, we learnt that:
1. Fertilizers are manufactured either as single or multinutrient
2. The multinutrient fertilizers can be complex, compound or mixed/blends.
3. Some fertilizer blends are not compatible with one another
4. A very useful relationship for calculating amount required to applied is given by A = (R x 100)/ C.

6.0 TUTOR MARKED ASSESEMENT

Calculate the amount of urea (46% N), SSP (18% P_2O_5) and MOP (60% K_2O) to be applied in a rice field with a hydro dimension of 100 m x 25 m if the recommended rate is 100 kg N, 40 kg P_2O_5 and 30 kg K_2O per hectare

Answer = 54.35 kg urea, 55.56 kg SSP and 12.5 MOP.

7.0 REFERENCES / FURTHER REEDING

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UNIT 2 FACTORS EFFECTING FERTILIZER USE

CONTENT

1.0 INTODUCTION

Many factors affect the use of fertilizers. These include the crops to which the fertilizers will be applied in terms of the type and amount of the fertilizer the crop may require. The soil in which the plants grow also effect the fertilizers applied to them positively or otherwise. The climate of the area also determines the time of application, reaction of the fertilizer. Humid regions and dry regions determine the formulation and application time and rate of a fertilizer. The economic condition of the farmer also tells the type and amount of the fertilizer he or she afford. The manage practices earlier imposed to the field and the current management practices also determine fertilizer applications. The type of fertilizer determines the method of application. For instance, nitrogen fertilizers are applied in split because of their tendencies to be loss through various processes such as volatilization and leaching, while potassium and phosphorus fertilizers are applied as a single dose. These shall be explained in detail in this module.

2.0 OBJECTIVES

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

- State the factors effecting fertilizer use
- Describe how crop factors effect fertilizer use
- Describe how soil factors effect fertilizer use
- Describe how climatic factors effect fertilizer use
- Describe how economic factors effect fertilizer use
- Describe how management factors effect fertilizer use

3.0 MAIN CONTENT

3.1 Crop factors

Fertilizer application cannot be productive unless the crop can respond to it. Certain crops need higher amount of particular nutrients than others. Legumes for instance require large amounts of phosphorus whereas cereals require proportionately more nitrogen. More recently developed varieties also have higher doses of fertilizers to meet their yield potential, which usually higher yield than the previously developed varieties or have special ability to stand certain conditions or produce special product.

3.2 Soil factors

The ability of soils to supply plant nutrients differs significantly from one place to another and from time to time. Physical properties of the soil such as depth, texture, and structure, contribute to its response to fertilizers and subsequent productivity. Similarly soil chemical properties such as cation exchange capacity (CEC) determines the rate at which soils retain fertilizers for supply to plants, those with high CEC retains more nutrients, while those with low CEC easily leads to loss of nutrients applied. Other chemical properties such as pH determines the availability of nutrients, at high and low Ph values, soil nutrient are usually not available. Hence each soil has its inherent production potential, based on its properties. Heavy application of fertilizer can be profitable in soil with high productive potential, but which are low in fertility.

3.3 Climatic factors

Soils in low rainfall areas loss only little fertilizer through leaching so their inherent fertility level is relatively high. However, if only limited amount of water is available, there is no justification for raising fertility levels high. Soils of humid regions often loss most of their available nutrients through leaching and weathering. The water supply is adequate for high crop production but nutrient supplies are inadequate. Hence, fertilizer application is highly profitable.

3.4 Economic factors

The use of fertilizer is increased by low prizes and decreased by high prices. Crop prices have the opposite effect, because the high price of the crop will give a profitable return for high rates of fertilizer application. However, increase in crop yield with increase in fertilizer application follows the law of diminishing returns. Application a small amount of essential fertilizers results in the greatest return per kilogram of fertilizer applied. Additional application of fertilizer yields progressively lower increases in yield. Eventually, a point is reached, where an increase in the amount of fertilizers, only increases yield enough to pay for the cost of the extra fertilizer.

3.5 Management factors

Increased crop output usually requires increased fertilizer inputs. High yields depend on many factors and a good manager learns how to control or adjust as many of these factors as possible. These factors include, soil type, climate, present and past crop type, crop variety grown, cropping history, present and past fertilizer applications, and soil amendments, tillage practices, weed control and the timing of operations.

4.0 CONCLUSION

Fertilizers are only good for reducing soil fertility problems. Adding more fetilizers will bring little or not increase in production when other factors such as crop, soil, climate, economy and management are limiting.

5.0 SUMMARY

1. Many factors affect the use of fertilizers.
2. Fertilizer application cannot be productive unless the crop can respond, since certain crops need higher amount of particular nutrients than others.
3. The ability of soils to supply plant nutrients differ significantly from one place to another and from time to time such as physical properties of the soil such as depth, texture, and structure and chemical properties such as CEC and pH.
4. Soils in low rainfall areas loss only little fertilizer through leaching so their inherent fertility level is relatively high while soils of humid regions easily loss nutrient through leaching and other processes.
5. The use of fertilizer is increased by low prizes and decreased by high prices, while continuous increase fertilizer application makes it unprofitatable.
6. Control of such as soil type, climate, present and past crop type, crop variety grown, cropping history, present and past fertilizer applications, and soil amendments, tillage practices, weed control and the timing of operations determines profitability of fertilizer application.

6.0 TUTOR MARKED ASSIGNMENTS

Explain the factors determining the use of fertilizers.

7.0 REFERENCES/FURTHER READING

S. O. Olaitan, G. Lombin and O. C. Onazi (1988). Introduction to tropical Soil Science. Macmillan Publishers Ltd. London and Basingstoke.

UNIT 3 METHODS OF FERTILIZER APPLICATION

CONTENT

CONTENT

1.0 INTRODUCTION

The amount and timing of nutrient uptake depend on various factors including variety, planting date crop rotation, soil and weather condition. Timing and quantity should be chosen in such away that as much as possible of the nutrients is used by plant. Nutrient should be applied, as near to the time the crop needs them to ensure optimum crop use efficiency and to minimize the potential of environmental pollution. This is particularly important for mobile nutrient such as nitrogen, which can leach out of the soil profile if not taken by roots.

Once the choice of fertilizers has been made and the amount determined for a given crop, there remain the important problems of determining how and when the job should be done to obtain the best yields. This is particularly important when a limited supply of fertilizers is to be used to obtain optimum increases in crop yields. The selection of the best method of fertilizer application depends on a number of factors, notably the kind of soil, its moisture status, its fixing power for the different nutrients, previous management, the crop to be treated, its root development and the ability to extract nutrients in the soil as well as the kind and amount of fertilizer to be used.

2.0 OBJECTIVES

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

- Describe the timing of fertilizer application.
- State the different type of application methods.
- Describe the impact of fertilizer application on environment.

3.0 MAIN CONTENT

3.1 Broadcasting

The main objectives in broadcasting are to distribute the fertilizer evenly and to incorporate it with part of, or throughout the plough layer. Broadcasting is also employed when applying large quantities of fertilizers that can be easily applied at the time of planting. In broadcasting, the fertilizer is spread over the entire soil areas to be treated, either before the land is ploughed, immediately before planting or while the crop is growing. The latter is usually referred to as side dressing if the crop is in wide rows, and as top-dressing if the crop is in narrow rows or not in rows. Delayed applications of nitrogen are made, commonly as top-dressing; top dressing of P and K are ordinarily made only on pasture that occupy the land for several years.

3.2 Placement

Placement refers to applying fertilizers into the soil, but with special reference to the location of the seed or plant. When the fertilizer is placed close to the seed or plant the application is said to be localized. The placement of solid fertilizers can be done with the help of simple implement (e.g. ploughs) and such hand-tools as hoes. Hill or row placement refers to applying the fertilizers either in bands or localized areas near the plants or along the planted row, but often in a definite space relationship to the seed or plant. This method allows for a greater availability of nutrients by reducing losses of P and K through fixation than when fertilizers are mixed with the soil. The greatest hazard of placing fertilizers near the seed is that germination may sometime be hindered or the young plant damaged by an excessive concentration of soluble salts, if the materials are put too close to the seed or plant. Such injury is greatest in dry sandy soils.

3.3 Fertilizing Tree Crops/Plants

The method of fertilizer application to tree plants is often a compromise between broadcasting and localized placement. Often, the fertilizer is broadcast under the tree to a distance of 30 - 60cm beyond the spread of the branches. On the other hand, when a cover or green manure crop is grown between the trees, a large part of the fertilizer may be applied to this crop. In forest zones and on very sandy soils the fertilizer application may be repeated several times during the season.

3.4 Foliar Application of Fertilizer

Liquid fertilizer is applied direct to the foliage of a crop for maximum utilization. This is often advantageous when the soil contains insufficient moisture or when its physical and chemical conditions are otherwise unfavorable. This method is useful in correcting micronutrient deficiencies in tree or orchards, and arable crops.

3.5 Fertilizers and the Environment

Fertilizers are agro-chemicals. When applied appropriately and in the correct dosage, fertilizers, by enhancing vegetative growth in plants, keep the environment healthy. Leaf canopy protects the soil from the direct impact of raindrops, which could result in soil erosion. The life of microorganisms living beneath the soil and animals is protected. During eutrophication, fertilizer elements are eroded into the rivers and lakes for the nutrition of aquatic life. The ecosystem is maintained and biodiversity rejuvenated.

4.0 CONCLUSION

Generally, the methods used for applying fertilizers may be grouped into two: broadcasting and placement. Broadcasting distributes the fertilizer evenly but this may lead to fixation of some important nutrients such as P and K. The placement method on the other hand ensures more availability of nutrients by reducing losses of P and K through fixation. However, care must be taken in placing the fertilizer near seeds or seedlings as it can affect germination or burn already existing plants.

5.0 SUMMARY

1. Amount and timing are paramount when applying fertilizers
2. Methods of application of fertilizers are generally categorized in two groups: broadcasting and placements
3. Broadcasting is employed when large quantity of fertilizer is to be applied at planting. It ensures equal distribution of nutrients but can lead to fixation of some important nutrients.
4. Placement application of nutrients at a specified location. It ensures greater nutrient availability but can be detrimental to seed germination or burn the young seedlings when improperly placed.
5. Other method of application includes folia application, which is useful in correcting micronutrient deficiency.
6. Fertilizer application has great impact on environment.

6.0 TUTOR MARKED ASSESSMENT

Explain the various methods of fertilizer application. What are the consequences of employing each method?

7.0 REFERENCES / FURTHER READING

Chude, V.O., Olayiwola, S.O., Osho, A.O. and Daudu, C.K. (2012). Fertilizer use and management practices for crops in Nigeria. pp. 230.

UNIT 4 PHOSPHORUS FERTILIZER PRODUCTION AND USE CONTENT

CONTENT

1.0 INTRODUCTION

Phosphorus (P) is a primary nutrient elements and very essential for plant nutrition. It is usually taken up mostly as phosphate ions ($H_2PO_4^-$ and HPO_4^{2-}). Other importance of P includes: involvement in photosynthesis, energy transfer, cell division and enlargement. It is also very important in root formation and growth, improves the quality of fruit and vegetable crops, vital to seed formation, improves water use and helps in hastening maturity of crop.

Phosphorus plays vital role as an essential nutrient for animal nutrition: It is a major component of bones and teeth; It is important for lactating animals; P and Ca are closely associated in animal nutrition; it is essential for energy transfer and utilization.
Historically, early sources P were mostly animal based bones, guano and manure. Treatment of bones with acid to increase P solubility started early in mid 1800s. Sulfuric acid treatment process of bones and P mineral (apatite) was patented in mid 1800s. Today most P fertilizer production is based on the acidification of apatite from phosphate rock (PR).

2.0 OBJECTIVES

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

- State the sources of phosphorus fertilizers
- To have an insight on the technology of P fertilizer production
- To know the various P fertilizer– sources
- To know action of P fertilizers in soil

3.0 MAIN CONTENT

3.1 Production of P fertilizers

3.1.1 Mining of Phosphate rock

Phosphate rock is the primary raw material for fertilizer and phosphoric acid, which occurs as high-grade ore (+30% P_2O_5), medium-grade ore (20%–30% P_2O_5), and low- grade ore (15%–20% P_2O_5). The very high-grade ore blends with medium-grade ore for direct sale. The high-grade ore is mined, crushed, and sold to various fertilizer plants.
Most phosphate rock is extracted through open pit mining techniques such as draglines, bucket wheel excavators and front-end loader removal. The surface mining is the most utilized method by far for mining phosphate deposits. In high-volume applications, the surface mining methods are typically less costly and are generally the preferred methods when the deposit geometry and other factors are favorable (Sung *et al*., 2013).

3.1.2 Beneficiation

Beneficiation is the second step in the mining process, after removal of the ore from the ground. Beneficiation is the technical term used in describing the industrial process of mechanically separating minerals from each other. No chemical changes to the minerals are made at this point in the mining process.

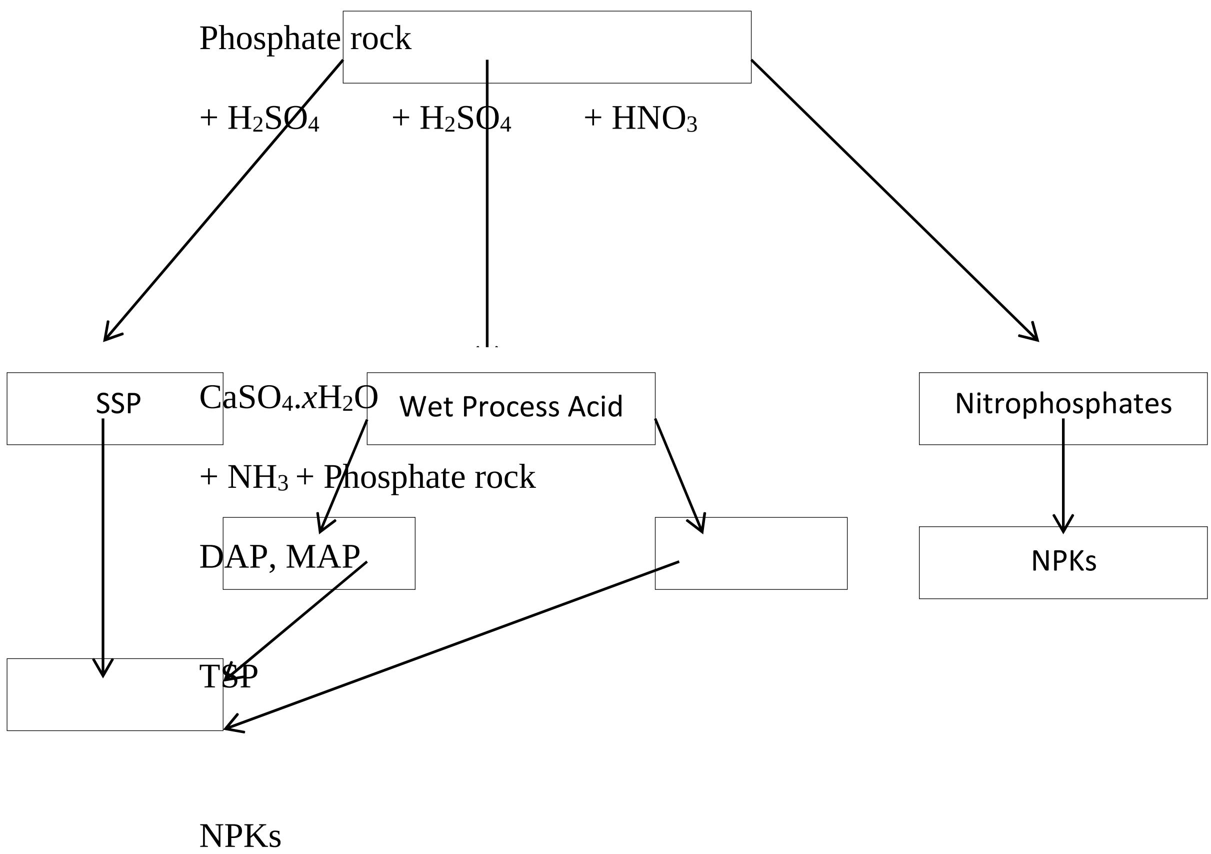
The very first unit operation in the beneficiation process is to disaggregate the various particles. This actually starts while the matrix is flowing through the multi-mile pipeline from the mine to the beneficiation plant. While in the pipeline, the matrix is exposed to shear forces as it passes through the various centrifugal pumps along the pipeline. These intense shear forces cause a significant percentage of the sand and phosphate particles to be liberated from the clay-balls by the time they arrive at the plant. Once reaching the plant, the first goal is to finish disaggregating the clay and follow that by making a size separation at 1 mm. This processing is conducted in the **"washer"**.

The next objective is to remove the clays. To reject the clay, all that is required is to size at 0.1 mm and discard the fine fraction. The beneficiation plant does this with equipment called **"hydro-cyclones"**. Coarse sand and phosphate particles swirl to the bottom of the cyclone and exit. The fine clays are collected and pumped to large impoundment. The next step is **"flotation"** which is a separation process that is used in mineral beneficiation plants around the world. Flotation separates valuable minerals (copper, lead, zinc, iron, and phosphate too) from the contaminating minerals in the ore (sand in this case). In the direct flotation process the valuable mineral is coated with a special hydrocarbon (fatty acid) that makes coated particles behave the same as a waxed car. Once the phosphate surfaces are coated, they repel water just like a freshly waxed car during a rainstorm. The slurry of waxed-phosphate and un-waxed sand is diluted and put in agitated tanks. Tiny air bubbles are injected into the tanks (called flotation cells),

which attach to the waxed phosphate. The air bubbles rise with the phosphate to the top of the flotation cell where the valuable froth is skimmed from the surface and collected.

In order to upgrade the initial phosphate, concentrate to a saleable product, a second cleaning flotation process is used to remove the last of the residual sand. The original hydrocarbons are stripped from the phosphate surfaces and then a different hydrocarbon is applied to the concentrate. This second hydrocarbon is an amine-based reagent that coats sand, but not phosphate. Once again, the slurry is fed into flotation cells, agitated and exposed to tiny air bubbles. The air carries the remaining sand to the surface where it is skimmed off and discarded. The remaining phosphate mineral ("concentrate") is collected, blended with the pebble product and shipped via rail or truck to the chemical plant for the third step in making phosphate fertilizer.

A Simplified Flowchart of granular P production



3. 2 Phosphorus fertilizers and Soil

- Common commercial P fertilizers are highly (≥90%) water soluble
- Once dissolved in soils, orthophosphate is available for plant uptake
- Poly phosphates in APP must be converted to orthophosphates for plant uptake
- Conversion or hydrolysis of poly to ortho in soils happens readily and does not affect nutritional value
- Phosphorus chemistry in soils is complex, P may become sparingly available to plants in some soils due to formation of less soluble products

4.0 CONCLUSION

Phosphorus is essential for plant production and plays a vital role as an essential nutrient for animal nutrition. Phosphate rock is the primary source of P fertilizers, which is extracted through surface mining and is the most utilized method by far for mining phosphate deposits.

5.0 SUMMARY

1. Phosphorus is essential for healthy plants and animals
2. Most P fertilizer comes from reacting Phosphate rock with sulphuric, phosphoric or nitric acids
3. The industrial process of mechanically separating minerals from each other is called Beneficiation
4. Many excellent granular, liquid and suspension P fertilizers are available for specific needs
5. Most P fertilizers are water-soluble and easily dissolve in soil.

6.0 TUTOR MARKED ASSESSMENT

Outline the procedure involved in beneficiation of phosphate rock. List the various P fertilizer sources you learnt.

7.0 REFERENCES / FURTHER READING

Sung, W.P., Kao, J.C.M. and Chen R. (2013). Environment, Energy and Sustainable Development. CRC Press, ISBN: 978-0203799017.

Chien, S.H., Prochnow, L.I. and Cantarella, H. (2009). Recent Developments of Fertilizer Production and Use to Improve Nutrient Efficiency and Minimize Environmental Impacts. *Advances in Agronomy*, 102: 279 – 322.

UNIT 5 POTASSIUM FERTILIZER PRODUCTION AND USE

CONTENT

1.0 INTRODUCTION

Potassium ions are an essential component of plant nutrition and are found in most soil types (Greenwood and Earnshow, 1997). Fertilizers consume 95% of global potassium chemical production and about 90% of this potassium is supplied as KCl. In 2005, about 93% of world potassium production was consumed by the fertilizer industry (Ober, 2008). Furthermore, potassium can play a key role in nutrient cycling by controlling litter composition (Roy, 2007).

Potassium is essential for plants taken as K^+. It does not form organic compounds in the plant but is vital to photosynthesis and proteinsynthesis. It is associated with many metabolic functions and plays essential role in regulating leaf stomata and controlling water use.

Potassium also involve in animal nutrition by being essential for many metabolic functions including maintenance of salt balance between cells and body fluids. Adequate K is essential for nerve function and preventing muscle cramps. Potassium is routinely added to many animal feeds. Since K^+ is not stored in the human body, dietary replacement is required on a regular basis. Government agencies state that: *"diets containing foods that are good sources of potassium and low in sodium may reduce the risk of high blood pressure and stroke".*

2.0 OBJECTIVES

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

- State the sources of Potassium fertilizers
- Describe the technology of K fertilizer Manufacturing
- Describe the various K fertilizer sources

3.0 MAIN CONTENT

3.1 Manufacture of K Fertilizers

Potassium bearing minerals are mined from underground ore deposits, salt lakes and brines. Then, the ore must be beneficiated and purified using dry and slurry processes. The majority of mined KCl is used for obtaining various grade fertilizers based on the particle size (granular, standard, fine, soluble). Granular KCl is often applied in mixtures with other N and P based fertilizers to provide, in one application, the nutrients required by the crops.

Another potassium fertilizer is potassium sulfate, which is frequently used for crops where additional chloride from more common KCl fertilizer is undesirable. Potassium sulfate can be extracted from the mineral langbeinite or it can be synthetized by treating potassium chloride with sulfuric acid at high temperature. By adding magnesium salts to potassium sulfate, a granular potassium-magnesium compound fertilizer can also be produced.

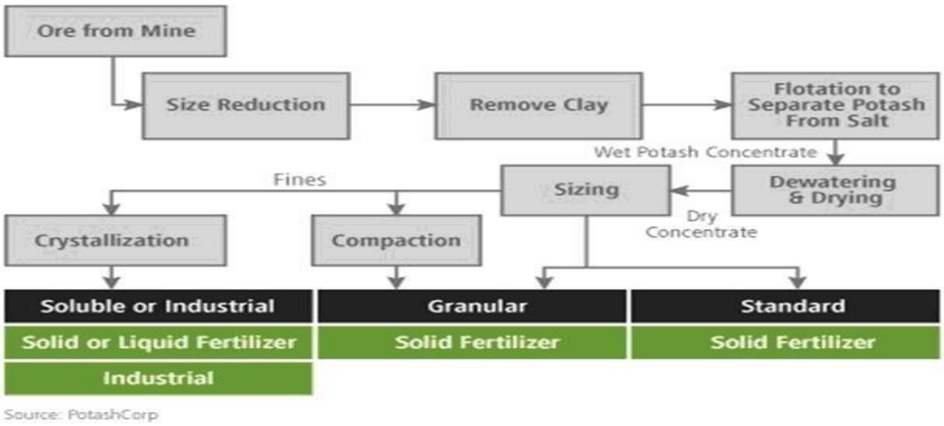
3.2 K fertilizers and Soil

Once in the soil, soluble potassium is either taken up by plants or adsorbed on the soil colloidal complex or lost through leaching. Leaching of potassium is quite a serious problem in the humid tropics.

All are manufactured from basic potash materials.

4.0 CONCLUSION

Potassium deposits are found deep beneath earth surface and therefore its recovery requires complex and expensive mining techniques. However, some quantities are found in water bodies such as Dead Sea and Great Salt Lake through the process of evaporation of brine.



Schematic presentation of K fertilizer production.

5.0 SUMMARY

1. Potassium is essential for healthy plants and animals
2. Most K fertilizers are found in deep down the earth.
3. Also K fertilizers can be found in water bodies
4. Excavation requires complex and expensive equipment

6.0 TUTOR MARKED ASSESSMENT

Give characteristics of different sources of K fertilizers.

7.0 REFERENCES / FURTHER READING

Chien, S.H., Prochnow, L.I. and Cantarella, H. (2009). Recent Developments of Fertilizer Production and Use to Improve Nutrient Efficiency and Minimize Environmental Impacts. *Advances in Agronomy*, 102: 279 – 322.

Greenwood, N.N., Earnshaw, A. (1997). Chemistry of the Elements (2nd ed.). Butterworth-Heinemann. ISBN 978-0-08-037941-8.

Ober, J.A. (2008). "Mineral Commodity Summaries 2008:Potash".United States Geological Survey. Retrieved 2008-11-20.

Roy, A.H. (2007). Kent and Riegel's handbook of industrial chemistry and biotechnology. Springer. pp. 1135–57.

UNIT 6 CHEMICAL AND PHYSICAL PROPERTIES OF FERTILZERS

CONTENT

1.0 INTRODUCTION

The chemical quality of fertilizers is almost a self-evident fact and strictly defined by agreements. On the other hand, the physical quality is less well defined i.e. without either agreement on methods or information on figures. Chemical properties usually focus on release nutrients into the soil, but the physical characteristics of are almost as important as the nutrient content. They determine how easily and uniformly the fertilizer spreads during application. Fertilizers with poor physical properties form lumps or dust, flow badly, accumulate too much water or become segregated.

Fertilizer analyses are done to ensure guaranteed or declared analysis, which may be changed or be altered by chemical reactions under poor storage conditions, errors in manufacturing or deliberate adulteration by unscrupulous dealers. Analysis is also done to ensure that there are no health or environmental hazards (e.g. to avoid excesses of Zn and Cu or avoid contamination with the toxic heavy metal such as Cd, Pb, Ar etc. from the use of town wastes or, less importantly, from P fertilizers). Furthermore, crops are poor indicators for the presence of excessive contents of predominately toxic substances. Crops are more tolerant of high levels of toxic substances than a low level in the food chain would allow.

Analyses of fertilizers are also important to address the concerns arising from the various limitations in organic fertilizers. Standards for organic fertilizers are not as simple as for inorganic fertilizers because the quality of organic fertilizers varies depending on the source of materials and process of decomposition.

2.0 OBJECTIVES

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

- Describe the chemical and physical properties of fertilizer
- Determine the quality of fertilizer
- Ascertain the guaranteed or declared analysis is correct.

3.0 MAIN CONTENT

3.1 Chemical properties

The chemical properties as mentioned earlier in the introduction section, is self-evident fact and strictly defined by agreement. It focuses on the release of nutrient sin the soil, nutrient content and solubility (availability to plants), compatibility of blending straight fertilizers based on considerations of safety (e.g. chemical reaction causing release of toxic gases), production problems (e.g. liquid formation, state of stickiness, corrosive mix due to free acidity) and/or quality aspects (e.g. high tendency for caking). The nutrient content is most valuable parameter measured and is usually done through laboratory analysis.

3.2 Physical properties

The physical properties seek to address the physical qualities of fertilizers. The parameters that usually affect the quality of fertilizer include: caking, dustiness, granular size distribution, granular strength, abrasion resistance, even spreading, hygroscopicity, bulk volume and granular roundness. Mostly, the physical characteristics of fertilizer involve the following:

3.2.1 Particle Size

This is measurement of particle size. Particles in a particular fertilizer have a range of different diameters, which is the particle size distribution. Smaller particles dissolve in water faster are quick in releasing nutrients. Particle size also affects application and storage of the fertilizer.

3.2.2 Density

This measures the weight of fertilizer in relation to its volume. It depends on how closely packed the particles are. A low-density fertilizer will take up more space than the same weight of a high-density one. This has implications for storage and is important when calibrating machinery.

3.2.3 Granule Hardness

Fertilizer particles need to be hard enough to withstand the pressures of handling and storing them depend on the chemical composition and other physical properties (shape and moisture content). Determining the granular hardness is also important to cope with crushing forces, abrasion and impacts (such as hitting a hard surface during spreading). Hard particles also make fertilizers less dusty.

3.2.4 Moisture Content

Most fertilizers absorb water to a certain extent. Moisture absorption depends on the chemical composition of the fertilizer, environmental conditions and the shape and size of the particles. Granules with larger surface areas absorb relatively more water and too much water can be problematic. Critical relative humidity (CRH) is the level of humidity required for the fertilizer to absorb water above which the material absorbs moisture and below which it does not. CRH is the value of the relative humidity of the surrounding air measured at 30˚C. Fertilizers with high CRH values can be handled and stored in wetter environments. If the CRH is too low, fertilizer can clump together and be difficult to spread, need to be stored more carefully to prevent it from getting wet.

4.0 CONCLUSION

In order to have fertilizers in good condition for safe application, both physical and chemical properties need to be good. Properties such as the nutrient content, compatibility, granular strength, abrasion resistance, hygroscopicity etc. should be observed before declaring fertilizer safe for application.

5.0 SUMMARY

1. The chemical quality of fertilizers is almost a self-evident fact and strictly defined by agreements.
2. The physical quality is less well defined i.e. without either agreement on methods or information on figures.
3. Chemical property focuses on the release of nutrients in the soil, nutrient content, solubility and compatibility of blending straight fertilizers.
4. The physical properties seek to address the physical qualities of fertilizers.

6.0 TUTOR MARKED ASSESSMENT

Describe the physical attributes of fertilizer.

7.0 REFERENCES / FURTHER READING

Chien, S.H., Prochnow, L.I. and Cantarella, H. (2009). Recent Developments of Fertilizer
Production and Use to Improve Nutrient Efficiency and Minimize Environmental Impacts. *Advances in Agronomy*, 102: 279 – 322.