COURSE
GUIDE

SLM 305
INTRODUCTORY SOIL CHEMISTRY, FERTILITY AND MICROBIOLOGY

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INTRODUCTION

Welcome to *Introductory Soil Chemistry, Fertility and Microbiology (SLM 305)*. This is one semester course of three credits. It is designed for students in agricultural sciences. This course has 22 study units which covers the basic rudiments of soil chemistry, fertility and microbiology. The course deals with the meaning and explanation of the basic principles of soil chemistry, fertility and microbiology. Explanations were also given on the basic concepts of these fields of soil science. The course focused on: soil phases; cation exchange capacity and base saturation; soil acidity and liming; nutrient movement in soils; nutrient uptake mechanisms; chemistry, status and availability of essential nutrients in soils. Microorganisms in soil-kinds, number and activities; role of microorganisms in plant growth; the dynamic nitrogen and phosphorus pools; organic matter-sources, transformation and functions in soil.

Being an introductory class, the pre-requisite of this course is *SLM 201 (Principles of Soil Science)*. This course deals with the introduction into soil chemistry, fertility and microbiology as a discipline and its relationship with other fields of science. Attempt is also made to define and explain some terms in soil chemistry, fertility and microbiology. This course material is equipped with worked examples and tutor-marked assignment. Also, it is designed to give you a brief description of the content of the course, the work to be done and the materials that you need. There is also a list of relevant textbooks that could be consulted by you for further learning.

It has been my experience over the years that students who do the exercises in the tutorials are prepared for the tests and the examination and achieved a pass mark. Experiences have also shown that many students who enrolled for the course pass it with distinction. On more than one occasion there has been a student who obtained a final mark in excess of 90%.
The message: work hard from the start and persevere! I trust that you will enjoy the course and will find it interesting and informative.

WHAT YOU WILL LEARN IN THIS COURSE

The overall aim of this course is to introduce you to the basic concepts of soil chemistry, soil fertility and soil microbiology. In this course, you will:

- Learn the fundamental principles of the chemistry of soil (that is, nature of chemicals and reactions going on in the soil).

- Learn how different soils have varying nutrient supplying power depending on the amount of total reserves, on mobilisation and accessibility of the chemically available nutrients to plants (that is nutrient movement in the soils).
- Learn the essentiality of nutrients in soil, their status and availability.
- Be familiar with the microorganisms in the soil and their role in plant growth and the soil environment.
- Learn soil organic matter transformation and the dynamics of N and P pools in soil.

COURSE AIM

The purpose of the course is to take you through the basic principles in soil chemistry, fertility and soil microbiology. However, the aim of the course (SLM 305), an introductory teaching to assist you in better understanding the basic concepts and processes of soil chemistry, soil fertility and soil microbiology bearing in mind recent advances in agricultural development, especially in relation to increase in food production.

The aim of the course will be achieved by:

- Learning the chemistry of basic soil reactions.
- Understanding the essentiality of nutrient elements, their status and availability in the soil.
- Helping you to understand the diversity of microorganisms in the soil and their role in plant growth.
- Helping you to understand soil organic matter transformation and role of organic matter in soil.
- Helping you to understand the changes in the nitrogen and phosphorus pools in soil.

COURSE OBJECTIVES

The objective of this course is to give you to an introduction to soil chemistry, soil fertility and soil microbiology. To achieve the aims mentioned above, the course has overall objectives. In addition, each unit has also specific objectives. The unit objectives are given at the beginning of a unit; you should read them before you start working through the unit. You may refer to them in the course of your study of the unit, so as to check on your performance and understanding. Go through the unit objectives after completing a unit, so as to be sure that you have done what is required of you by the unit. At the end of the course, you should be able to:

- Give the definition of soil chemistry and basic chemical reactions that take place in the soil.
- Explain basic concepts in soil chemistry, soil fertility and soil micro biology
- Have an understanding on how plants take up nutrients and factors that affect the availability of soil nutrients.
- Know the kinds and role of microorganisms in soil.
- Know the essentiality of nutrient elements in soil and the essentiality of nutrient elements in soil and the essential nutrient elements for plant growth
- Know the sources and importance of soil organic matter.
- Have a basic understanding of the changes or dynamics of soil N and P pools.

WORKING THROUGH THE COURSE

To complete this course, you are expected to read the study units, as well as other related materials. Pay attention to the objective of each unit and allow it to guide you through. Each unit contains self-assessment exercises, and you are required to submit assignment for assessment purposes (tutor-marked assignment) when needed to. At the end, you are expected to write a final examination. The study material has a marking scheme to enable you assess your performance after going through the assignment questions. Below is a list of all the components of the course, what you have to do and how you should allocate your time to studying this course. Final examination time will be communicated to you.

STUDY UNITS

Each study unit is a week's work and it is introduced by the objective which you are expected to study before going through the unit. In each study unit or after a group of related units, you also have the reading materials and the self assessment exercises. The tutor-marked assignments; the study units, the tutorials, and the marking scheme all put together, will help you to achieve the stated objective for this course. There are four modules and 22 units in this course and they are as follows:

Module 1. The first two units define soil chemistry, its importance in agriculture and its relationship to other fields of science.
Module 2. This deals with the details of soil chemistry and fertility. It contains 13 units and deals with soil chemistry and fertility, its importance in agriculture, essential nutrient elements in soil and the processes affecting both their movement and availability in soil. It also addresses some soil reactions and their effects in soil.

Module 3. This five-unit module highlights soil organism types and their importance in soil transformations.
Module 4. This comprises of two units. It deals with how soil organic matter benefits in the soil, its decomposition processes under various soil conditions and how to maintain soil organic matter in soil for sustainable crop productivity.

Each unit includes specific objective and summaries of key issues and ideas. There are lists of recommended text books and references to provide additional information. You can also go online to get the desired information needed.

SET TEXTBOOKS

Each unit has a list of recommended textbooks and materials. Go through the recommended textbooks and materials for necessary assistance while going through the unit and before attempting the exercises. Where you think you cannot find the necessary references that have been quoted in any of the units, just go on-line and type in the name of the author on Google, it will bring out all the available works of that author and I am sure you will find the ones you are looking for.

ASSESSMENT

You will be assessed in two ways in this course – the tutor-marked assignments and a written examination. You are expected to do the assignments and submit them to your tutorial facilitator for formal assessment in accordance with the stated deadlines in the presentation schedule and the assignment file. Your tutor-marked assignments will account for 30% of the total course mark.

TUTOR- MARKED ASSIGNMENT

SLM 305 involves a lot of reading and study hours. There are tutor-marked assignments at the end of every unit which you are expected to do. You are expected to go through the study units very carefully so that you can attempt the self-assessment exercises. You will be assessed on the different aspects of the course but only three of them will be selected for continuous assessment. Send the completed assignments (when due) together with the tutor-marked assignment form to your tutorial facilitator. Make sure you send in your assignment before the stated deadline.

FINAL EXAMINATION AND GRADING

The modalities for the final examination for SLM 305 will be determined by NOUN. The pattern of the questions will not be too different from those you have responded to in the tutor-marked exercises. However, as the university has commenced online examinations, you may have to adjust to whatever format is made available to you at any point in time. Nonetheless, you can be assured of the content validity of the examinations. You will only be examined strictly on the content of the course, no matter the form the examination takes. It is thus advisable that you revise the different kinds of sections of the course properly before the examination date.

HOW TO GET THE BEST FROM THE COURSE

The study units in this course have been written in such a way that you can easily go through them without the lecturer being physically around and this is what happens in distance learning. Each study unit is for one week. The study units will introduce you to the topic for that week; give you the objective for the unit and what you are expected to be able to do at the end of the unit.

Follow these religiously and do the exercises that follow. In addition to the above, unlike other courses where you just read and jot notes, SLM 305 has a lot of basic principles and theories to learn. You therefore need a lot of concentration while going through the course.

TUTORS AND TUTORIALS

There are 10 tutorial hours for this course. The dates, times and location of these tutorials will be communicated to you as well as the name and phone number of your tutorial facilitator. You will also be notified of your tutorial group. As you relate with your tutorial facilitator, he/she will mark and correct your assignments and also keep a close watch on your performance in the tutor-marked assignments and attendance at tutorials. Feel free to contact your tutorial facilitator by phone or e-mail if you have any problem with the contents of any of the study units.

COURSE MARKING SCHEMES

The following table lays out how the actual marking scheme is broken.

Table 1: Course Marking Scheme

Assessment	Marks
Assignments (1-11)	11 assignment count for 30 % of the overall course marks (2.7 % each)

Final Examination	70 % of the overall course marks
Total	**100 % of course marks**

COURSE OVERVIEW

This Table bring together the units, the number of weeks you should take to complete them and the assignment that follows them.

Table 2: Course Schedule

Units	Title of work	Weeks Acti-vity	Assessment (End of Unit)
	Module 1 Soil Chemistry and its Relation to Other Fields of Science		
1	Meaning of Soil Chemistry	1	Assignment 1
2	Relationship Between Soil Chemistry, Water Chemistry and Pollution Science		
	Module 2 Soil Chemistry/Fertility		
3	Soil Composition	1	Assignment 2
4	Factors Affecting the Ability of the Soil to Supply Nutrients in Available Forms		
5	Availability of Phosphorus and Potassium	1	Assignment 3
6	Availability of Nitrogen		
7	Boron (B) and Iron (Fe)	1	Assignment 4
8	Manganese And Molybdenum		
9	Availability of Zinc, Copper, Chlorine and Sodium	1	Assignment 5
10	The Ion Exchange Phenomenon		
11	Cation Exchange Capacity (CEC), Anion Exchange Capacity (AEC), Base Saturation, Flocculation and Dispersion	1	Assignment 6
12	Buffering Capacity, Soil Salinity, Alkalinity and Sodicity		
13	Soil Reaction and Lime Requirement	1	Assignment 7
14	Adsorption/Desorption		
15	Nutrient Uptake by Plant Roots	1	Assignment 8
	Module 3 Soil Microorganisms		

16	Soil Organisms		
17	Bacteria	1	Assignment 9
18	Fungi, Actinomycetes and Algae		
19	Nematodes, Earthworms and Termites	1	Assignment 10
20	Reactions of Nitrogen and Phosphorus In The Soil		
	Module 4 **Soil Organic Matter**		
21	Soil Organic Matter	1	Assignment 11
22	The Role of Organic Matter in Tropical Soils		

SUMMARY

SLM 305 is designed to introduce you to the principles of soil chemistry, fertility and microbiology. The course is to assist you in better understanding of the basic concepts and processes of soil chemistry, soil fertility and soil microbiology at the School of Agricultural Sciences, National Open University (NOUN). Soils are complex heterogeneous medium that reflects/shows various physical, chemical and biological conditions of soil. This course is an introduction to the chemistry of soil, the importance of the nutrient elements in soil to plant growth and development and the role of microorganisms in nutrient availability and transformation. You will be able to answer these key questions:

- What do you understand by the term soil chemistry?
- What is the importance of soil chemistry and its importance in agriculture?
- What are the essential nutrient elements in soil?
- What are the factors affecting nutrient uptake and availability?
- What are the roles of microorganism in nutrient availability and transformation?
- What are the effects of different soil conditions on organic matter decomposition?
- How you can maintain organic matter levels in soil.

The list of questions you can answer is not limited to the above. To gain a lot from this course, you should try to apply the principles learnt especially to agricultural production.

We wish you the best and hope that you will find the course interesting and useful. I wish you the best and outstanding success as you go through this course.

MAIN COURSE

CONTENTS

MODULE 1 SOIL CHEMISTRY AND ITS RELATION TO OTHER FIELDS OF SCIENCE

UNIT 1 MEANING OF SOIL CHEMISTRY

CONTENTS

1.0 INTRODUCTION

Soil chemistry, fertility and soil microbiology are some of the many fields of soil science. Your knowledge in SLM 201 have enabled you appreciate soil as a source and sink for plant nutrients and also has a component of the environment that needs to be taken care for sustainability of our production systems. When plant grows poorly, an average person knows he needs to apply fertiliser (plant food). The farmer expects to see changes in the crops after such application. However, soil chemistry studies the various reactions that go on in the soil after fertiliser application and those factors that could either hinder or facilitates the availability of the applied nutrients to crops. The study of soil microbial population is also needed to ensure that the right type and amount of microbes are in the soil to make the mineralisation (biochemical breaking down into the useful component) of the fertiliser nutrients possible. In this unit you will learn about meaning of soil chemistry and how it relates with other field of science.

2.0 OBJECTIVE

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

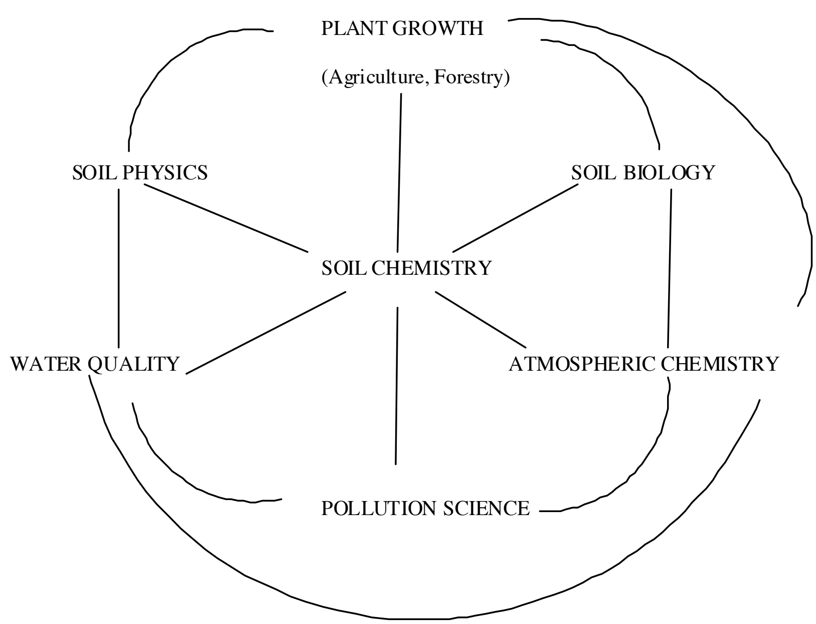
- define and explain soil chemistry
- explain how soil chemistry relates with other scientific fields.

3.0 MAIN CONTENT

3.1. Definition and meaning:

Soil Chemistry is an important branch of soil science. It is fundamental to all soil processes that affect the use of soil. Soil chemistry studies the nature of chemical elements in the soil system in organic and inorganic combinations. It also studies the inter-relationship between these chemical elements and how they relate with three states of matter.

Soil chemistry is regarded as the most central of all the scientific disciplines that interact to make up of the complex web of environmental science. This is illustrated in the figure in the figure below:



Schematic representation of the interaction between soil chemistry and other branches of soil science and environmental science

3.2 Soil Chemistry and Plants

Soil chemistry regulates the availability of essential major elements (N, P, S, K, Ca and Mg) and trace elements (B, Cu, Fe, Mn, Mo and Zn). Soil chemistry characteristics also govern the availability of elements such as Co. Soils are also important in restricting undesirable side effects from plant protection chemicals such as selective herbicides, fungicides, molluscicides, etc. Plant, in turn, may substantially influence soil physicochemical properties in many ways. The major mechanisms include soil acidification by release of hydrogen ions at the root to compensate for plant uptake of base cations (Ca, K, Mg, and Na), anion uptake, modification of soil moisture content, the effects of organic compounds oxidation from roots, root respiration, incorporation of plant litter and its subsequent degradation in the soil, etc.

3.3 Soil Chemistry, Soil biology and Biochemistry

The biological population of the soil, especially the microbial population, plays a vital role in the biogeochemical cycling of nutrient elements such as C, N, P and S, and hence, in the regulation of soil fertility. However, the activities of macro and microorganism in the soils are regulated by soil chemistry properties.

3.4 Soil Chemistry and Soil Physics

The chemical reactions which occur in soil may have far-reaching effects upon the physical properties of the soil, such as the stability of its structural units, especially in regions with arid climates. In many soils in wetter areas, the particle size distribution, which governs its drainage characteristics, is a function of the chemical weathering of the minerals present in the soil pm. Some also plays an important role in water retention, and in the establishment of stable soil structure, the macro pores created facilitating drainage.

3.5 Soil chemistry, Geochemistry and Soil Formation

The chemical natures of the minerals initially present in the rock, till or sediment from which a soil has developed influences the soil chemical properties at any given time. These properties may in turn, have a striking effect on soil bio activity and the combined biological and chemistry effects govern the type of soil which is formed and the uses to which it may be put.

SELF-ASSESSMENT EXCERCISE

What is the meaning of the term “mineralisation”?

4.0 CONCLUSION

Soil chemistry is a central to many other scientific fields.

5.0 SUMMARY

Soil chemistry studies the nature of chemical elements in the soil system in organic and inorganic combinations. It also studies the inter-relationship between these chemical elements and how they relate with three states of matter. It is central to many scientific fields.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is soil chemistry?
2. List four scientific fields that is closely related to soil chemistry

7.0 REFERENCES/FURTHER READING

Lindsay, W.L., 1979. Chemical equilibria in soils. United States. John Wiley and Sons, Inc.

Stevenson, F.J., 1986. Cycles of soil; carbon, nitrogen, phosphorus, sulfur, micronutrients. Canada, John Wiley and Sons, Inc.

Sparks, D.L., 1986. Soil physical Chemistry. United states, CRC Press, Inc.

Tan, K.H., 1993. Principles of Soil Chemistry. 2nd ed. United States of America, Marcel Dekker, Inc.

UNIT 2 RELATIONSHIP BETWEEN SOIL CHEMISTRY, WATER CHEMISTRY AND POLLUTION SCIENCE

CONTENTS

1.0 INTRODUCTION

This unit is a continuation of the previous one. It seeks to elucidate the link between soil chemistry and some other scientific endeavours.

2.0 OBJECTIVE

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

- explain how soil chemistry relates with water chemistry and pollution science.

3.0 MAIN CONTENT

3.1 Soil Chemistry and Water Chemistry

Except where outcropping rock dominates the landscape, precipitation (rain, sleet, snow, etc.) reaching the soil surface flows through and over the soil before reaching groundwater or draining into streams or lakes. During this period of soil – water contact, a range of chemical reactions takes place which regulates the chemical composition of the freshwater eventually obtained.

Precipitation itself contains a significant amount of solute which also interacts with the soil solid components as the water drains through or over the soil.

3.2 Soil Chemistry and Pollution Science

The world's soils serve as a depository of vast quantities of pollutants. Sometimes the fate and consequences of individual pollutants becomes very important and emotional e.g. nuclear waste or fallout, acid rain or lead from petrol. Another important source of potential pollution is the spreading of manures or sewage sludge on soil, either for disposal or for fertiliser effect. The fate of these pollutants and of fertilisers and other agrochemical added to the soils is an increasingly important area of study by soil chemists. Many soils have an extraordinary capacity for rendering pollutants ineffective, but at the present time, this capacity is being abused to the extent that critical loads may be exceeded.

3.3 Significance of Soil Chemistry

Understanding soil chemistry is very important to crop production in terms of:

1) Improving the availability of nutrients to plants.
2) To utilise soil microbial organisms to the best advantage.
3) To improve the physical conditions of the soil.
4) Helps to explain the basic properties of soils as they occur in nature.
5) Helps to monitor and follow rapid changes that occur in the soil as a result of the introduction of intensified modern techniques in crop production.

4.0 CONCLUSION

Soil chemistry is fundamental to all soil processes that affect the use of soil and the most central of all the scientific disciplines that interact to make up of the complex web of environmental science. The significance of soil chemistry ranges from its use in explaining processes that affect nutrients availability to plants to its usefulness in providing ways of managing soil as a component of the environment.

SELF-ASSESSMENT EXCERCISE

Soil is known to render pollutants ineffective in the environment, when is the problem of soil pollution made known to man?

5.0 SUMMARY

Soil chemistry, water chemistry and pollution science are related.

6.0 TUTOR-MARKED ASSIGNMENT

1. How do soil chemicals affect water chemistry?
2. What are the benefits of the knowledge of soil chemistry?

7.0 REFERENCES/ FURTHER READING

Bear, F.E. (1964). *Chemistry of the Soil*. (2nd ed.). United States of America: Reinhold Publishing Corporation.

Bohn, H.L., Mcneal B.L., O'connor G.A. (1985). *Soil Chemistry*. Canada: John Wiley and Sons, Inc.

Cresser, M., & Killham, K. (1993). *Soil Chemistry and its Application*. Australia: Cambridge University Press.

Lindsay, W.L. (1979). *Chemical Equilibria in Soils*. United States. John Wiley and Sons, Inc.

Stevenson, F.J. (1986). *Cycles of Soil; Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients*. Canada, John Wiley and Sons, Inc.

Sparks, D.L. (1986). *Soil Physical Chemistry*. United States, CRC Press, Inc.

Tan, K.H. (1993). *Principles of Soil Chemistry*. (2nd ed.). United States of America: Marcel Dekker, Inc.

MODULE 2 SOIL CHEMISTRY/FERTILITY

UNIT 1 SOIL COMPOSITION

CONTENTS

1.0 INTRODUCTION

Soil is a major component of the environment; it is the repository of all human activities and a sink for soil nutrients for crop production. Just like any other natural material, soil is composed of some basic constituents, some which are visible to naked eyes while others are very small and cannot be seen by the ordinary eyes (microscopic). This units deal with the basic composition of soil and the factors that affects their composition is explained.

2.0 OBJECTIVES

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

- identify the components of soil
- mention the factors that affect the composition of the soil.

3.0 MAIN CONTENT

Soil may be defined as material of variable depth with a substantial solid content at the Earth's surface which is undergoing change as a consequence of chemistry, physics and biology processes.
Soil essentially consists of three phases; a solid phase, a solution phase and a gas phase.

3.1 The Solid Phase

Usually includes an intimate mixture of mineral material, originating from rock, sediment or till, and organic material arising as a consequence of biological activity. Solid phase occupies about 50% of the soil's volume. It is composed of 97% inorganic material and about 3% organic material in an average silt loam soil. There is a wide variation in the composition of the solid state of a soil e.g. an organic soil could contain more than 50 % O.M. The mineral particles in the soil vary in size. The size ranges from sand particles with 2.0-0.05 mm size range; silt (0.05 – 0.002 mm) and clay (less than 0.002mm. Sand particle can be seen with the naked eyes and feel gritty when rubbed between the fingers. The particles do not adhere to one another; therefore sands do not feel sticky. Silt particles are too small to be seen without a microscope or to feel individually, so silt feels smooth but not sticky, even when wet. Clay particles are the smallest of the three particles, they adhere together when wet to form a sticky mass and also forms a hard clod when dry.

3.2 The Solution Phase

This interacts continuously with the solid phase. It originates infiltrating the soil (from water as rainfall, dew, snow, fog etc) or from rising water or water moving laterally (pools of water in the soil, this could be water from the ground source etc). The chemical composition of the soil solution depends on:

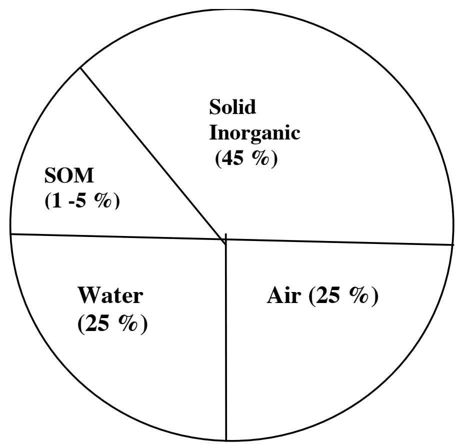
(a) Physico-chemical characteristics of the soil solids. Since the soil water is in close contact with the solid, the component of the solid is therefore expected to dissolve in the soil water. Thus, soil solid made from acidic parent material for example is expected to impact some level of acidity on the soil water.

(b) Precipitation solute composition. Water that falls on the soil interact with the soil solid and water content. The amount and type of materials dissolved in the falling water is then automatically transferred into the soil water content. Precipitation is usually in form of rainfall, dew, snow or fog.

(c) Biological activity within the soil matrix. Soil with microbial activity is expected to have high volume of gases produced by the micro organisms and subsequently dissolved in the soil water while the excess escapes into the atmospheric air. Hence, the soil water composition is affected by the level of microbial activities and the composition of the microbes and the types of gases produced by them. Root respiration is also a source of gases that dissolves and affects soil water composition.

(d) Contact time. The effect of the factors in a-c above is greatly affected by the time the factors interacts with the soil component involved.

3.3 The Gas Phase, or soil atmosphere composition depends upon biological activity. It may be greatly enriched in CO_2 (3-4%) compared to normal above-ground air (0.035%) as a consequence of microbial and root respiration and relatively depleted in O_2. Under certain conditions, it may contain significant amount of gases such as nitrous oxide, NH_2, H_2S and ethylene.



Soil Composition (Hypothetical)

4.0 CONCLUSION

Soil is made up of solid, liquid and gaseous materials.

5.0 SUMMARY

The soil is made up of the three states of matter. The constituent of the soil has a large effect on determining the soil properties.

SELF-ASSESSMENT EXCERCISE

What is the determinant of the composition of the soil gaseous phase?

6.0 TUTOR-MARKED ASSIGNMENT

1. List four determinants of the composition of the soil liquid phase.
2. List five types of gases in the soil.
3. List two sources of the soil solid materials.

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils*. (12th ed.). New Jersey: Prentice-Hall.

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UNIT 2 FACTORS AFFECTING THE ABILITY OF THE SOIL TO SUPPLY NUTRIENTS IN AVAILABLE FORMS

CONTENTS

1.0 INTRODUCTION

Soil is a major source of nutrients for crop production is expected to supply the nutrients to the plants when needed and at the right amount. However, the soils may have the abundance of soil nutrients that may not be made available for crop use. This may be due to some extraneous factor that determines the availability of nutrients rather than just the abundance or deficiency of the nutrients. In this unit you will learn about the factors that affect the ability of the soil to supply nutrients in available forms.

2.0 OBJECTIVE

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

- mention the specific soil factors that determine the availability of nutrients.

3.0 MAIN CONTENT

Nutrients that are essential for plant growth are broadly divided into structural nutrients, major nutrients (primary and secondary nutrients) and micro nutrients. Each of the groups will be discussed with reference to the factors that affect the availability of the nutrients in the groups.

3.1 Micronutrients cations

(Fe, Mn, Zn, Cu, Al and Co) is influenced in the same way in the soil environment. Some of the factors that affect their availability are:

3.1.1 Soil pH

Micronutrients are most soluble and available under acid conditions. In very acid soils, there is a relative abundance of the ions of Fe, Mn, Zn and Cu. Ni also follows the same pattern. Under this condition soil solution concentrations or activities of one or more of these elements (most commonly Mn) is often toxic to plants.

As the pH increases, the ionic form of the micronutrients are changed to the hydroxyl ion and finally to the insoluble hydroxides or oxides of the elements.

All the hydroxides of the micronutrients cations are relatively insoluble, the exact pH at which precipitation occurs varies from element to element and between oxidation states of a given element. Over-liming of an acid soil often leads to deficiency of Fe, Mn, Zn, Cu and sometimes B. This occurs mostly in calcareous soils with high pH. The general desirability of a slightly acid soil (pH 6 and 7) largely stems from the fact that for most plants this pH allows micronutrient cations to be soluble enough to satisfy plant needs without becoming so soluble as to be toxic.

3.1.2 Inorganic Reactions

Micronutrient cations interact with silicate clays in two ways: (a) They may be involved in cation exchange much like those of Ca and Al (b) They may be tightly bound or fixed to certain silicate clays, especially the 2:1 type. Zn, Mn, Co and Fe sometimes occur in the crystal structure of these clays. Depending on conditions, they may be released from the clays or fixed by them. The fixation may cause serious deficiency in the case of Co and Zn.

Application of large quantities of phosphate fertiliser can adversely affect the supply of micronutrients. The uptake of both Fe and Zn may be reduced in the presence of excess phosphate.

3.1.3 Organic Matter

Organic matter residues and manure applications affect the immediate and potential availability of micronutrient cations. Some organic compounds react with these cations to form water-insoluble complexes that can protect the nutrients from interaction with mineral particles that can bind them in even more insoluble forms. Deficiencies of Cu and to a lesser extent Mn are often found on poorly drained soils high in organic matter (e.g. peats and marshes). Zn is also retained by organic matter.
Microbial decomposition of organic plant residues and animal manures can result in the release of micronutrients. However temporary deficiencies of the trace elements may occur when the residues are added due to the assimilation of micronutrients in the bodies of active microorganisms.

3.1.4 Role of Mycorrhizae

A symbiosis between most higher plants and certain soil fungi produces mycorrhizae (fungus root), which are more efficient than normal plant roots in several respects. Mycorrhizae have been known to increase plant uptake of P, and also micronutrients. It also protects plants from excessive uptake of micronutrient and other trace elements where these elements are present in potentially toxic concentration.

3.2 Availability of Mo

Soil pH is the most important factor affecting the availability and plant uptake of Mo. At low pH, Mo is adsorbed by silicate clays, especially oxides of Fe and Al through ligand exchange with hydroxide ions on the surface of the colloidal particles.
Liming of acid soils will increase the availability of Mo. The phosphate anions seem to improve the availability of Mo by competing with the latter for sorption sites on soil surfaces.

SELF-ASSESSMENT EXCERCISE

What is the meaning of mycorrhizae?

4.0 CONCLUSION

Soils may have the abundance of soil nutrients that may not be made available for crop use. This may be due to some extraneous factor that determines the availability of nutrients rather than just the abundance or deficiency of the nutrients.

5.0 SUMMARY

Availability of nutrients in the soil is dependent on factors that both internal and external to the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the effect of pH on the availability of soil micronutrients (Molybdenum excluded)?
2. Mention two ways by which silicate clays may affect soil micronutrients.
3. How does organic matter affect the availability of micronutrients?
4. What is the influence of soil pH on Mo availability?

7.0 REFERENCES/FURTHER READING

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UNIT 3 AVAILABILITY OF NITROGEN

CONTENTS

1.0 INTRODUCTION

The availability of nitrogen is dependent on many factors. However the nutrient is a major nutrient that is needed in large quantities by the plants. In this unit you will learn about the factors that affect the ability of the soil to supply nitrogen.

2.0 OBJECTIVE

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

- state the specific soil factors that determine the availability of nitrogen.

3.0 MAIN CONTENT

3.1 Symbiotic Nitrogen Fixation:

The symbiosis of legumes and bacteria of the genera Rhizobium and Bradyrhizobium provide a biological source of fixed N in agricultural soils. They infect the root hairs and the cortical cells, ultimately inducing the formation of root nodules, which serve as the sink of N fixation.

3.2 Microbial and Plant C:N Ratio:

Soil microbes require a balance of nutrients to build their cells and extract energy. Hence, they need carbon to build essential organic compounds and energy for life processes and also N to synthesize N-containing cellular components e.g. amino acids, enzymes and DNA. On the average soil microbe must incorporate into their cells about 8 parts of C for every 1 part of N (i.e. 8:1). But ⅓ of the C metabolised by microbes is incorporated into their cells; the excess is respired and lost as CO_2. i.e. They need to find about 24 parts of C for every 1 part of N assimilated (i.e. 24:1). But if organic material added to the soil exceeds about 25:1, the microbes will have to scavenge the soil solution to obtain enough N. Thus the incorporation of high C/N residues will deplete the soils supply of soluble N, causing its deficiency. Secondly, the decay of organic materials can be delayed if sufficient N to support microbial growth is neither present in the material undergoing decomposition nor available in the soil solution.

SELF-ASSESSMENT EXCERCISE

What happens when the soil C:N ratio is 30:1?

4.0 CONCLUSION

Nitrogen availability in the soil is determined by the quality of the organic material added to the soil and microbial activities.

5.0 SUMMARY

Nitrogen is a very important nutrient in the soil. It plays a major role in plant nutrition.

6.0 TUTOR-MARKED ASSIGNMENT

1. List two bacteria genera responsible for N fixation.
2. What is the optimum soil C: N ratio?

7.0 REFERENCES/FURTHER READING

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UNIT 4 AVAILABILITY OF PHOSPHORUS AND POTASSIUM

CONTENTS

1.0 INTRODUCTION

Next to nitrogen in importance to plant nutrition is phosphorus and potassium and their availability is also dependent on many soil and other extraneous factors. However the nutrients are major nutrient that is needed in large quantities by the plants. In this unit you will learn about the factors that affect the ability of the soil to supply P and K.

2.0 OBJECTIVE

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

- mention specific soil factors that determine the availability of phosphorus and potassium.

3.0 MAIN CONTENT

3.1 Phosphorus

3.1.1 Amount of Clay

Most of the compounds with which P reacts are in finer soil fractions. Therefore, if soil with similar pH values and mineralogy are compared, P fixation tends to be more pronounced and ease of P release tends to be lowest in those soils with higher clay contents.

3.1.2 Types of Clay Mineral Present

Generally, clay with greater anion exchange capacity (due to positive surface charged) have a greater affinity for phosphate ion, e.g. High P fixation is characteristics of allophone clays found in Andisols and others with volcanish ash. Oxides of Fe and Al, such as gibbsite and goethite also strongly hold P. Among the layer silicate, kaolinite has a greater P-fixation capacity than others. The soil components responsible for P-fixing capacity are, in order of increasing extent and degree of fixation.

2:1 clay << 1:1 clays < carbonate crystals < crystalline Al, Fe, Mn oxides < amorphous Al, Fe, Mn oxides, allophone. i.e. Vertisols & Mollisols < Ultisols & Oxisols < Andisols

3.1.3 Soil pH

Greatest degree of P fixation occurs at very low and very high soil pH. As pH increases from below 5 to about 6, the Fe and Al PO_3^{2-} become more soluble. Also as pH drops from greater than 8 to below 6, $CaPO_3$ compounds increases in solubility. So the P fixation is at its lowest (plant availability is highest) when soul pH is between 6 and 7.

3.1.4 Organic Matter

This has little capacity to strongly fix P ions. This is due to large humic molecules that adhere to the surfaces of clay and metal hydrous oxides particles, masking the P-fixation sites. Secondly organic acids attracted to positive charges and hydroxyls on the surfaces of clays and hydrous oxides, these organic anions may compete with P ions for fixation sites. Certain organic acids can entrap Al and Fe in stable organic complexes called chelates. Once chelated, these metals are unavailable for P ions in solution.

3.2 Potassium

3.2.1 Type of Clay and Moisture

The ability of the various soil colloids to fix K varies widely. Kaolinite and other 1:1 type clays fix little K. On the other hand, 2:1 clays such as vermiculite, Mite and smectite, fix K very readily and in large quantities. Alternative wetting/drying and freezing/thawing has been shown to enhance the fixation of K in non-exchangeable forms and release of previously fixed K to the soil solution.

3.2.2 Soil pH

Application of lime sometimes results in an increase in K fixation of soils. In acid soil the tightly held H^+ and hydroxyl Al ions prevent K from being close with colloidal surfaces, which reduce its fixation. As the pH increases, the H^+ and hydroxyl Al ions are removed or neutralised, and it's easier for K ions to move closer to the colloidal surfaces where they are more susceptible for fixation in 2:1 clays.

SELF-ASSESSMENT EXCERCISE

What is the effect of pH on potassium (K) availability?

4.0 CONCLUSION

The soil clay type, pH and organic matter are some of the major factors that determine the availability of P and K in the soil.

5.0 SUMMARY

Phosphorus and potassium are important nutrient in the soil. Their vavilability is dependent on many soil factors.

6.0 TUTOR-MARKED ASSIGNMENT

- What is the effect of soil clay content and pH on P availability to crops?
- What is responsible for the low P fixation in soil high in organic matter?

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils*. (12th ed.). New Jersey: Prentice-Hall.

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UNIT 5 BORON (B) AND IRON (Fe)

CONTENTS

1.0 INTRODUCTION

Boron and Iron are micronutrients because they are needed by plants in minute quantities. However they deficiency in the soil and plant systems affects the productivity of the crops.
In this unit you will learn about the factors that affect the ability of the soil to supply B and Fe.

2.0 OBJECTIVE

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

- mention the specific soil factors that determine the availability of B and Fe.

3.0 MAIN CONTENT

3.1 Boron (B)

This is a light non-metal occurring in soil as borosilicate, an e.g. is tourmaline, this is the main B containing minerals in soil. Its deficiency has been reported in legumes, root crops and fruit crops. Its deficiency symptoms includes the breakdown of internal tissue of roots, death of terminal buds, brittle leaves, shortened internode resulting in abnormal short plant, older leaves becomes chloristic (B is immobile hence, younger parts are affected first).

Functions: It is responsible for transportation of sugars and for terminal bud growth, it is responsible for enzyme activation.

3.1.1 Factors Influencing Boron Availability

1. Organic matter content (high organic matter, high Boron).
2. Clay content (texture), heavy soil contains more B than light soils (sandy soil).
3. Soil pH, Boron availability drops at pH level >6.5.
4. Soil moisture, Boron availability drops under dry soil conditions.

3.2 Iron (Fe)

Although the total amount in earth crust is high, this is not related to its availability.

Role: It is required by some enzyme systems and cytochromes
It is associated with chloroplast proteins.

Deficiency has always been associated with high pH, high $CaCO_3$ or both. Fe is immobile therefore symptom of chlorosis and stunted growth is first noticed on upper younger leaves.

In the soil system Fe occurs in the following minerals: (1) Fe_2O_3 (Heamatite) (2) Fe_3O_4 (Magnetite) (3) $FeCO_3$ (ferrous carbonate) (4) $Fe(SO_3)_3$ (Iron pyrite) (5) $Fe_2O_3.3H_2O$ (limonite).
Fe also occurs in primary minerals as biotite, chlorites, olivine and other ferromagnessia.

3.2.1 Factors Affecting Iron Availability

1. Soil pH. Fe reduces with increasing pH.
2. Ratio of Fe:Mn, (Negative Interaction/antagonism), increasing Mn level causes Fe deficiency.
3. High concentration of P may cause Fe chlorosis. Here, Fe is fixed by P.
4. Excess HCO_3^{2-} (bicarbonate). This reduces Fe availability.
5. Free $CaCO_3$ also reduces Fe availability.
6. High levels of Zn, Cu and Mn.
7. High soil moisture and poor aeration.

SELF-ASSESSMENT EXCERCISE

What is the main function of boron in plants?

4.0 CONCLUSION

Availability of soil B and Fe is dependent on soil factors such as pH, clay types, soil moisture and organic matter.

5.0 SUMMARY

Boron and iron are important micro nutrients in the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the Factors influencing Boron availability.
2. What is the major soil mineral rich in boron.
3. List three iron minerals in the soil.
4. What factors affect iron availability in the soil.

7.0 REFERENCES/FURTHER READING

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UNIT 6 MANGANESE AND MOLYBDENUM

CONTENTS

1.0 INTRODUCTION

Manganese and molybdenum are micronutrients because they are needed by plants in minute quantities. However they deficiency in the soil and plant systems affects the productivity of the crops.
In this unit you will learn about the factors that affect the ability of the soil to supply Manganese and molybdenum.

2.0 OBJECTIVE

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

- mention specific soil factors that determine the availability of Manganese and molybdenum.

3.0 MAIN CONTENT

3.1 Manganese (Mn)

It is similar to Fe in many respects. It is immobile. Mn is absorb by plant as Mn^{2+}. It occurs in a number of minerals like braunite Mn_2O_3, Manganite MnO, augite etc. Mn occurs in many oxidation states but for plant nutrition, only Mn^{2+}, Mn^{3+}, Mn^{4+} states are most important. In the divalent state (Mn^{2+}) it occurs in acid soils and colloidal surfaces, Mn^{3+} exists as highly reactive oxides Mn_2O_3, this occur in neutral pH. Mn^{4+} occurs as menganic oxide MnO_2 in alkaline state.

These three states are interrelated through a dynamic equilibrium.
Functions: It acts as catalyst in several important enzymatic reactions:

- It helps in carbohydrate metabolism, phosphorylation and citric acid cycle.
- It is an important activating component involved in N metabolism.

3.1.1 Factors Affecting Availability

1. High organic matter leads to availability of many organic by-products usually by product of humic acid (humus), forms complexes readily with Mn hence, unavailable.
2. At high pH fixation of Mn occurs, hence, unavailable.
3. Under waterlogged condition Mn^{2+} becomes more soluble and more available.

Symptoms: Mn is immobile, the deficiency shows inform of grayish colouration near the base of younger leaves. Other sings of its deficiency are necrotic spots, wringled leaf formation.

3.2 Molybdenum (Mo)

It is absorbed as molybdate (MoO_3). It occurs as wulferrite ($PhMoO_4$), ferromolybdate ($FeMoO_4$). Mo occurs in several oxidation states as Mo^{2+}, Mo^{3+}. It is the only micronutrient available in alkaline condition.
Functions

(1) It is required as enzyme activator, particularly for NO_3 reductase enzyme (by legumes).
(2) Helps in the fixation of atmospheric N.
(3) It has positive relationship with nodulation.
(4) It is required in ascorbic acid synthesis.

3.2.1 Factors Affecting Availability of Mo

1. In acid soils with high Fe & Al oxides, these oxides form cystalls which occlude the Mo.
2. Soil texture soil clays are known to adsorb Mo in acid soils, but the Mo is easily released at high pH.
3. High NO_3 content reduce the level of available Mo. How? – Mo is needed by bacteria to change $NO3^-$ to NH_3. If the level of Mo is

low, the bacterial will utilise the Mo in the soil, hence, making it temporarily deficient (Immobilisation).

4. High lime application results in high level of Mo

   Deficiency – Mo, deficiency appears first on older leaves and later on younger ones. Deficiency symptoms include chlorosis and leaf mottling which will lead to marginal curling and interveinal chlorosis.

SELF-ASSESSMENT EXCERCISE

What are the availability forms of Mn in soils?

4.0 CONCLUSION

Availability of soil manganese and molybdenum is dependent on soil factors such as pH, clay types, soil moisture and organic matter.

5.0 SUMMARY

Manganese and Mo are needed for enzymatic reactions in the plants.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the effect of soil organic matter on Mn availability?
2. List four factors affecting Mo availability.

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils*. (12th ed.). New Jersey: Prentice-Hall.

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UNIT 7 AVAILABILITY OF ZINC, COPPER, CHLORINE AND SODIUM

CONTENTS

1.0 INTRODUCTION

Manganese and molybdenum are micronutrients because they are needed by plants in minute quantities. However they deficiency in the soil and plant systems affects the productivity of the crops.
In this unit you will learn about the factors that affect the ability of the soil to supply Manganese and molybdenum.

2.0 OBJECTIVE

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

- mention the specific soil factors that determine the availability of Manganese and molybdenum.

3.0 MAIN CONTENT

3.1 Zinc (Zn)

The element occurs in nature as ZnS and it is absorbed by plant as Zn^{2+}, Zn has very great tendency to form stable complexes. It is a metal activator of enzymes, it is vital for carbohydrate transportation from roots to other parts, it aids in the formation of auxins (plant growth hormones). Zn promotes the absorption of water by plant.

3.2 Factors affecting its availability

(1) pH, Zn is more available at low pH and vice versa.
(2) P Zn antagonism, high P content may induce Zn deficiency.
(3) Zn is part of organic matter. It is chelated by organic matter. In organic soil, where organic matter is too much, the chelate may be to the extent of having Zn unavailable.

3.3 Copper (Cu)

This is absorbed by plant as Cu^{2+}, 99% of the earthcrust has Cu in impure form, in the form of sulphite and oxide, e.g. chacocite (Cu2S), Copper pyrite (CuFeS), etc. Cu serves as fungicides or germicides because it is toxic to lower form of lives.
e.g. Copper helps as an activator in enzyme system and its deficiency is normal in organical soil. It is a precursor of chlorophyll but not part of the chlorophyll molecule. Copper inactivates certain toxins produced by certain fungi and bacteria.
Copper is also associated with N fixation and mineralisation.

3.3.1 Factors affecting Cu availability

(1) pH – Cu availability increases with decrease in pH
(2) Organic matter – organic adsorption ties-up a lot of Cu. In many cases they are soluble, however, Cu deficiency may still occur in organic soil because of fixation and chelation
(3) Nutrient interaction

3.4 Chlorine (Cl) and Sodium

It is recently found to be essential, it is required in very small quantity, the problem is usually with its excess rather than its deficiency. It is usually in form of $CaCl_2$, $MgCl_2$. Excess it affect the quality of some crop e.g. Tobacco leaves and the storage quality of potatoe, yam **Sodium (Na)**
Recently found essential for plants like tomatoe.

4.0 CONCLUSION

There are many factors that affect the availability of soil nutrients. Hence, plant growth is not only determined by the abundance of soil nutrients but also on the factors that will enhance or militate against the uptake.

SELF-ASSESSMENT EXCERCISE

What is the natural form of Zn?

5.0 SUMMARY

Availability of Zn, Cu, Cl and Na in soil is dependent on soil and external factors.

6.0 TUTOR-MARKED ASSIGNMENT

What is the effect of soil pH and organic matter on soil copper and zinc?

7.0 REFERENCES/FURTHER READING

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UNIT 8 THE ION EXCHANGE PHENOMENON

CONTENTS

1.0 INTRODUCTION

Next to photosynthesis and respiration, no process in nature is more vital to plant and animal life than the exchange of ions between soil particles and plant roots. These cation and anion exchanges occur mostly on the surfaces of the finer or colloidal fractions of both the inorganic and organic matter (clay and humus). The silicate minerals make up the largest and most important source of exchange sites in soils. In this unit you will learn about the meaning of some basic terms (soil chemical properties) in soil science.

7.0 OBJECTIVE

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

- state the meaning and definitions of cation exchange capacity (CEC), anion exchange capacity (AEC), soil reaction, base saturation and liming.

3.0 MAIN CONTENT

The importance and ability of clay minerals and colloidal to hold cations cannot be over emphasised, these serves as the store house for many nutrients required for plant growth. The soil system provides a buffer system that tends to maintain the nutrients in correct proportions required by plants. Soil colloid have un-neutralised negative charges, thus positively charged ions (cations) are adsorbed at these negatively charged sites by electrostatic attraction, these adsorbed cations resist removal by leaching water but can be replaced by other cation in solution by mass action. The exchange of one positive ion by another is called cation exchange. Cation exchange takes place on the surfaces of clays and humus colloids as well as on plant root surface. Cations on exchange sits are Ca^{2+}, Mg^{2+}, H^+, K^+, Al^{3+},NH_4^+, Na^+, etc. The proportion of these nutrients are constantly changing as ions are added from dissolving minerals (weathering), or by addition of lime, gypsum or fertilisers, losses occurs by plant root absorption and leaching.

Cations adsorbed on the colloidal particles are called exchangeable cations because they can be replaced or exchanged by other cations from the soil solution surrounding the particle. Cation exchange is the process of replacement or exchange of one cation for another the exchange complex refers to all soil particles like clay and humus that adsorb or exchange cations.

Soil management practices like liming of acid soils, applying gypsum to alkaline soil and fertilising soils are beneficial because they induce cation exchange reactions which change the kind and proportion of cations adsorbed and therefore modify soil properties. Liming of acid soil results in Ca^{2+} ion replacing H^+ and Al^{3+} on the exchange complex, sodic soils have excessively high Na on the exchange complex, addition of gypsum results in the Ca^{2+} replacing Na^+ of the exchange sites.

SELF-ASSESSMENT EXCERCISE
Name any four cations held on the exchange sites?

4.0 CONCLUSION

Soil management practices like liming of acid soils, applying gypsum to alkaline soil and fertilising soils are beneficial because they induce cation exchange reactions which change the kind and proportion of cations adsorbed and therefore modify soil properties.

5.0 SUMMARY

Next to photosynthesis and respiration, no process in nature is more vital to plant and animal life than the exchange of ions between soil particles and plant roots.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the sites for ion exchange reactions in the soil system?
2. What is cation exchange?
3. List two soil management practices that use the principles of cation exchange.

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils*. (12th ed.). New Jersey: Prentice-Hall.

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UNIT 9 CATION EXCHANGE CAPACITY (CEC), ANION EXCHANGE CAPACITY (AEC), BASE SATURATION, FLOCCULATION, AND DISPERSION

CONTENTS

1.0 INTRODUCTION

In this unit an attempt is made to explain some basic concept in soil chemistry. These are important soil chemical processes that takes place in the soil. They determine the soil properties and also affect the performance of the crops.

2.0 OBJECTIVE

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

- state the meaning and definitions of cation exchange capacity (CEC), anion exchange capacity (AEC), soil reaction, base saturation flocculation and dispersion.

3.0 MAIN CONTENT

3.1 Cation Exchange Capacity

This is the amount of exchangeable cations that soil can adsorb. By standard methods all the adsorbed cations in a soil are replaced by a common ion, such as Ba^{2+}, K^+, or NH_4^+; then the amount of adsorbed Ba^{2+}, K^+ or NH_4^+ is determined. Cation Exchange Capacity refers to the ability of the growing medium to hold exchangeable mineral elements within its structure. These cations include ammonium-nitrogen, potassium, calcium, magnesium, iron, manganese, zinc and copper. Peat moss and mixes containing bark, sawdust and other organic materials all have some level of cation exchange capacity.

It is measured in moles of positive charge adsorbed per unit mass expressed as centimoles of positive charge per kilogram of soil (cmolc/kg) or Meq/100g of soil.

3.2 Anion Exchange Capacity (AEC)

This is the amount of exchangeable anions that soil can adsorb. Colloids having appreciable anion exchange are those having low CEC and on these colloids OH^-, SO_4^{2-}, PO_3^- can be exchanged. Highest AEC occur in amorphous days and Al-oxide clays. The amount of AEC is generally low usually a few tenth of a meq/100g of soil. Positive charges occur at the edges of clay minerals. This kind of charge is usually pH dependent and is known to be responsible for anion exchange. Secondly anions can react with oxide or hydroxides forming inner sphere complexes.

3.3 Base Saturation

This expresses the % of the CEC composed of basic cations. It is mathematically expressed as: % base saturation = exchangeable base forming cations (cmol/kg) CEC (cmol/kg)

3.4 Flocculation

This is the process of aggregation of clay particles into microscopic chimps or floccules. Flocculation can be explained by the fact that clay has negative charges that attract positive ions from the soil solution. If two clay platelets come close enough to each other, the cations compressed in a layer between them will attract the negative charges on both platelets, thus serving bridges to hold the platelets together. Examples of flocculating materials are the polyvalent cations like Ca^{2+}, Fe^{2+}, Al^{3+} and humus.

3.5 Dispersion

This is the direct opposite of flocculation. Considering when Na^+ (rather than polyvalent cations such as Ca^{2+} or Al^{3+}) is a prominent adsorbed ion, the attractive forces are not able to overcome the natural repulsion of one negatively charged clay by another. The clay platelets cannot approach closely enough to flocculate, so remain dispersed.

3.5.1 Effect of Flocculation and Dispersion on Plant Growth

Stable aggregates can be formed only on soils containing clay that will flocculate, if it remains dispersed, the soil is puddle. Puddled soils are sticky when wet and hard when dry root growth and soil aeration require a porous condition in soils. A flocculating concentration of electrolytes should be maintained in the soil. To reach such a condition, the soil should be limed, although acidic soils high in Al are usually flocculated. Ca and Mg are known to have high flocculation powers on the negative clay particles and will reduce the toxic effect of high Al concentrations.

SELF-ASSESSMENT EXCERCISE
Name any four anions held on the exchange sites?

4.0 CONCLUSION

Cation Exchange Capacity, Anion Exchange Capacity, Base Saturation, Flocculation and Dispersion are important soil chemical processes that takes place in the soil.

5.0 SUMMARY

Cation exchange capacity (CEC), anion exchange capacity (AEC), soil reaction, base saturation flocculation and dispersion are important concepts in soil chemistry.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is cation exchange capacity of the soil?
2. What is the unit of measurement of soil CEC?
3. Why are soils with a high CEC considered to be more fertile than soils with a low CEC?
4. List three anions involved in anion exchange reactions in the soil.
5. What type of charge is responsible for anion exchange in soils?
6. Define soil flocculation.

7.0 REFERENCES/FURTHER READING

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UNIT 10 BUFFERING CAPACITY, SOIL SALINITY, ALKALINITY AND SODICTY

CONTENTS

1.0 INTRODUCTION

In this unit an attempt is made to explain some basic concept in soil chemistry. These are important soil chemical processes that takes place in the soil. They determine the soil properties and also affect the performance of the crops.

2.0 OBJECTIVE

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

- state the meaning and definitions of buffering capacity, soil salinity, alkalinity and sodicty.

3.0 MAIN CONTENT

3.1 Buffering Capacity of Soils

A buffer solution is defined as that which resists a change in pH on addition of acid or alkali. Buffer solutions contain compounds that react with both acid and base so that the H^+ ion conc in the solution remains constant. In soil, clay and humic fractions act as a buffer system. The potential acidity is in equilibrium with active acidity. If the active acidity is neutralised by the addition of lime, the potential acidity will release exchangeable H^+ ions into solution to restore equilibrium. Buffering capacity is greater in clay soil than in sandy soils.

3.2 Soil Alkalinity

The degree or intensity of alkalinity in a soil, expressed by a value >7.0 for the soil pH. A soil is described as alkali if (i) it has a a pH of 8.5 or higher or with an exchangeable sodium percentage greater than 0.15 (ESP>15). (ii) It contains contains sufficient sodium to interfere with the growth of most crop plants.

3.3 Alkaline Soils

These soils contain high exchangeable Na. If sodium is more than 15% of ions retained on the clay complex, the soil is then considered alkaline soil or sodic- soil. Such soils are very hard and cloddy when dry. In these soils water intake is severely restricted. The soil pH is often above 9 and sometimes plant imbalance occurs. The problem is solved by adding gypsum or $CaCl_2$ (faster but expensive).

3.4 Saline Soils

These soils have excessive amount of water soluble salts that adversely affect seed germination and plant growth. These salts are usually white in colour, chemically neutral and include Cl^-, SO_4^{2-} and sometimes NO_3^- of Ca, Mg, Na and K. No chemical amendment, conditioners or fertilisers will ameliorate this condition. The only remedy is leaching the salts beyond the root zone of crop.

A non-sodic soil so high soluble salt as to adversely affect the growth of most crop plants.
Salinity is measured in terms of electrical conductivity of soil extract. The lower limit of saturation extract electrical conductivity of such soils is conventionally set at 4 dS m-1(at 25°C).

3.5 Sodic Soil

A non-saline soil that contains so high a level of exchangeable sodium as to adversely affect crop production and soil structure under most conditions of soil and plant type. The exchangeable sodium percentage (ESP) of at least 15.

3.6 Saline-Sodic Soil

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

3.7 Saline-Alkali Soils

These contains high amount of soluble salts as well as more than 15% Na. It has the characteristics of the two sets discussed above. The problem is solved by leaching the soil with good quality water and adding gypsum or $CaCl_2$.

3.7.1 Measurement of Soil Salinity

This is achieved by making a saturated paste of the soil and measuring the electrical conductivity. This is expressed in terms of decisiemens per meter (dS/m) formerly millimhos per centimeter. (1dS/m = 1mmho/cm).

3.8 Some causes of Soil Salinity

1) Natural causes due to salty ground water andpoor soil drainage.
2) Man-made causes due to
   (a) usage of salty irrigation water
   (b) poor management of the soil.

The larger the buffer capacity, the larger the amount of lime needed to raise the soil pH to the desired level. Soil bc. can also be ability of the soil to act as a filter for dissolved and colloidal contaminants.
1 dS/m = 1 mmho/cm

SELF-ASSESSMENT EXCERCISE

What is a buffer solution?

4.0 CONCLUSION

Buffering capacity, soil salinity, alkalinity and sodicity are important soil chemical processes that takes place in the soil.

5.0 SUMMARY

Buffering capacity, soil salinity, alkalinity and sodicity are important soil chemical processes that takes place in the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the two buffer materials in the soil?
2. What are alkaline soils?
3. When is soil termed saline?
4. What is a saline-sodic soil?
5. List two man-made causes of soil salinity.

7.0 REFERENCES/FURTHER READING

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UNIT 11 SOIL REACTION AND LIME REQUIREMENT

CONTENTS

1.0 INTRODUCTION

The soil reaction measures the relative amount of acid or alkali in the soil. The amount of acid in the soil has implication on soil nutrients and also determines the ability and type of microorganisms that thrives in the soil. Hence, the soil reaction had indirect effect on the decomposition of organic material. It is measured by soil pH meter. Liming is aimed at solving the problem of soil acidity, with the application of some liming material that could be natural or synthetic. The details of soil pH and its implication in the soil will be discussed in this unit.

2.0 OBJECTIVE

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

- mention the different the definition of soil reaction
- discuss the causes of soil acidity
- discuss the importance of soil pH
- state the soil lime requirement and methods of its determination.

3.0 MAIN CONTENT

3.1 Soil Reaction

The degree of acidity or alkalinity is an important variable that affects all soil properties (chemical, physical and biological). Soil acidity is then total amount of acid present in the soil. The soil reaction is expressed as the soil pH, this is the measure of the relative acidity and alkalinity of the soil. Soil pH is defined as a measure of the hydrogen ion (H^+) concentration of the soil. It is the negative logarithm of the H+ concentration. There are four ranges that are informative viz: (1) pH < 4 indicates presence of free acids, (2) pH < 5.5 indicate occurrence of exchangeable Al (3) pH of 7.8-8.2 indicates presence of excess $CaCO_3$, (4) pH > 8.5 indicates the soil is with high exchangeable Na (Alkaline or sodic soils). The pH scale ranges from 1-14 but the soil pH varies between 3-9, a neutral soil has a pH of 7. At pH 7, the number of H^+ and OH^- are equal.

Active acidity is that measured by the soil pH while the **reserve** acidity is that left within the soil microcell, it is usually measured by titrating the soil solution with a base.

3.1.1 Causes of Soil Acidity

1) Leaching loss of bases like Ca, Mg, etc.
2) Application of acid-forming fertilisers e.g. urea, NH^{4+} based fertilisers.
3) Acid rain.
4) Decomposition of organic matter, CO2 is evolved, it mixed with soil water to form weak carbonic acid (H_2CO_3).
5) Hydrolysis of Al. $Al^{3+} + 3H_2O \quad Al(OH)_3 + 3H^+$.

3.1.2 Importance of Soil pH in Crop Production

1) It is useful in determining the availability of plant nutrients e.g. P is fixed by Al and Fe oxides at low pH, at high pH it is fixed by Ca. Therefore, P is available maximally at near neutral pH.
2) pH influences the availability in toxic amounts minerals and elements that may reduce crop growth (At low pH, Fe and Mn are present in toxic amount in soil).
3) It influences the population and activities of beneficial microbe.

3.2 Lime Requirement

Soil acidity is commonly decreased by adding carbonates, oxides or hydroxides of calcium and magnesium, these compounds are referred to as agricultural limes. Also wood ash are used locally to help control soil acidity.

Lime requirement is the amount of liming material required to bring about a desired pH change. (i.e., amount of lime required to raise a soil from one pH to a desired pH value). LR is determined by (1) the change in pH required (2) the buffer capacity of the soil (3) chemical composition of the liming material (4) finess of the liming materials.

3.2.1 Methods of Determining Lime Requirement

1) Field plot techniques (apply rates, plant and monitor for best yield and best rate performance.
2) Titration with a base (soil solution with a base).
3) Incubation studies (8 weeks with different rates of lime test for best pH.
4) Use of buffer like woodruff buffer, Adams and Evans, etc.

SELF-ASSESSMENT EXCERCISE

Name one local material useable as liming material?

4.0 CONCLUSION

The degree of acidity or alkalinity is an important variable that affects all soil properties (chemical, physical and biological). Soil acidity is commonly decreased by adding carbonates, oxides or hydroxides of calcium and magnesium, these compounds are referred to as agricultural limes.

5.0 SUMMARY

Soil acidity is an important property of the soil that can predict the chemical properties of the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is the qualitative definition of soil pH?

2. What is the quantitative definition of soil pH?
3. List three causes of soil acidity.
4. What is soil lime requirement?
5. Can the lime requirement of an acid soil be determined from the soil pH? Explain your answer.
6. If all the soil you tested for CEC had equal pH values, which would require the most lime to neutralise exchangeable acidity?
7. List the factors affecting lime requirement.

7.0 REFERENCES/FURTHER READING

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UNIT 12 ADSORPTION/DESORPTION

CONTENTS

1.0 INTRODUCTION

The three states of matter (solid, liquid and gaseous phases) could inter relate with each other without having one of the phases consumed by the other phase. Water could be held on the surface of a solid while gases could also be held on soil material. The same applies for dissolved soil nutrients and soil colloids. The nutrients in solution are held on the surface of colloids because of the differing charges (positive and negative charges). This surface phenomenon is called adsorption; this is opposed to absorption, where an entity penetrates the inner surfaces of the other phase. The release of adsorbed materials is called desorption. In this unit you will learn about the meaning of the concept of adsorption/desorption and the forces involved in the process.

2.0 OBJECTIVES

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

- define the meaning of adsorption/desorption
- Memtion the forces of adsorption.

MAIN CONTENT

Adsorption is the process of concentrating materials at the interphase of two phases. It may or may not lead to absorption, which is the penetration of component into the material when a distinction may not be made between these two processes, the term sorption is used. Adsorption may occur either on the surface of liquid or solid by a gas or liquid. Description is used to indicate the release or removal of materials that were adsorbed. The substance sorbed is called sorbate and the material in which sorption occurs is called sorbent.

stationary phase	**mobile phase**	**adsorption system**
liquid	liquid	liquid – liquid
solid	gas	liquid – solid gas – liquid gas – solid

2.1 Adsorption Characteristics

1) Adsorption is dependent not only on the surface charge but also on the surface area. The amount of material adsorbed is directly proportional to the specific surface.
2) Adsorption reactions are reversible and are equilibrium reactions i.e. adsorption and desorption are reversible.
3) Adsorption is characterised by a positive heat of adsorption, meaning that energy is released during the adsorption process.
4) Adsorption generally decreases as temperature increases i.e. adsorption is less at high temperature. This is caused by an increased kinetic energy of the molecules at higher temperature, which interferes with the concentrating process. In contrast, the rate of a real chemical reaction increases as temperature is increased. Therefore, these differences can be used to distinguish an adsorption process from a true chemical reaction, although a similar equilibrium can be reached.

3.2 Forces of Adsorption

Forces responsible for adsorption reactions include

1) Physical forces
2) Hydrogen bonding

3) Hydrophobic bonding
4) Electrostatic bonding
5) Coordination reaction
6) Ligand exchange.

4.0 CONCLUSION

Adsorption and desorption are reversible reactions. Cations are adsorbed on soil colloids and hence, made available to plant roots when needed. Desorption on the other hand is the detachment of the adsorbed materials from the colloidal complex.

SELF-ASSESSMENT EXCERCISE

When is the term sorption used in soil science?

5.0 SUMMARY

Adsorption and desorption are reversible reactions in the soil, they are dependent on several forces in the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is adsorption?
2. What is the effect of temperature on adsorption process?
3. List the forces of adsorption.

7.0 REFERENCES/FURTHER READING

Bear, F.E. (1964). *Chemistry of the Soil*. (2nd ed.). United States of America: Reinhold Publishing Corporation.

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UNIT 13 NUTRIENT UPTAKE BY PLANT ROOTS

CONTENTS

1.0 INTRODUCTION

For nutrients to be taken by the plant, it has to be in a soluble form and located very close to the roots of the plants. Some of the roots mass are very close to the soil particle that there is direct exchange of nutrients between them. However, when the close nutrients sink is exhausted, the questions becomes how will the root obtain additional nutrients from the soil. This is the focus of this unit, to explain how nutrients are taken by plant roots.

2.0 OBJECTIVE

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

- differentiate between the mechanisms by which nutrients are taken by plant roots.

3.0 MAIN CONTENT

Nutrient element must be in a soluble form and must be located at the root surface in order to be taken up by a plant. Often, parts of a root are in such intimate contact with soil particles that a direct exchange may take place between nutrient ions adsorbed on the surface of soil colloids and H^+ ions from the surface of root cell walls. There are three basic mechanisms by which the concentration of nutrient ions at the root surface is maintained.

3.1 Root Interception, this comes into play as roots continually grow into new, undepleted soil. Nutrient ions must also travel some distance in the soil solution to reach the root surface. This movement takes place by mass flow

3.2 Mass Flow, as when dissolved nutrients are carried along with the flowing soil water towards a root that is actively drawing water from the soil. On the other hand, plants can continue to take up nutrients even at night, when water is only slowly absorbed into the roots. Nutrient ions continually move by

3.3 Diffusion from areas of greater concentration toward the nutrient depleted areas of lower concentration around the root surface. Diffusion process, is independent of any mass flow of water in which the ions are dissolved.

Factors such as soil compaction, cold temperatures, and low soil moisture content, which reduce root interception, mass flow, or diffusion, can result in poor nutrient uptake by plants even in soils with adequate supplies of soluble nutrients.

Availability of nutrients can also be positively or negatively affected by microorganisms that thrive in the immediate vicinity of roots. Plant membrane separating the inside of the root cell from the soil solution is permeable to dissolved ions only under special circumstances. Nutrients is taken up when a chemical carrier molecule in the root cell membrane forms an activated complex with the nutrient and then travels across the membrane to the interior of the root cell before releasing the nutrient.

4.0 CONCLUSION

Soil nutrients are either scavenged for and intercepted by the roots before uptake or dissolved plant nutrients moves in the soil and then come in contact with root hairs (mass flow). Nutrients can also be taken through the movement of nutrients from area of high concentration to low concentration (diffusion).

SELF-ASSESSMENT EXCERCISE
What is mass flow?

5.0 SUMMARY

Nutrient uptake processes in plants are diffusion, mass flow and root interception.

6.0 TUTOR-MARKED ASSIGNMENT

1. List three ways by which plant uptake soil nutrients.
2. List factors that affect nutrient availability in soil.

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils*. (12th ed.). New Jersey: Prentice-Hall.

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MODULE 3 SOIL MICROORGANISMS

UNIT 1 SOIL ORGANISMS

CONTENTS

1.0 INTRODUCTION

All the organisms living within the soil are collectively termed soil life or soil biota. Soil organism is any organism inhabiting the soil during part or all of its life. Soil organisms range in size from microscopic cells that digest decaying organic material to small mammals that live primarily on other soil organisms. They play an important role in maintaining fertility, structure, drainage, and aeration of soil. They also break down plant and animal tissues, releasing stored nutrients and converting them into forms usable by plants.

This unit is dedicated to the classification and types of soil microorganism and their activities in the soil.

2.0 OBJECTIVE

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

- mention the types of soil organisms that exist, their classes and activities.

3.0 MAIN CONTENT

The soil is a very complex medium where many chemical, biological, biochemical, geochemical, biogeochemical and physical processes take place. The soil is also the medium where plants obtain most of their nutrients. The soil has a vast population of living organisms including micro and macro flora, micro and micro fauna, insects, etc.
The activities of some of these organisms are detrimental to plants, particularly the disease causing organisms.

The activities of most are however beneficial to crops particularly with regards to soil aggregation, nutrient cycling, biological nitrogen fixation, nutrient uptake, disease control/prevention and production of growth hormones.

These organisms interact with one another in the soil giving rise to diverse relationships/interactions such as symbiosis, parasitism, commensalism, protocooperation, neutralism, competition. The soil microorganisms constitute the highest populations of soil organisms and because of their enzymatic capabilities, they are more important in soil processes than other soil organisms.

3.1 Classification of Soil Microorganisms

Soil microorganisms can be classified based on physiology or nutrition, mode of respiration and origin

3.1.1 Physiological/Nutritional Classification

Microorganisms need food as sources of energy to enable them carry out their activities, for growth and multiplication. Microorganisms differ in their nutrition requirements, whereas some organisms can use the same source of food as carbon and energy, others require different sources.
On this basis microorganisms are divided into:

3.1.1.1 Autotrophs/Lithotrophs

These are organisms that can use CO_2as the sole source of carbon.
Based on the source of energy they are further classified as:

3.1.1.2 Photoautotrophs/Photolithotrophs

These are organisms deriving their energy from sun through the process of photosynthesis. Such organisms contain a pigment known as chlorophyll which enable them convert CO2to carbohydrate in the presence of sun energy, e.g. Algae.

3.1.1.3 Chemoautotrophs/Chemolitotrophs

These are organisms which derive their energy from carrying out biochemical oxidations. These organisms release energy from the reactions, e.g. oxidation of NH4+ to NO2- and NO2-to NO_3^- , Nitrosomonas sp, Nitrobacter sp.

3.1.1.4 Heterotrophs

These are organisms that organic compounds as their carbon and energy source. They derive both carbon and energy from the same source. Most of the microorganisms belong to this class, in addition to carbon other nutrients like N, K, P, Na, Mg, Ca, Fe, etc. which they need are obtained from organic matter.

3.1.2. Classification Based on Respiration

Based on mode of respiration, soil microorganisms can be classified as aerobes, anaerobes and facultative anaerobes.

3.1.2.1 Aerobes

These organisms require free oxygen for their respiration they cannot survive in the absence of oxygen. Most bacteria, all fungi and actinomycetes fall into this class.

3.1.2.2 Anaerobes

These organisms can grow optimally only in the absence of molecular oxygen, this group incorporates many bacteria, e.g. Clostridium.

3.1.2.3 Facultative Anaerobes

These organisms can survive either in the presence or absence of oxygen. Although they need oxygen, they do not necessarily need to have access to molecular oxygen. They can survive by extracting the required oxygen from an oxygen rich compound such as nitrates or sulfates, the compounds are reduced thus changing their availability to plants.

3.1.3 Classification Based on Origin of Microorganisms

Based on their origin bacteria are classified as:

3.1.3.1 Autochthonous or Indigenous Microorganisms

These are the original residents in the soil, their numbers are constant, they do not usually respond to additions of organic matter and they grow very slowly. They may have developmental stages used to endure in soil for a long period without being active metabolically.

3.1.3.2 Allochthonous or Zymogenes or Invaders

These microorganisms develop under the influence of specific soil treatments such as addition of organic matter, fertilisation or aeration. They do not contribute significantly to soil processes.

Transient microorganisms: These microorganisms are introduced into the soil intentionally e.g. Rhizobium sp, mycorrhizal fungal or unintentionally, e.g. through diseased plants. They die rapidly or may survive in the soil for a period of time in the presence of host plant or animal

4.0 CONCLUSION

Soil organism is any organism inhabiting the soil during part or all of its life. They range in size from microscopic cells that digest decaying organic material to small mammals that live primarily on other soil organisms. They play an important role in maintaining fertility, structure, drainage, and aeration of soil. Soil microorganisms can be classified based on physiology or nutrition, mode of respiration and origin.

SELF-ASSESSMENT EXCERCISE

What is soil organism?

5.0 SUMMARY

Soil micro-organisms play an important role in maintaining fertility, structure, drainage, and aeration of soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the beneficial effect of soil microbes to plants.
2. What are photoautotrophs?
3. What are facultative anaerobes?
4. What are transient microorganisms?

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils* (12th ed.). New Jersey: Prentice-Hall.

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UNIT 2 BACTERIA

CONTENTS

1.0 INTRODUCTION

Bacteria are microscopic and play important role in maintaining fertility, structure, drainage, and aeration of soil. They also break down plant and animal tissues, releasing stored nutrients and converting them into forms usable by plants.
This unit is dedicated to the classification and types of soil bacteria and their activities in the soil.

2.0 OBJECTIVE

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

- state the types of soil bacteria that exist, their classes and activities.

3.0 MAIN CONTENT

These are unicellular organisms without organelles or nucleus they are one of the simplest forms of life. The size ranges from 1-5 microns. The shape varies from cocci (round shaped), to bacilli (rod shaped) and to spiral.
In terms of population they probably the most numerous microbes whose population range from a few hundreds to 3 billion per gram soil.
They are very versatile in their metabolic activities some can use simple inorganic materials as energy source while other are heterotrophic. Some bacteria need oxygen for their respiration others are anaerobic and some can adapt to presence or absence of oxygen.

3.1 Importance

1. Bacteria are very important in the general decomposition of organic matter in soil.
2. They carry out specific functions important in nutrient cycling such as nitrification.
3. A group of bacteria are important in nitrogen fixation- conversion of atmospheric nitrogen to plant available forms.
4. Some soil bacteria cause diseases.

3.2 Growth Conditions

Bacteria can survive under diverse environmental conditions.
Optimum pH condition for bacteria growth is slightly acidic to neutral, however some groups survive under highly acidic conditions and they are termed acidophilic bacteria.

The optimum temperature range for most bacteria is 25 to 35^{o}C and these are termed mesophiles, however, some are able to tolerate extreme temperatures these are Psychrophiles (0 to 20^{o}C) and Thermophiles (40 to 65^{o}C).

4.0 CONCLUSION

Bacteria are single cell organisms in the soil; they are the most abundant in the soil and very important for many soil processes. They can survive in diverse environmental conditions.

SELF-ASSESSMENT EXCERCISE
Name the shapes of bacteria?

5.0 SUMMARY

Bacteria are important soil microorganism.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the importance of bacteria.
2. What are acidophilic bacteria?

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils* (12th ed.). New Jersey: Prentice-Hall.

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UNIT 3 FUNGI, ACTINOMYCETES AND ALGAE

CONTENTS

1.0 INTRODUCTION

Fungi, actinomycetes and algae are microscopic and play important role in maintaining fertility, structure, drainage, and aeration of soil. They also break down plant and animal tissues, releasing stored nutrients and converting them into forms usable by plants.
This unit is dedicated to the classification and types of soil bacteria and their activities in the soil.

2.0 OBJECTIVE

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

- state the types of soil fungi, actinomycetes and algae that exist, their classes and activities.

3.0 MAIN CONTENT

3.1 Fungi

They have well developed organelles including nuclei, mitochondria, they are more developed than bacteria. The most important characteristic of fungi is the possession of a filamentous body consisting of strands of hyphae. The mycelium can be sub-divided into cross-wall called septa, however there many non-septate fungi.

They about 5 μm in diameter the population range between 0.1 – 1 million propagules per gram of soil. Almost all fungi are heterotrophic in nature and all are aerobic thus they do not occur in diverse environment as bacteria.

3.1.1 Importance

1. Fungi are important in decomposition of organic residues in soil.
2. They are especially important in decomposing woody material which many bacteria cannot decompose.
3. They are important in processes leading to humus formation.
4. They play important roles in the formation of stable aggregates in soil.
5. Some soil fungi cause plant and animal diseases.
6. Some fungi form symbiotic association with roots of higher plants.

3.2 Actinomycetes

Structurally, these organisms lie between bacteria and fungi, they bear similarity to bacteria in terms of cell size and structure characteristic and they are filamentous organisms like fungi.
They are the next populous in soil after bacteria, the number ranging from 10^5- $4x10^6$
cell/g of soil. The organisms prefer moist and well aerated soil. They are sensitive to acidic condition, optimum pH ranging from 6 – 7.5.

3.2.1 Importance

1. They are important in decomposition of organic matter, especially cellulose, chitin and
phospholipids.
2. Some actinomycetes produce antibiotics e.g. Streptomyces sp.
3. Some actinimycetes cause plant diseases e.g. potato scab disease.

3.3 Algae

These are sub-divided into two groups:

1. Green algae (True algae)
2. Blue-green algae (Cyanobacteria)

Morpologically, the true algae have nucleus, cell wall compose mainly of cellulose and chloroplast distributed within the various organelles.
The blue-green algae do not possess nucleus, cell wall compose of a substance call muramic acid. They have a blue pigment called Phycocyanin distributed throughout the cytoplasm.
Nutritionally, algae are autophototrophic.

3.3.1 Importance

1. Some algae are capable of nitrogen fixation, these can be especially important in some ecological condition e.g. rice paddies.
2. They form symbiotic associations with fungus (lichens) and fresh water fern (azolla). Lichens
3. They are important in early stages of pedogenesis while azollas are important in fertility management of rice paddies.

4.0 CONCLUSION

Fungi are more developed than bacteria and have hyphae. Almost all fungi are heterotrophic in nature and all are aerobic thus they do not occur in diverse environment as bacteria.
Actinomycetes have similarity with bacteria in terms of cell size and structure characteristic and they are filamentous organisms like fungi. The major division of algae is: (1) Green algae (True algae) (2.) Blue-green algae (Cyanobacteria).

SELF-ASSESSMENT EXCERCISE

What is the optimum pH range for actinomycetes?

5.0 SUMMARY

Fungi and actinomycetes are important microbes in the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. Mention one major characteristic of fungi.
2. What are the importances of fungi?
3. What are the importances of actinomycetes?
4. What are the importances of algae?

7.0 REFERENCES/FURTHER READING

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UNIT 4 NEMATODES, EARTHWORMS AND TERMITES

CONTENTS

1.0 INTRODUCTION

Nematodes, earthworms and termites are some other organisms that dwell in the soil. Nematodes are microscopic while earthworm and termites can be seen with the naked eyes. The affect crops and thus have interactions with the soil. This unit is dedicated to the explanation of their activities in the soil.

2.0 OBJECTIVE

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

- state the different their activities of nematodes, earthworms and termites in the soil.

3.0 MAIN CONTENT

3.1 Nematodes

These are of microscopic size they are like worms round and spindle-like in shape.
The importance of nematodes in soil is not all that related to soil fertility but that some are pathogenic to some agricultural crops. They usually infect the roots of such plants thereby interfering with normal physiology and

obstructing water and nutrient uptake. The plants infected are mostly horticultural crops like tomatoes, carrots, ornamental and fruit trees.

3.2 Earthworms

These are the first known larger animals in the soil. They thrive best in moist soil with abundant supply of organic matter. They are very important in the fertility of the soil because they aid in humus formation by in jesting some organic debris and later egesting same as worm cast. The worm cast usually contains high amounts of organic matter, N, Ca, Mg and P.
Earthworms help in the process of soil formation by building new top soil every year. Study has shown that earthworms contribute about 2 cm thick layer of soil every 10 years.
Earthworm is also important because of the burrowing activities the channels they leave behind are very effective in surface drainage and aeration. Earthworm also helps to improve soil water infiltration thereby preventing erosion.

3.3 Termites

The presence of termites is one of the characteristics of most tropical soils. Termites exhibit very great diversity in their feeding habits; some feed on organic residues, some on wood and some cultivate fungi in their nest.

There are different forms of termite nests, some build huge nests about 3 meters in height and 12 meters in diameter. The population of nests per hectare can be very high, in some cases they can make up to 20 % of the landscape and as many as 3,000 per hectare especially during rainy season.

Importance: This is under physical, chemical and pedological aspects of the soil.

3.3.1 Physical Effects

1. They carry only finer particles, thereby leading to increase in the finer structure of the soil.
2. The mound materials are more stable and better aggregated than the surrounding soil thus
affecting the structure of the soil.
3. Because of the numerous underground channels they create, the bulk density of the soil is
reduced.

4. Also because the mound contains finer particles like clay and high organic matter, the water holding capacity is increased.

3.3.2. Chemical Effects

1. The soil pH is higher in the mound material because of accumulation of $CaCO3$.
2. Organic matter is higher than in adjacent soil.
3. The termite mound contain higher amount of Mg, P, Ca and K, thus important in soil fertility.

3.3.3 Pedological Effect

1. The activities of termites in bringing finer particles from the sub-soil to the surface contribute to formation of gravel and soil free horizon.
2. Up to 560 kg per hectare per year of soil materials can be turned over through the activities of termites, thus helping in soil formation.
3. It has been shown that activities of termites lead to the formation of 3 cm thick of soil every 100 years.

4.0 CONCLUSION

Nematodes are microscopic, worm like or spindle-like soil organisms. They interfere with normal physiology of plant and obstruct water and nutrient uptake. Earthworms are larger, very important in the fertility of the soil because they aid in humus formation. Termites have physical, chemical and pedological effect on the soil.

SELF-ASSESSMENT EXCERCISE

Give a brief description of soil nematode.

5.0 SUMMARY

Most nematode is parasitic microbes in soil while earthworms are important in soil fertility.

6.0 TUTOR-MARKED ASSIGNMENT

1. Mention the effect of nematodes on plants.
2. What is worm cast?
3. Mention two physical effect of termite on the soil.

7.0 REFERENCES/FURTHER READING

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UNIT 5 REACTIONS OF NITROGEN AND PHOSPHORUS IN THE SOIL

CONTENTS

1.0 INTRODUCTION

The atmosphere contains 70 % N_2 gas and it is required in large quantities by crops, the N_2 gas is not normally available except to some leguminous plant by virtue of their N fixing apparatus (root nodule). This element is the most likely to be deficient as far as crop production is concerned. Nitrogen is a major element in the soil needed in large quantities in the soil. It is a soil nutrient that undergoes different reactions in the soil depending on the soil conditions. Phosphorus is less abundant in plant in relation to nitrogen. It is taken by plant as $H_2PO_4^-$ or HPO_4^{2-}. Phosphorus is involved in energy transfer reactions, cell-division, and conversion of sugar to starch, flowering and fruiting. It gives resistance to certain diseases and assists in root development especially lateral and fibrous root. The unit discusses about the various reaction by N and P in the soil system and the importance of the nutrients in plant nutrition.

2.0 OBJECTIVES

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

- state the different N and P reactions in the soil
- discuss the soil conditions that affect the type of soil N and P reactions.

3.0 MAIN CONTENT

3.1. Nitrogen

The major form of N in the soil is the organic form, about 95% of total N in the soil is in organic combinations as amino-acids, nucleic acid, nucleoproteins. The inorganic N constitutes only about 5-6% of total soil N, they are inform of NO_3^-, NH_4^+ and NO_2^-. The inorganic forms could also be present in exchangeable form, also in fixed form, or in solution. Nitrogen, N, stimulates leaf and stem growth. Nitrogen deficiency causes reduced growth and pale yellowish green leaves. The older leaves turn yellowish first since the nitrogen is readily moved from the old leaves to the new growth. If the soil is cold and wet, nitrogen in the soil is not as available to the plants. Excess nitrogen may cause potassium deficiency.

3.1.1 Sybiotic Fixation

Legumes and free living microbes that lives in the soil are able to fix atmospheric nitrogen in the root nodules of most legumes. Rhizobium and bradyrhizobium are the two genera responsible for the fixation of N.

3.1.2 Ammonification

There is the need to convert the organic form of N to inorganic form through a series of biochemical process known as N-mineralisation. This is the first, it's the conversion of organic matter, amines, amino acids to ammonium. This is affected by heretotrophic general purpose organisms, usually facilitative anaerobes. Ammonification also includes the hydrolysis of urea-N.

3.1.3 Nitrification

After the conversion of amino (NH_2) group to NH_4^+ form, there is conversion of NH_4^+-N to NO_3-N by soil bacteria. The organisms involved are the nitrifying bacteria, usually autotrophic aerobes.

3.1.4 Denitrification

This is an avenue for loss of N usually in poorly aerated soils. NO_3-N is converted to atmospheric nitrogen and therefore lost to the atmosphere.

3.1.5 Immobilisation

When crop residue is relatively high in C in relation to N, available NH_4^+ or NO_3^-N is temporarily tied-up or immobilise by bacteria that decompose crop residues.

3.1.6. Other Reactions

(1) N fixation viz; NH_4^+. This could react with 2:1 clay and then got trapped inside the layers e.g. chlorites, illite, vermiculite.
(2) Volatilisation of NH_3.
(3) Leaching loss/Erosion loss

3.2 Phosphorus

Phosphorus, P, is important in the germination and growth of seeds, the production of flowers and fruit, and the growth of roots. Phosphorus deficiency causes reduced growth and small leaves that drop early, starting with the oldest leaves. Leaf color is a dull, bluish green that becomes purplish or bronzy. Leaf edges often turn scorched brown. Excess phosphorus may cause potassium deficiency. About 50% of soil P are in organic form, 50% is also in inorganic forms. Organic P includes phospholipids, nucleoproteins, inositols, nucleic acid, etc.Inorganic P is found as definite PO_3^{2-} compounds and surface films of PO_3^{2-} held on inorganic particles. Definite phosphates are, monocalcium phosphate, dicalcium PO_3^{2-}, tricalcium PO_3^{2-}, hydronylapatite ($Ca_{10}(PO_4)_6OH_2$), floro apatite $a_{10}(PO_4)_6$ F_2, $Ca_3(HPO_4)_2$, Fe & Al PO_3, occluded PO_3^{2-}, solution PO_3^{2-}

3.2.1 Phosphorus Reactions

Acid soils favours accumulation of Fe, Al and Mn. In strongly acid soil PO_3 is most abundant as $H_2PO_4^-$. This reacts with Fe, Al, Mn to form insoluble phosphate.
This makes P unavailable in acid soil.

In alkaline soil P is in the form HPO_4^{2-} (pH 6.5-8.5), in such soils Ca & Mg are dominant in the exchange site. Hence, they react with PO_3^{2-} to form an insoluble compound.
P is maximally available at near neutral pH. P deficiency is noted by purplish colouration of leaves (P is immobile in soil but mobile in plant). Hence, the effect is shown more in older leaves. Other symptoms are stunted growth and delayed maturity. Practical control of P availability includes (1) control of pH by liming (2) Band application (2.5cm to plant) and addition of O.M. (disperse) PO_3^{2} since it's negatively charged.

4.0 CONCLUSION

Nitrogen and phosphorus is not stable in the soil. They undergo myriads of conversions in the soil, depending on soil conditions. Nitrogen undergo fixation, ammonification, nitrification, denitrification, immobilisation, etc., while phosphorus mainly undergoes fixation reactions in the soil.

SELF-ASSESSMENT EXCERCISE

Give two genera of bacteria responsible for N fixation in root nodules?

5.0 SUMMARY

Reactions of N and P in the soil are very important at determining soil fertility.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is nitrogen mineralisation?
2. What organism is responsible for ammonification?
3. What is denitrification?
4. What are the soil cations responsible for P fixation in acidic and alkaline environments?

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils* (12th ed.). New Jersey: Prentice-Hall.

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MODULE 4 SOIL ORGANIC MATTER

Unit 1 Soil Organic Matter
Unit 2 The Role of Organic Matter in Tropical Soils

UNIT 1 SOIL ORGANIC MATTER

CONTENTS

1.0 INTRODUCTION

Soil Organic Matter (SOM) determines soil nutrient level, it determines the amount of other cations such as K, Ca, Mg and micronutrients as Zn, Bo, Cu and anions like PO_4^{3-}, NO_3^-, Cl^-. The SOM consists of fresh organic material and humus. The fresh organic material is transformed by soil organisms into humus. In the process, nutrients are released into the soil. Humus itself is also broken down by the soil organism, which releases even more nutrients. Cropping with hoe and cutlass or mulching fairly maintains soil organic matter. This unit deals with the explanation of the meaning of soil organic matter, its importance in the soil and its disadvantages, types of soil organic matter, and ways of maintaining soil organic matter.

2.0 OBJECTIVES

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

- define and explain soil organic matter
- state the disadvantages of soil organic matter.

3.0 MAIN CONTENT

Soil organic matter consists of a wide range of organic substances including living organism, carbonaceous remains of organisms which once occupied the soil and the compound produced by current and past metabolism in the soil. Although the importance of Organic matter has been realised from time immemorial, its need have become even more relevant in modern times due to the following reasons:

1. Ever increasing cost of commercially manufactured fertilisers.
2. Increasing organic residue from both crop and the farms.
3. Greater awareness of the need for ecological conservation of resources and environmental safety.
4. Introduction of zero/minimum tillage practices to promote high soil organic matter hence, promoting high yield.
5. Greater agricultural production from both crop and livestock to meet the nutritional and fibre news of the population.

Organic matter is an active and important portion of the soil. Although most cultivated soils contain 1-5% soil organic matter in the top 25cm, it can still modify the soil physical properties and strongly affect the chemical and biological properties. Chemically, it is nearly the only source of N, 5-60 % P, 80 % S and major part of Mo, B and many other micronutrients. It is undergoing constant changes and there is need to constantly and replenish it to maintain soil fertility and crop production.

3.1 Disadvantage of Organic Matter

1. It may provide the source of pathogens for root borne diseases, nematodes, insects, etc.
2. Crop residues low in N and other essential nutrients can result in immobilisation of the available nutrients and therefore affect their uptake for crop growth.
3. Toxic levels of some substances can be released early in organic matter decomposition and this may affect crop growth.

Most of the organic matter derived from nature originated from the CO_2 of the air (through photosynthesis). Organic materials (crop and animal residue) and many of the simple proteins are decomposed very quickly by soil bacteria and fungi, fats and oils decomposed next followed by cellulose and lignin. The most resistant are crude protein and the lignins which remain as a dark brown to dark grey organic matter called humus. Humus impacts or gives a soft feel or friable consistency to all soils.

Microorganisms get their energy and nutrients by 'eating' (decomposing) soil organic matter, these decomposition results in:

1. The use of some of the carbon, nitrogen and other elements by the microorganism.
2. Release of CO_2, water and other elements to the soil solution or atmosphere.
3. Humus.

Bacteria and fungi are the most active organic matter decomposers but are aided by actinomycetes. Bacteria and fungi work optimally in moistened soils at temperature of about 35^{o}C and soils of neutral pH. Organic matter that is still undergoing considerable decomposition is referred to as active organic matter. Active organic matter releases more nutrients than the less active organic matter (humus). Besides, it releases a lot of gums for cementing particles to form stable soil aggregates (desirable soil structure). These underscore the need for the continuous addition of active organic matter to ensure continuous supply of polysaccharides (gum) because these are depleted within a year in the soil.

4.0 CONCLUSION

Soil organic matter is a major source of soil nutrients. Organic matter is an active and important portion of the soil. It can modify the soil physical properties and strongly affect the chemical and biological properties. It is undergoing constant changes and there is need to constantly and replenish it to maintain soil fertility and crop production. There are also some disadvantages of soil organic matter.

SELF-ASSESSMENT EXCERCISE

What is the optimal temperature and soil moisture at which bacteria and fungi thrive?

5.0 SUMMARY

Soil organic matter is the store house of soil nutrients.

6.0 TUTOR-MARKED ASSIGNMENT

1. Why is soil organic matter relevant in the present day study?
2. List the disadvantages of organic matter.

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils* (12th ed.). New Jersey: Prentice-Hall.

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UNIT 2 THE ROLE OF ORGANIC MATTER IN TROPICAL SOILS

CONTENTS

1.0 INTRODUCTION

The soils of the tropics are generally of low fertility. This is partly because the soil is composed of low activity clays that are not very rich in cation exchange sites. Hence, one of the major ways of increasing the cation exchange capacity of the soil and soil fertility is to add organic matter. There are various benefits of the addition of organic matter to the soil and some will be explained in this unit. This unit deals with the explanation of the roles of organic matter in tropical soils.

2.0 OBJECTIVES

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

- explain the roles of soil organic matter in tropical soils
- mention the types of soil organic matter
- mention the ways of maintaining soil organic matter.

3.0 MAIN CONTENT

3.1 Roles of Soil Organic Matter

1. Organic matter functions as an exchanger or sorption agent. Especially in kaolinitic soils with naturally very low CEC. Organic matter contributes to the storage and release of nutrient ions. On

acidic, weathered soils, organic matter is responsible for almost the entire CEC.

2. On soils with low mineral exchange capacity, organic matter functions as a buffer system for the pH-value and ion concentration. It regulates the balance of nutrients in the soil solution.
3. Organic matter is the product of a 'bio-accumulation' of nutrients in the topsoil. It is therefore a nutrient carrier because the small amounts of Ca and Mg and the available P in the oxisols and ultisols of the humid tropics and moist savannas are concentrated in the humic topsoil.
4. Organic matter also works as a slow-release source of nutrients thereby reducing the risk of leaching.
5. On sites that have a tenency for Fe or Al toxicity, humifying organic matter works to combat toxic metal concentrations by forming stable complexes with a high molecular weight.
6. Organic matter improves the waterholding capacity of soils. Organic matter can hold up to 3-5 times its own weight in water.
7. Organic matter improves structure. Humus contributes to the formation of aggregates. The clay-humus complexes are a good protection against wind and water erosion and help promote permeability while simultaneously improving water storage.
8. Organic matter is essential as a habitat and source of nutrients for microorganisms and for soil fauna as earthworms and termites.

3.2 Types of Organic Matter

1. ***Crop residue*****:** These are materials after harvest and residues left on the soil. It includes straw, stalks and roots.
2. ***Green manure*****:** Leguminous crops are used for this, e.g. mucina, crotolaria, cowpea, soybean, etc. Usually, they are fast growing with a lot of vegetative cover and incorporated green into the soil.
3. ***Animal manure*****:** The wastes, it could be solid or liquid e.g. poultry-droppins, piggery droppings, livestock dung, etc.
4. ***Sewage sludge*****:** Municipal wastes. These can be treated, concentrated and made into commercial fertilisers.
5. ***Compost*****:** Combination of the manure, sewage sludge, leaves, grass, cuttings, etc.
6. ***Peal*****:** Naturally occurring organic material that has accumulated over many years in wet and cool places. It can be used as mulches or soil conditioners.

3.3 Maintenance of Soil Organic Matter

All efforts must be made to maintain soil organic matter, although continuous cropping tends to reduce its level.

1. Crop residue incorporation (not bush burning).
2. Conservation cropping systems as zero tillage, minimum tillage.
3. Use of animal manure.
4. Alley cropping (strips of arable crops interspersed with leguminous shrubs.
5. Use of compost.
6. Green manuring.
7. Mulching.
8. Encouraging and using natural symbiots e.g.
   (a) Vesicular-arbuscular mycorrhiza (VAM)
   (b) Biological nitrogen fixation.
9. Fallowing.

4.0 CONCLUSION

Organic matter plays a very important role in the soils of the tropics. Organic matter could be sourced from both plant and animal origin. There are various ways of maintaining soil organic matter.

SELF-ASSESSMENT EXCERCISE
Name two basic source of soil organic matter?

5.0 SUMMARY

Organic matter is an important soil property. Its management and maintenance is important in the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the roles of soil organic matter in tropical soils.
2. What is green manuring?
3. Mention five ways of maintaining soil organic matter.

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (1999). *The Nature and Properties of Soils* (12th ed.). New Jersey: Prentice-Hall.

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