COURSE GUIDE

SLM 501
ADVANCED SOIL FERTILITY

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Printed 2020

ISBN: 978-978-970-166-7

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INTRODUCTION

SLM 501 focuses on the study of the fertility of Soils, and it is designed for undergraduate students studying Agriculture and those who need a basic knowledge of the fertility status of the soil because of their passion for farming. The course has twenty-five units, divided into five broad subject areas, starting with background knowledge of soils and soil fertility, including its importance in plant growth and development; essential nutrient elements in soil fertility which includes: roles, deficiency and toxicity symptoms, and ways by which they are transported in soil and taken up by plants and the factors.

The course also exposes you to soil acidity and basicity reactions in soil fertility; soil fertility evaluation and soil fertility management practices. These topics therefore will help to improve the understanding required to provide a foundation for the inter-disciplinary approaches that will continue to provide exciting new ideas in the field of agriculture.

You are encouraged to devote, at least, two hours studying each of the twenty - five units. You are also advised to attempt the self-assessment exercises as they are important for better understanding of the units. You are advised also to pay attention to the Tutor-Marked Assignments (details provided in a separate file).

There will be tutorial classes. Details of location of the tutorials and time will be made known to you; this is a great opportunity for you to have direct contact with your course coordinator. Areas not understood in the course of study will be properly explained.

WHAT YOU WILL LEARN IN THIS COURSE

SLM 501 course focuses or lays emphasis mainly on the fertility status of the soil and ways to improve it for better plants growth and development that will result to increased yield and better livelihood which is the farmer’s ultimate goal. An understanding of this course is important to further understanding agricultural and environmental impacts on plant life.

In this course, the overall aim is for you to have an insight into the various fertility approaches important for plant growth and development and the criteria for determining how essential the soil nutrient elements are to plant life (essentiality). You will also learn about the role of soil nutrient elements; their deficiency and toxicity symptoms, ways by which they are transported in soil and taken up by plants. Also, you will learn the effects of the different soil reactions on the fertility of the soil;

how to evaluate the fertility of the soil; and various soil fertility management practices.

COURSE AIMS

The overall aim of this course is for you to have a comprehensive knowledge of the importance of soil fertility for plant growth and development. The aim of the course will be achieved by:

- exposing you to the meaning of soil and soil fertility
- discussing the importance of soil in soil fertility
- discussing the difference between soil fertility and soil productivity
- explaining the essential soil nutrient elements required by plants and their forms in soil
- discussing the movement of nutrient elements in soil and uptake by plants
- describing the factors affecting soil nutrient element availability in the soil environment.
- describing the effects of soil reactions on the nutrient elements in soil fertility
- explaining the meaning of soil fertility evaluation and their approaches
- discussing the management practices in soil fertility

COURSE OBJECTIVES

To achieve the above mentioned aims, the course sets up objectives given as units. In addition, each unit has its specific objectives. The unit objectives are given at the beginning of the unit; you should read them before you start working through the unit. You may also want to refer to them during your study of the unit so as to check on your progress. You should always look at the unit objectives after completing a unit. By this, you can be sure that you have done what was required of you by the unit.

Below are the broader objectives of the course, as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole. On completion of the course, you should successfully be able to:

- define soil and soil fertility and classify the soil types
- discuss the major essential soil nutrient elements for plant growth and development and the criteria for determining essentiality
- discuss the functions, deficiency and toxicity symptoms and their correction

- explain soil nutrient element movement in soil and uptake by plant
- discuss the effects of soil acidity in soil fertility
- discuss the effects of soil basicity in soil fertility
- explain liming and liming materials
- discuss the various soil types obtained under these soil reactions – salinity and sodicity
- define soil fertility evaluation and enumerate the various approaches
- discuss the factors affecting soil fertility evaluation
- explain ways to maintain soil fertility

WORKING THROUGH THIS COURSE

To complete this course, you are required to read the study units, as well as other related materials. Each unit contains self-assessment exercises, and at certain points in the course, you are required to submit assignments for assessment purposes. At the end of the course, you are going to sit for a final examination. The course should take you about 18/ 21 weeks in total to complete. Below you will find listed all the components of the course, what you have to do and how you should allocate your time to studying the course.

COURSE MATERIALS

The major components of the course include the following:

1. Course Guide
2. Study Units
3. Textbooks and References
4. Assignment file
5. Presentation schedule

STUDY UNITS

There are twenty-five (25) study units in this course as follows:

Module 1 Soils and Soil Fertility

Unit 1 What is Soil?
Unit 2 Types of Soil in the Nigerian Savanna
Unit 3 What is Soil Fertility?
Unit 4 Relationship between Soil and Soil Fertility
Unit 5 Importance of Soil Fertility in Agriculture
Unit 6 What is Soil Productivity?

The first six units, center on soil and soil fertility and its importance in Agriculture, relationship between soil, soil fertility and soil productivity **- Module 1**. The next four units address the soil nutrient elements, their essentiality and factors affecting their availability **- Module 2.** Units 11-14 highlights soil acidity, basicity, liming, liming materials, salinity and sodicity– **Module 3** and **Module 4** comprising of units 15 – 18 deals with soil fertility evaluation; while **module 5** having units 19 – 25 deals with the soil fertility management practices.

REFERENCES AND FURTHER READING

Experience in teaching this subject has shown that you often stumble on many new terms that are introduced during the course of study. To help you overcome this obstacle, a comprehensive description or explanation of crop mineral nutrition terms is given under each unit or where appropriate. You should note that bolded terms in each unit are defined in the text. Recommended textbooks and references are listed below:

Advantages of Irrigation- www.civileblog.com

Brady, N.C. & Weil, R.R. (2007).*The Nature and Properties of Soils.*(13th ed.). Upper Saddle River, NJ : Prentice Hall. p 881.

Chude, V.O; Malgwi, W.B; Amapu,I.Y & Ano, O.A).(Ed). (2004) *Manual on Soil Fertility Assessment*. Federal Fertilizer Department (FFD) in collaboration with National Special Programme for Food Security, FAO, Abuja, Nigeria. p48.

Chude, V.O; Olayiwola, S.O; Osho, A.O & Daudu, C.K.(Ed.). (2011). *Fertiliser Use and Management Practices for Crops in Nigeria.*. Federal Fertiliser Department (FFD) in collaboration with National Special Programme for Food Security, FAO, Abuja, Nigeria. p45.

Foth, D. H. (1990). *Fundamentals of Soil Science*. (8th ed.)..John Wiley andSons Inc. p384.

Irrigation-Wikipedia: https://en.m.wikipedia.org

Irrigation-Agriculture Victoria (April 2018). agriculture.vic.gov.au

Irrigation-Importance of Irrigation School Mattazz (2016). www.schoolmattazz.com

Maier, R. M; Pepper, I. L & Gerba, C. P. (2009). *Environmental Microbiology*. San Diego, California : Academic Press, p589.

Marschner, H. (1995). Mineral Nutrition of Higher Plants.|(2nd ed.). San Diego, California: Academic Press. p889.

Raina, M.M., Ian, L.P. & Charles, P.S. (2009). *Environmental Microbiology*. (2nd ed.). Elsevier Academic Press.

Sanginga, N. & Woomer, P.L. (2009). *Tropical Soil Biology and Fertility*. Institute of the International Centre for Tropical Agriculture (TSBF – CAT). Nairobi, p263.

Sanchez, P.A.(n.d.). *Management of Soils in the Tropics.*

Tisdale, S.L.; Nelson, W.L.; Beaton, J.D. & Havlin, J.L. (2003). *Soil Fertility and Fertilisers*. (5th ed.). New Delhi,India . Prentice-Hall.p634.

Troch, F.R. & Thompson, L.M. (2005). *Soils and Soil Fertility*.(6th ed.). Wiley – Blackwell. p.498.

ASSIGNMENT FILE

In this file, you will find the details of the work you must submit to your tutor for marking. The marks you obtain will form part of your total score for this course.

ASSESSMENT

There are two aspects to the assessment of this course. The first being the Tutor-Marked Assignments (TMA) and the second the final written examination. You are advised to attempt the exercises as this will help you apply the information, knowledge and techniques learnt during the course.

The assignments must be submitted to your tutor for formal assessment in accordance with the deadlines stated in the presentation schedule and assignment file. The work you submit to your tutor for assessment will count for 30% of your total course mark. At the end of the course, you will sit for a final examination; this examination will count for 70% of your total course mark.

TUTOR-MARKED ASSIGNMENT

You are advised to submit your assignments as required. Each assignment counts for 6% of your marks for the course. You should be able to complete your assignment from the information obtained from the study units and other recommended texts. However, it is advisable that you research more and study other references as this will give you a broader view point and many provide a deeper understanding of the subject.

When you complete each assignment, send it to your tutor. Make sure that each assignment reaches your tutor on or before the deadline given in the presentation schedule and assignment file. If for any reason, you cannot complete your work on time, contact your tutor to discuss the possibility of an extension. Extensions will not be granted after the due date, except for exceptional circumstances.

FINAL EXAMINATION AND GRADING

The final examination for this course will take three hours and have a value of 70% of the total course grade. The examination will consist of questions which reflect the types of self-assessment exercises and tutor-marked assignments you have previously encountered. All areas of the course will be assessed. Take time to revise the entire course before the examination. The examination covers all parts of the study units.

PRESENTATION SCHEDULE

Your course materials give you important dates for attending tutorials and the timely completion and submission of your Tutor-Marked Assignments. Remember that you are required to submit all assignments by the due date. Please guard against lagging behind in your work.

COURSE MARKING SCHEME

The following table shows how the marking scheme is divided.

Table 1: Course Marking Scheme

Assignment	**Marks**
Assignments 1 – 5	Five assignments count 6% each = 30% of course marks
Final examination	70% of overall course marks
Total	**100% of course marks**

COURSE OVERVIEW

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

Table 2: Course schedule

Units	**Title of Work**	**Weeks activity**	**Assessment (End of each module)**
	Course Guide		
	Module 1: Soils and Soil Fertility		
1	What is Soil?	1	Assignment 1
2	Types of Soil in the Nigerian Savanna	1	

3	What is Soil Fertility?	1	
4	Relationship between soil and soil fertility	1	
5	Importance of soil fertility in Agriculture		
6	What is soil productivity?		
Units	**Title of Work**	**Weeks activity**	**Assessment (End of each module)**
	Module 2:Essential Soil Nutrient Elements in Soil Fertility		
1	Essentiality of Nutrient Elements, Classification and Their Forms in Soil	1	Assignment 2
2	Roles, deficiency symptoms, toxicity and correction of nutrient elements in plants		
3	Movement of nutrient elements in soils	1	
4	Factors affecting nutrient elementsavailability in soil	1	
	Module 3: Soil Acidity And Basicity In Soil Fertility		
1	Soil Acidity	1	Assignment 3
2	Liming and Liming materials	1	
3	Soil Alkalinity (Basicity)	1	
4	Salinity and Sodicity	1	
	Module 4: Soil Fertility Evaluation		
1	What is Soil Fertility Evaluation?	1	Assignment 4
2	Approaches/Ways to Soil Fertility Evaluation	1	
3	Factors Affecting Soil Fertility Evaluation	1	
4	Maintenance of Soil Fertility	1	
	Module 5: SOIL FERTILITY MANAGEMENT PRACTICES		
1	Soil and Crop Productivity	1	
2	Irrigation	1	

3	Soil Tillage	1	Assignment 5
4	Organic Matter in Soil	1	
5	Rotation and Continuous Cropping	1	
6	Animal Manure	1	
7	Green Manure / Cover Cropping	1	
	Revision	1	
	Examination	25	

HOW TO GET THE MOST FROM THIS COURSE

In distance learning, the study units replace the conventional university lecturer. This is one of the advantages of distance learning; you can read and work through specially planned study materials at your own pace, time and place that suits you best.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with other units. Next is a set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit. You should use these objectives to guide your study. When you have finished the unit, you must go back and check whether you have achieved the objectives. If you make this a habit you will improve significantly your chances of passing the course.

FACILITATORS/TUTORS AND TUTORIALS

There are 20 hours of tutorials provided in support of this course. As soon as you are allocated a tutorial group, you will be notified of the dates, times and location of tutorials, together with the name and phone number of your tutor.

Your tutor will mark and comment on your assignments; he/she will keep a close watch on your progress and on any difficulties you may encounter and provide assistance to you during the course. You must mail your tutor-marked assignments to your tutor well before the date due (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible.

Do not hesitate to contact your tutor by telephone, e-mail or via the discussion board if you need help. The following might be circumstances in which you would find help necessary. Contact your tutor if:

- you do not understand any part of the study unit
- you have difficulty with the assignments/exercises

- you have a question or problem with your tutor's comments on any assignment or with the grading of an assignment

Try your best to attend tutorials as this is the only chance to have face to face contact with your tutor and to ask questions. You can ask questions on any problem encountered during the course of your study. To gain maximum benefit from the tutorials, make a list of questions before hand and participate actively in the discussions.

SUMMARY

Crop plants require a soil that has all three activities (physical, chemical and biological) in place for it to become a productive soil. A soil may be fertile but not productive and adequate supply of nutrient elements which are essential for their life activities (growth and development) is necessary. When you consider the health of the plants or the quality of the crops produced using the essential nutrient elements that enhance or improve crop quality and quantity, and the constant activity of soil organisms (biological activity) that aid nutrient release from decomposition/degradation process, the importance of soil fertility will be understood by you and productivity of soils will be improved leading to enhanced crop yield on a sustainable basis which is the ultimate goal of the small scale farmer. The important questions that require answers show that many of the new ideas in agriculture will come through the study of soil fertility and its maintenance, including ways through which the nutrient elements are transported within the soil and taken up by plants.

This course (SLM 501), therefore has topics on the essential nutrient elements, their reaction in different soil types, how fertility of the soil can be evaluated as well as on how to maintain the fertility of the soil in an attempt to improve the understanding needed to have a foundation for the interdisciplinary approaches that will continue to provide exciting new concepts in the field of agriculture.

We wish you the best and hope that you will find this course both interesting and useful.

MAIN COURSE

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MODULE 1 SOILS AND SOIL FERTILITY

UNIT 1 WHAT IS SOIL?

CONTENTS

1.0 INTRODUCTION

Soil is a term that is well understood by many, yet the meaning varies. It is considered as the articulation of natural bodies which cover the earth surface that support plant growth and have properties resulting from the effects of climate and organisms on the parent material controlled by relief over a period of time. It is divided into two broad groups namely **Edaphology** and **Pedology**, where **Edaphology** is the science of the soil as a medium for plant production while **Pedology** is the science that studies the characteristics, genesis, morphology and taxonomy of soils. In this unit, emphasis will be on the soil as a soil fertility medium for plant growth and development.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define soil and the major components
- explain the importance of soil.

3.0 MAIN CONTENT

3.1 Definition of Soil

The term soil has been defined in so many ways by several people. Some defined it as the articulation of natural bodies that cover the surface of the earth, support plant and animal growth and have properties resulting from the effects of climate and organisms on parent material controlled by relief over time. Others see it as a "thin layer of material that covers most of the earth surface" or as the most complicated biomaterial on the plant.

In general, it simply means the surface layer (topsoil or furrow soil) which contains and supplies nutrient elements essential for plant production and soil organism's growth and development.

3.2 Components of Soil

As already discussed under mineral nutrition of crops, the major components of soil are air, water, mineral matter and organic matter, and it consists of three phases – solid, liquid and gas. The solid phase consists of the inorganic (mineral) and organic matter which make up the soil structure within which you have pores. Air and water occupy these pore spaces and change depending on weather conditions. These soil components influence the behavior and productivity of soils while the three phases encourage simple and complex reactions within and between the components for plant growth.

3.3 Functions / Role of Soil

The soil plays five important functions in soil fertility:

- It supports plant growth by supplying nutrient elements necessary for its growth.
- The soil properties control water loss, utilisation, contamination and purification processes in soil.
- It is a natural recycling system of waste products of plants and animals.
- A habitat for diversity of organisms (from micro to macro organisms)
- Utilised as an important building material in human ecosystem.

4.0 CONCLUSION

From our discussion in this unit, soil is a reservoir or sink for plant nutrient elements essential for plant production and a habitat for diversity of soil organisms mainly the surface layer or topsoil. It is divided into two major groups namely edaphology and pedology. Its properties control natures recycling system, water holding capacity, infiltration, contamination, purification processes and an important building material. Therefore, in conclusion it is a medium for plant production.

5.0 SUMMARY

In this unit, you have learnt that:

- soil is a natural medium for nutrient elements essential for plant production
- a complex habitat for soil organisms
- an important building material for humans
- soil properties control fate of water in the soil water system
- natural recycling system for waste products.

6.0 TUTOR-MARKED ASSIGNMENT

What is soil?

7.0 REFERENCES/FURTHER READING

Brady, N.C. & Weil, R.R. (2007).*The Nature and Properties of Soils.*(13th ed.). Upper Saddle River, NJ : Prentice Hall.

Foth, D. H. (1990). *Fundamentals of Soil Science*. (8th ed.). John Wiley andSons Inc.

Tisdale, S.L.; Nelson, W.L.; Beaton, J.D. & Havlin, J.L. (2003). *Soil Fertility and Fertilisers*. (5th ed.). New Delhi,India . Prentice-Hall.

Troch, F.R. & Thompson, L.M. (2005). *Soils and Soil Fertility*.(6th ed.). Wiley – Blackwell.

UNIT 2 TYPES OF SOIL IN THE NIGERIAN SAVANNA

CONTENTS

1.0 INTRODUCTION

The classification of the major soil types of the Nigerian Savanna has been difficult because it is not based on a uniform classification and standard scale. But recently, the National Soil Correlation Committee and the Federal Department of Agricultural Land Resources have worked in different areas of the country to come up with their classification into types. Four major soil types have been shown to occur in the Nigerian Savanna region.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- state the four major soil types
- differentiate the soil major types.

3.0 MAIN CONTENT

3.1 Major Soil Types in the Nigerian Savanna

The four major soil types that occur in the Nigerian savanna region are:

- Entisols / Inceptisols
- Alfisols (USDA) or Luvisols (FAO)
- Ultisols (USDA) or Acrisols (FAO)
- Vertisols or Pellic and Chronic Vertisols (FAO)
- Oxisols present but on a much smaller scale and found mainly in the Southern fringes of Nigeria.

3.2 Features of the Major Soil Types

Entisols / Inceptisols

i. They are recently formed, young and immature sandy, well drained, shallow soils with weak profile development or differentiation. They have little or no clear distinct horizons formed.
ii. They are derived mainly from recent Aeolian deposits and always almost low in organic matter, available phosphorus (P) and cation exchange capacity (CEC).

Their weak profile development is due to three interplay factors:

- Sandy nature of parent material
- Dry or semi – arid climatic conditions
- Constant deposition of recent alluvial materials

These soils are generally suited for the growth of sorghum, millet, groundnut, cowpea, maize and cotton. The fadama soils with them are very fertile and popular for dry season cultivation of vegetables, sugarcane and paddy rice when waterlogged (flooded).

Alfisols (USDA) or Luvisols (FAO)

- They are generally mildly acidic and less leached.
- They are derived from pre-cambrian crystalline basement complex rocks and found mainly in the Guinea and derived savanna zones (with average rainfall about 6600mm).
- They are coarse in texture with pH (water) between 5.5 – 7.0.
- Organic matter is low and total nitrogen hardly exceed 0.1%.
- Available phosphorus is low (less than 10ppm) while exchangeable cation levels are moderate but CEC is very low (>5meq/100g of soil).
- The dominant clay mineral is kaolinite, hence cation and water holding (retention) abilities are low.

These soils are poorly structured in the plough layers, bulk density increases after cultivation causing impeding root development.

Ultisols (USDA) or Acrisols (FAO)

- They are just like Alfisols but much more developed, weathered and leached.
- They have a lower base saturation level than Alfisols.
- Organic matter and CEC are low, showing the presence of kaolinites and oxide clay minerals.
- Exchangeable aluminium level is high, the soil reaction is acidic and fertility impoverished.

Vertisols

- They are heavy, cracking clay soils with more than 35% clay and a high content of expanding clay minerals.
- They shrink and swell with changes in moisture content.
- They are high in basic cations (Ca^{2+}, Mg^{2+}, K^{+}) but low in organic matter, N, P and micronutrients.
- These soils are found in the North Easten region (Borno, Bauchi, Gombe, Taraba), also in some parts of Plateau, Sokoto and Kebbi states. Crops good for production are mainly wheat, cotton, rice and sorghum. Problems of tillage, poor drainage, flooding and erosion affect wide scale utilisation.

All the vertisols in Nigeria are equivalent to pellic or chronic vertisols (FAO).

Exisols (USDA) or Nortisols / Ferratsols (FASO

- They are extremely weathered, leached and consists of mixtures of kaolinites, Fe oxides and quartz.
- They are deep, well – drained and reddish in colour with clear granular structure.
- They have very low fertility level resulting in mainly shifting cultivation practice.

These soils are mainly limited to the Southern fringes like Ankpa area in Kogi state where annual rainfall is high (about 1800mm).

3.3 Soil Management Practices of the Soil Types for Efficient Use

Soils of the Nigerian Savanna are seen as relatively infertile and it is believed that addition of chemical fertilisers together with other agricultural inputs (improved seed, pesticides application) crop productivity will continue to decrease. Fertility under natural forest is satisfactory because they have dark thick layer of surface (top) soil rich in nutrients necessary for plant growth. Low crop productivity does not always follow when land is put into agricultural use. Soil changes that decrease crop productivity is as a result of cropping system, leaching and soil erosion.

The worst being soil erosion, especially in the humid rainforest areas of Southern Nigeria, even if you apply adequate amount of fertiliser to highly eroded soil, its efficiency would be highly reduced, hence it's difficult to get the back to its full production once top soil is eroded. Thus for soil conservation the soil should be used in according to its capabilities and limitation but this may be difficult to follow due to some socio – economic problems.

How to Maintain these Soil Types:

Entisols / Inceptisols
These soils are managed by the addition of organic manure and crop residue incorporation to help bind the soil particles together.

Alfisols / Luvisols
Since the dorminant soil is kaolinite, organic matter, CEC and water holding capacity is low, the soils are managed by addition of organic manure to increase organic matter content.

Ultisols / Acrisols
Since the soil reaction is acidic, the soils are managed by liming because of acidity.

Vertisols
Wide scale utilisation problems associated with vertisols are tillage, poor drainage, flooding and erosion, for these reasons, management of vertisols involves:

- Construction of drains
- Plough to increase aeration and soil workability
- Add organic matter, NPK fertilizer and other fertilizer types.

Oxisols / Ferralsols / Nitosols
The dominant soils are a mixture of kaolinite, Fe oxides and quartz, the soils are managed by liming to reduce acidity.

4.0 CONCLUSION

From our discussion in this unit, there are four major soil types in the Nigerian Savanna. These are entisols / inceptisols, alfisols, ultisols and vertisols (USDA classification). Oxisols though present but on a very small scale and found only in the Southern part of Nigerian Savanna. Because of the nature of the parent materials and climatic conditions of their location mainly, different management practices are carried out to enhance the fertility status of each soil type from addition of organic manure, fertiliser, liming to construction of drains. Soil conservation and good soil management enhances soil fertility more than just preventing soil losses. Soil erosion is an indication of poor soil management, be it inadequate plant nutrient or improper cropping systems.

5.0 SUMMARY

In this unit, you have learnt about:

- major soil types in the Nigerian savanna
- the different management practices to improve soil fertility and boost crop production.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the major types of soil in the Nigerian Savanna and give three characteristics of each soil type mentioned.
2. Mention two management strategies to maintain each soil type.

7.0 REFERENCES/FURTHER READING

Chude, V.O; Olayiwola, S.O; Osho, A.O & Daudu, C.K.(Ed.). (2011). *Fertiliser Use and Management Practices for Crops in Nigeria*.. Federal Fertiliser Department (FFD) in Collaboration with National Special Programme for Food Security, FAO, Abuja, Nigeria. p.45.

Sanginga, N. & Woomer, P.L. (2009). *Tropical Soil Biology and Fertility*. Institute of the International Centre for Tropical Agriculture (TSBF – CAT). Nairobi, p.263.

UNIT 3 WHAT IS SOIL FERTILITY?

CONTENTS

1.0 INTRODUCTION

The nutrient supplying power or ability of the native soil has decreased due to higher plant productivity level in association with increasing human population demand for food. It is therefore, necessary to develop and put to use (implement) soil-organic nutrient management approaches that will improve the quality of the soil, water and improve its fertility status, it cannot continue to support food and fibre demand of our increasing population.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain what soil fertility means
- discuss the benefits of soil fertility
- explain the factors that affect the fertility of soil.

3.0 MAIN CONTENT

3.1 Definition of Soil Fertility

Soil fertility is the level or status of a given soil with respect to its ability to supply the needed nutrients for plant growth. In effect, it is the nutrient supplying power of the soil. It is also defined as the quality of nutrients which enables or helps a given soil to make provision of the right nutrients in the right quantity and in the right proportion for growth of a specific plant or crop when all necessary environmental factors such as temperature, water, pH, light are adequate / favourable. Hence, a fertile soil is that which has the power to supply the right amount of nutrients to the plants and in the right proportion.

3.2 Why is Soil Health Essential?

The healthiness of a soil is critical or crucial to the quality of the food that soil can produce and also the health or wellbeing of those who eat the food produced from it below is a diagram to explain the importance of a healthy soil

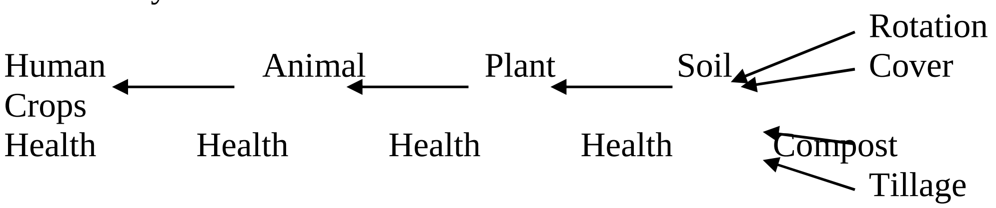

Fig.3.1

3.3 Factors Affecting Soil Fertility

It is necessary to understand the chemical, biological and physical properties of a soil and their relationship in the soil – plant – atmosphere continuum that control nutrient availability. One of the biggest constraints in soil fertility is to develop and implement soil, crop and nutrient management approaches that improve the quality of the soil, water and air.

Therefore, the factors that influence soil fertility include those that affect plant growth and development. These factors include:

- pH of soil (soil reaction)
- Climate factor especially temperature and precipitation (moisture)
- Activities of soil micro organisms
- Soil organic matter content
- Nutrient imbalance
- Light energy (Radiant energy)
- Soil type and Soil Structures

4.0 CONCLUSION

From our discussion in this unit, the fertility of the soil deals with mineral nutrient elements of plants and their conditions in the soil. Hence the health of the soil plays an important in the quality of the food produced including the well – being of those who feed on the produce. In conclusion, soil fertility is the ability of the soil to supply the mineral nutrient elements required by plants for growth.

5.0 SUMMARY

In this unit, you have learnt that:

- soil fertility is the nutrient supplying ability of the soil for plant growth and development.
- the health of the soil is important to the quality of food crop produced.
- the fact that affects the chemical, physical and biological properties of the soil will invariably affect the fertility of the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is soil fertility?
2. List the factors that affect the fertility of the soil?
3. Why is soil health an important part of soil fertility?

7.0 REFERENCES/FURTHER READING

Foth, D. H. (1990). *Fundamentals of Soil Science*. (8th ed.).John Wiley andSons Inc. p.384.

Tisdale, S.L.; Nelson, W.L.; Beaton, J.D. & Havlin, J.L. (2003). *Soil Fertility and Fertilisers*. (5th ed.). New Delhi India: Prentice-Hall.p.634.

UNIT 4 RELATIONSHIP BETWEEN SOIL AND SOIL FERTILITY

CONTENTS

1.0 INTRODUCTION

Soils are essential to the existence of plants on our planet earth. The type of soil determines the kind of plants grown and the ability of the soil to help support plant life. The soil has a great role towards the success of plant growth, this has to do with the nutrients present in the soil, which the plant takes up for growth.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain what soil is
- discuss soil fertility
- explain the relationship between soil and soil fertility.

3.0 MAIN CONTENT

3.1 What is Soil?

As earlier explained, soil is the coming together of natural bodies that cover the earth surface which support plant growth. The properties of soil result from the effects of climate and organisms on the parent material over time and controlled by relief. Generally, it refers to the surface layer (top soil) that contains and supplies nutrient elements necessary for plant production including soil organism growth and development.

3.2 What is Soil Fertility?

Soil fertility on the other hand is the ability of the native soil to supply nutrient elements necessary for plant growth and development to meet plant demand for higher productivity in association with increasing human population demand for food. Therefore, soil fertility is the status of the soil with respect to its ability to supply the necessary nutrient elements for plant crop. That is, the nutrient supplying power of the native soil.

3.3 Relationship between Soil and Soil Fertility

Our soils are so delicate (poor) that if we do not improve its fertility status, it cannot continue to support food and fibre production for our increasing population. Therefore, soil is an important natural nutrient medium that supports crop growth and development and good root development to enable the plant complete its crop cycle. It provides also a habitat for soil organisms important in agriculture especially those associated in carbon, nitrogen and phosphorus cycling and oxidation-reduction processes in soil. Hence the fertility status of the soil is essential to enhancing good crop quality and production.

4.0 CONCLUSION

From our discussion in this unit, soil is a natural medium that supports essential nutrient elements for plant growth and development including soil organisms to enable the plant completes its growth cycle. Therefore, the relationship between soil and soil fertility lies in the soil being a natural sink or reservoir for plant nutrient elements and its ability to supply these nutrients for crop growth and development.

5.0 SUMMARY

This unit discussed the relationship between soil and soil fertility. From this unit, you have learnt that:

- soil is a natural sink or reservoir for essential plant nutrients for crop growth and development.
- soil fertility is the ability of the soil to supply nutrients necessary for plant growth and development, thereby explaining the relationship between soil and soil fertility.

6.0 TUTOR-MARKED ASSIGNMENT

How is soil related to soil fertility?

7.0 REFERENCES / FURTHER READING

Sanchez, P.A.(n.d.). *Management of Soils in the Tropics*.

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UNIT 5 IMPORTANCE OF SOIL FERTILITY IN AGRICULTURE

CONTENTS

1.0 INTRODUCTION

As earlier discussed in previous units, the fertility of a soil is the ability of that soil to supply essential nutrients for crop growth and development. For a soil to be productive, it must be fertile though not all fertile soils are productive. Our soils are known to be poor in fertility that if we do not enhance its fertility level, it cannot continue to support crop productivity most especially under this era of intensive continuous cropping due to increasing population. The most important way to enhance or improve the fertility level of soil is by improving the soil organic matter level and handling it as organic matter is a reservoir for nutrients.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain the importance of soil fertility in agricultural production
- discuss the role of soil organic matter in soil fertility
- explain how to maintain soil organic matter level.

3.0 MAIN CONTENT

3.1 What is the Importance of Soil Fertility?

Soil fertility is important because it affects the quality of the food produced which indirectly affects animal’s life and humans when consumed.

3.2 Importance of soil organic matter in soil fertility.

Soil Organic Matter (SOM) comprises living organisms, remains of organisms that once occupied the soil and organic compounds produced by metabolism present and past in the soil. That means it is made up of the living organisms (biomass), identifiable dead tissue (detrites) and non – living, non – tissue material (humus). The soil organic matter is one of the best indicators of good soil tilth, (nutrition and structure). The importance of soil organic matter in soil fertility is as outlined below:

- Improvement of physical properties of soil (aeration, permeability, structure, water holding capacity).
- Enhancement of soil microbial activities
- Supplies the plant with available forms of nitrogen, phosphorus, sulphur
- Contributes/enhances the cation exchange capacity (CEC) by furnishing 30 – 70 of total amount
- Acts as chelate, a chelate is any organic compound that can bond to a metal casually (Fe, Zn, Cu and Mn) by more than one bond forming a ring or cyclic structure by that bonding. The soluble chelates help mobilise these micronutrients increasing their availability to plants and general mobility in soil production of well in

3.3 Maintenance of Soil Organic Matter

The need to maintain soil organic matter is of great importance for sustainable agricultural production. The maintenance or improvement of organic matter includes:

- Incorporation of crop or plant residues
- Use of green manure, mulching, cover crops
- Incorporation of farmyard or animal manure
- Application of compost
- Use of urban and industrial wastes
- Rotation / intercropping with legumes
- Application of fertiliser and liming
- Adaptation of reduced tillage (minimum tillage).

4.0 CONCLUSION

In this unit, we have discussed the importance of having a fertile soil (soil fertility), and soil organic matter as well as maintenance of soil organic matter. Following these discussions, it can be concluded that improving the soil organic matter is the most important factor to be considered in soil fertility enhancement because it is a sink for plant nutrient elements and makes these nutrient elements available for sustainable production if well maintained.

5.0 SUMMARY

In this unit you have learnt that:

- soil fertility improvement is essential for crop productivity to be sustained.
- organic matter consists of both living and dead remains of plants and organisms as well as the substances they produce.
- soil organic matter aids in enhancing soil structure, texture and water holding capacity and how it can be maintained using some material.
- soil organic matter also enhances nutrient availability through microbial activities in the soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. Why do you consider the fertility of the soil important?
2. a. List the importance of soil organic matter.
   b. How can soil organic matter be maintained?

7.0 REFERENCES/FURTHER READING

Brady, N. C. & Weil, R. R. (2007).The *Nature and Properties of Soils*. Pearson Education Inc. p. 976.

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UNIT 6 WHAT IS SOIL PRODUCTIVITY?

CONTENTS

1.0 INTRODUCTION

It is important for us to understand the relationship between chemical, physical and biological properties in the soil – plant atmosphere continuum that control nutrient uptake, and the ability of the soil to supply adequate / sufficient nutrient elements for plant productivity. Our soils are known to be poor infertility that if we do not improve its fertility status, it cannot continue to support crop productivity especially in this era of intensive continuous cropping due to increasing human population demand.

If we do not improve and or sustain the productive ability of our poor soils, we cannot continue to support the food demand of our growing population.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define soil productivity
- differentiate between soil fertility and soil productivity
- describe the factors that affect soil productivity.

3.0 MAIN CONTENT

3.1 Definition of Soil Productivity

Soil productivity can be defined as the ability of a soil to produce a succession of crops on a sustained basis under a specific management system. This involves the chemical, biological and physical properties affecting the soil. A productive soil must be fertile but not all fertile soils are productive. This is because productivity depends on other factors that provide extra support.

3.2 Soil Fertility versus Soil Productivity

Productivity of a soil does not depend on its fertility, because a fertile soil may not be productive due to constraints such as lack of irrigation facilities, presence of toxic substances, soil pH conditions, and poor drainage, and so on. On the other hand, the fertility of a soil can be improved to make that soil productive by employing adequate/sufficient management practices such as the addition of fertilisers and manures.

Some soils are high in fertility but not productive due to environmental factors but can be made productive also by proper management practices such as provision of adequate soil moisture through irrigation or drainage, adoption of suitable management practices, or the use of corrective measures that overcome problem of root penetration and toxicity conditions. Hence, from the above discussion, soil fertility in combination with environment factors and suitable management practices make up soil productivity, that is:

Soil Productivity = Soil Fertility + Environmental Factors + Management Practices.

3.3 Factors Affecting Soil Productivity

The factors that affect soil productivity includes those that affect soil formation and management activities of man in his effort to produce crops. These factors include:

- Climate (temperature and precipitation)
- Vegetation (especially native vegetation)
- Living Organisms activities
- Nature of parent material in relation to soil texture, structure, chemical and mineralogical composition)
- Topography
- Cultivation
- Cultural practices (use of fertilisers)
- Grazing (example overgrazing)

4.0 CONCLUSION

The ability of the soil to produce a succession of crops on a sustainable basis depends on the use of proper adequate / sufficient management practices such as use of fertiliser or manure and environmental factors (adequate moisture, temperature, soil pH and so on). Therefore, in conclusion, soil productivity is a combination of soil fertility and suitable management and environmental practices.

5.0 SUMMARY

In this unit, you have learnt that:

- a fertile soil may not necessarily be productive due to lack of other factors that support growth
- a productive soil must be fertile.

6.0 TUTOR-MARKED ASSIGNMENT

Is a fertile soil productive? why?

7.0 REFERENCES / FURTHER READING

Sanchez, P.A.(n.d.). *Management of Soils in the Tropics*.

Tisdale, S.L.; Nelson, W.L.; Beaton, J.D. & Havlin, J.L. (2003). *Soil Fertility and Fertilisers*. (5^{th} ed.). New Delhi,India:Prentice-Hall.p.634.

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MODULE 2 ESSENTIAL NUTRIENT ELEMENTS IN SOIL FERTILITY

UNIT 1 ESSENTIALITY OF NUTRIENT ELEMENTS, CLASSIFICATION AND THEIR FORMS IN SOIL

CONTENTS

1.0 INTRODUCTION

Plant growth involves a large number of highly integrated enzymes reactions and physiological and metabolic processes, all of which are dependent on adequate supply of nutrients. Most elements play multi - functional role in plants. A nutrient is a substance that promotes the growth, maintenance, function and reproduction of a cell or organism. The term “nutrition” refers to the interrelated steps by which a living organism accumulates food and uses it for growth and replacement of tissue. Very often people find it difficult to distinguish between plant nutrition and plant fertilisation. These two are entirely different aspects as a matter of fact. Plant nutrition refers to the needs and uses of the basic chemical elements in the plant whereas fertilisation is the term used when these nutrient are supplied to the environment around the plant.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define nutrient element
- classify them based on source, usage and physiological and biochemical behaviour
- state what makes a nutrient element essential
- discuss the various forms of nutrients elements in soil.

3.0 MAIN CONTENT

3.1 Definition of Nutrient Element

A nutrient element is an element highly required by plant for its growth and development and considered essential if that element is involved in the plant metabolic functions. Also, the plant cannot complete its life cycle without that element.

3.2 Classification of Nutrient Elements

i. Source
ii. Usage
iii. Physiological function and biochemical behavior

3.2.1 Source

The source could be from air, soil or water

3.2.2 Usage

Nutrients elements could be used or applied either in large or small quantity, depending on the demand of the crop for that nutrient.

3.2.3 Physiological Function and Biochemical Behavior

Nutrients elements undergo and undertake various physiological function and biochemical behavior in the soil.

3.3 Essentiality of Nutrients Elements in Soil fertility

Essentiality of element for plant growth emphasizes the functional nature of the element in plant metabolism. Nutrients required by plants for metabolism, growth and development are referred to as essential elements. According to Arnon and Stout (1939), for an element to be considered essential, three criteria must be met:

- A given plant must be unable to complete its life cycle in the absence of the mineral element.
- The function of the element must not be replaceable by another mineral element
- The element must be directly involved in plant metabolism.

3.4 Forms of Nutrient Elements in Soil

Essential nutrient elements exist basically in two [2] forms in the soil.

(a) Complex or insoluble compounds – These forms are referred to as the quantity factor or reserved status of the soil. The capacity of a soil to retain a certain amount of nutrients (storage or adsorption capacity) determines the natural fertility of a soil.

(b) Simple or more soluble forms – These forms are readily available to plants. It is referred to as the "intensity factor". Generally, the intensity in the soil is for a reaction to move from the insoluble to the soluble forms, and vice – versa reversibly following the law of mass action.

4.0 CONCLUSION

In this unit, we can conclude that for the growth and development of crops, nutrient element is essential in order for it to complete its life cycle, and these nutrient elements are classified based on their source, how they are used and their specific functions to the crops development. Nutrient element required by plants for metabolism, growth and development are referred to as essential element. Their insoluble compounds are not readily available for plant uptake while their soluble compounds are readily available to crops.

5.0 SUMMARY

In this unit, you learnt that:

- Nutrient elements are considered important for crops to complete its life cycle

- Nutrient elements are classified based on their source, how they are used and their physiological function and biochemical behavior
- Essential elements are nutrient required by plant for their growth, development and metabolism
- Two forms of nutrient elements exist in soil, namely complex and simple forms.

6.0 TUTOR–MARKED ASSIGNMENT

1. Define a nutrient element.
2. How are nutrient elements classified?
3. What are the criteria to be met for an element to be considered essential?
4. Explain the forms of nutrient elements that exist in soil.

7.0 REFERENCES / FURTHER READING

Brady, N.C. & Weil R.R. (2007). *The Nature and Properties of Soil*. Pearson Education Inc. pp.976 .

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UNIT 2 ROLES, DEFICIENCY SYMPTOMS, TOXICITY AND CORRECTION OF NUTRIENT ELEMENTS IN PLANTS

CONTENTS

1.0 INTRODUCTION

All elements absorbed by plants are not necessarily important for the growth of that plant. But any element that takes part in the plant nutrition (growth and development) regardless of whether its action is specific is a functional element. There are twenty [20] essential elements. Not all these elements are required by all plants. The macronutrients are N, P, K, S, Ca and Mg, the minor of trace elements or micronutrients are the remaining elements which are Fe, Zn, Mn, Cu, B, Cl and Mo which are found in very small amounts. Beneficial elements like Na, Cu, Va, Ni and Si have been found as essential elements in some plants.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain macronutrients
- discuss the role, deficiency symptom, toxicity and corrective measures of some macro and micronutrients.

3.0 MAIN CONTENT

3.1 Macronutrients

These are elements required in large amounts by plants for their growth and subsequent development. They are mainly: N, P, K S, Ca and Mg.

Nitrogen

Functions of Nitrogen (N)

- It has an essential role as a constituent of proteins, nucleic acids, chlorophyll and growth hormones.
- An adequate supply is associated with vigorous vegetative growth and deep green colour.
- Increases growth and development of all living tissues.

Deficiency symptoms of Nitrogen

- Stunted growth
- Lower protein content
- In acute deficiency, flowering is greatly reduced.

Toxicity of Nitrogen

- Luxuriant growth with poor yield

Correction

- Application of inorganic fertiliser like NPK, urea or farm yard manure

Phosphorus

Functions of Phosphorus (P)

- It plays an important role in the conservation and transfer of energy for a wide range of chemical processes (ATP and ADP)
- It is an important constituent of nucleic acids and phospholipids.
- Important for cell division, a constituent of chromosomes, stimulates root development and flowering.

Deficiency symptoms of Phosphorus

- Delayed maturity, little or no flowering, poor seed and fruit development
- Overall stunted appearance, the mature leaves have characteristic dark to blue green

coloration, restricted root development.

Toxicity of Phosphorus

- Eutrophication: Filling of lakes, streams or rivers with plants such as water hycianth due to excess phosphorus resulting in low oxygen supply for fishes. Eutrophication caused by human influenced is called Cultural eutrophication.

Correction of Phosphorus Deficiency

- Application of inorganic fertiliser like SSP, TSP (Triple Super Phosphate) or manure.

Sulphur

Functions of Sulphur (*S*)

- Important in protein synthesis and in the functioning of several enzyme synthesis
- Chlorophyll synthesis and activity of nitrate reductase depends strongly on sulphur.

Deficiency symptoms of Sulphur

- Plant retardation as characterised by uniform chlorotic plants.
- Stunted growth
- Thin-stemed and spindly, similar to that of *N* but sulphur symptoms appear first on younger leaves

Toxicity of Sulphur

- Rare but can cause nitrogen deficiency

Correction of Sulphur deficiency

- Application of sulphur dust and NPK 20:10:10 + 2S + Zn or farmyard manure

Potassium

Functions of Potassium (*K*)

- Contributes to regulating the osmotic potential
- Opening and closing of the stomata
- It is important in monitoring adequate water retention in plants.

Deficiency symptoms of Potassium

- Lodging and stalk breakage
- Poor crop quality and decreased resistance to diseases.

Toxicity of Potassium

- Reduces calcium uptake in plants and animals
- Causes nutritional imbalance in both plants and animals

Correction of Potassium deficiency

- Application of NPK, murate of potash containing K_2O.
- Crop residue management and manure.

3.2 Micronutrient and Beneficial Element

These are elements required in small amounts by plants for their growth and development

Zinc

Functions of Zinc (*Zn*)

- It is involved in the biosynthesis of Indole Acetic Acid (IAA) – auxins which is a growth hormone
- It plays a key role in nucleic acid and protein synthesis e.g. Trypthophan

Deficiency symptom of Zinc

- Symptoms appears on the 2^{nd} and 3^{rd} fully matured leaves (from top of plants)

It shows a characteristic little leaf and resulting or clustering of leaves, mostly at the top of fruit tree branches.

Toxicity of Zinc

- Zinc toxicity is reported to be rare and may occur due to acidification of soils

Correction of Zinc deficiency

- Application of $ZnSO_4$ fertiliser and NPK 20:10:10 +2S + Zn.

Copper

Functions of Copper (Cu)

- It enhances the formation of vitamin A.
- It constitutes of chromosomes and component of many enzymes such as oxidase and lactase.

It is a component of either natural or synthetic organic complexes like lignin.

Deficiency of Copper – Its deficiency symptoms varies with crops

- It causes poor grain set in cereals
- The youngest leaves become yellow and stunted in corn and causes die back in older leaves and restriction of ear protection.

Toxicity of Copper

- The leaves become chlorotic resembling that of *Fe* – deficiency

Correction of Copper deficiency

- Application of $CuSO_4$ and Bordeux mixture (lime + $CuSO_4$).

The beneficial elements important to some crops are Na, Cl, Si.

- Sodium (Na) – Are electrolytes necessary for osmotic pressure and acid – base balance
- Chloride (Cl) – Activates the O_2 – producing enzyme of photosynthesis.
- Silicon (Si) – Contributes to the structure of cell walls impacting greater disease resistance, stalk strength and resistance to lodging.

4.0 CONCLUSION

In this unit, we can conclude that all elements take part in plant nutrition regardless of whether its action is specific, not all of these elements are required by all plants. Different elements have roles that they play in growth and development of plant.

5.0 SUMMARY

In this unit, you have learnt that:

- All elements absorbed by plant are not necessarily important for the growth of that plant.
- Macronutrients are elements required in large amounts by plant for growth and development.
- Micronutrients are elements required in small or minute quantity by plant for growth.
- Various elements have functions, deficiency symptom, toxicity and corrective measures.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are macronutrients?
2. What are micronutrients?
3. List the functions, deficiency symptoms, toxicity and corrective measures of *N* and *P* macronutrients.
4. Mention the functions, deficiency symptoms, toxicity and corrective measures of *Zn* and *Cu* micronutrients

7.0 REFERENCES / FURTHER READING

Brady, N.C. & Weil, R.R. (2007). *The Nature and Properties of Soil*. Pearson Education Inc. p.976.

Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. (2^{nd} ed.). San Diego, California: Academic Press Publications. p.889.

UNIT 3 MOVEMENT OF NUTRIENT ELEMENTS IN SOIL

CONTENTS

1.0 INTRODUCTION

Nutrient availability to plants is determined both by factors which affect the ability of the soil to supply the nutrients and by factors which affect the plant's ability to utilise the nutrients which are supplied. The term "nutrient availability" is often used in plant nutrition but is frequently not precise. As a first approach, the available nutrient of a soil may be considered as that fraction in the soil which is accessible to plant roots.

The term nutrient availability thus encompasses both chemical and physical status of the nutrients in the soil as well as plant root relationship which involves plant metabolism. Indeed, a nutrient which is accessible to one plant species may not be accessible to another because of differences in root morphology and metabolism. It is important to know the factors and their casual relationships which contribute to nutrient availability.

2.0 OBJECTIVE

By the end of this unit, you will be able to:

- state how nutrient elements move to the root surface.

3.0 MAIN CONTENT

3.1 Nutrient Transport from Soil to the Root Surface

Root interception

The nutrients are made available to plants root through root interception. It's held that is plant roots grow through the soil, it comes across plant nutrients which are intercepted. The amount of nutrients which directly contacts plant roots (interception) is small as compared to the total nutrient demand; particularly for nutrients required in high quantities.

Mass flow

The movement of solutes (minerals + water) associated with net movement of water. It is one of the most important processes by which plant nutrients are transported from the soil to the root surfaces. Mass flow occurs when solutes are transported with the convective flow of water from the soil to plants. The amount of nutrients reaching the root is thus dependent on the rate of water flow or the water consumption of the plant and the average nutrient concentration in the water.

Diffusion

When the supply of a particular nutrient to the root surface by root interception or mass flow is not sufficient to meet plant demands, continued uptake by the plant depletes the concentration at the root surface. The resulting concentration gradient that forms from the bulk soil to the root surface causes nutrients to diffuse along that gradient towards the root surface. Diffusion therefore is the flow of nutrient along a concentration gradient. When there is a difference in concentration of a particular nutrient within the soil solution, the nutrient will move from an area of higher concentration to an area of lower concentration. It is directed towards the root when the concentration at the root surface is decreased and away from the roots when it is increased.

3.2 Nutrient Transport from Root to Plant

Mineral nutrients are transported in plants through the vascular tissue. When roots take up the nutrients from soil as molecules of inorganic compounds, they move up the plant through the xylem tissues. While the organic molecules are taken up by the phloem and transported to the needed plant parts, example the fresh new leaves and branches.

Diagram showing transfer in xylem (X) and phloem (P) in a stem with a connected leaf

where:
X=xylem
P=phloem
T=transfer-cell

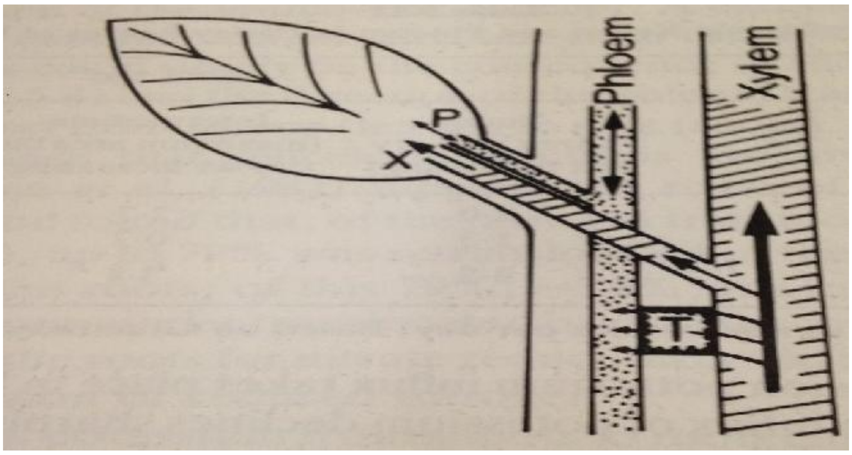

Fig.3.1
(Adapted from Marschner, H, 1986)

4.0 CONCLUSION

In this unit, you have learnt how nutrients are transported to the root surface in the soil.

5.0 SUMMARY

In this unit, you learnt:

- how nutrients are transported to the surface of root

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the various ways by which nutrients are transported to the root surface.
2. Give the difference between mass flow and diffusion.

7.0 REFERENCES/FURTHER READING

Brady, N.C. & Weil, R.R. (2007). *The Nature and Properties of Soil*. Pearson Education Inc. p.976.

Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. (2^{nd} ed.). San Diego, California: Academic Press Publications. p.889.

UNIT 4 FACTORS AFFECTING NUTRIENT ELEMENTS AVAILABILITY IN SOIL

CONTENTS

1.0 INTRODUCTION

The term nutrient availability thus encompasses both chemical and physical status of the nutrient in the soil as well as plant root relationship which involves plant metabolism. Indeed, a nutrient which is accessible to one plant species may not be accessible to another because of differences in root morphology and metabolism. It is important to know the factors and their causal relationships which contribute to nutrient availability.

2.0 OBJECTIVE

By the end of this unit, you will be able to:

- identify various factors affecting nutrient element availability in the soil.

3.0 MAIN CONTENT

3.1 Factors Affecting Nutrient Elements Availability in Soil

3.1.1 Soil temperature

Low temperature inhibits organic matter decomposition while higher temperature induces organic matter decomposition (faster decomposition) thereby releasing nutrient in the soil.

3.1.2 Soil moisture

Under many climatic conditions nutrient availability in the top soil declines more or less steeply during the growing season because low soil water content becomes a limiting factor for nutrient delivery to the root surface. Soil water content is an important factor affecting diffusion. At low soil water moisture, the water content at the root surface is much lower than that of the bulk soil.

3.1.3 Intensity/Quality ratio

The intensity/quality ratio of nutrient availability in soil is connected to the quality (e.g. extractability), mobility, spatial availability and root induced changes that take place in the rhizosphere.

3.1.4 Soil Structure

Soil structure plays a key role in determining the amount of mineral nutrients that are available for uptake by the roots. In a well-structured soil, not all roots have complete contact with the soil matrix, and in non-mycorrhizal plants the degree of root – soil contact varies between root segments. In the soil with higher bulk density contact is greater but root elongation growth is impaired. The optimal degree of soil root contact and soil bulk density for nutrient uptake and plant growth thus depends on soil fertility and aeration.

3.1.5 Soil *pH*

As a role root growth is not much affected by external pH in the range of 5.0-7.5. Root growth can possibly be inhibited by high pH either directly or indirectly. If the root growth is inhibited, then access to nutrients will be reduced.

3.1.6 Root density

High root density and long root hairs are important factors in the uptake of nutrients supplied by diffusion, for a given inter root distance the degree of competition mainly depends on effective diffusion and is therefore usually much higher for nitrate therefore potassium and is of minor importance for phosphorus. The high rooting density in the top soil is mainly caused by the usually more favourable physical, chemical and biological conditions in the top soil as compared with the subsoil.

3.1.7 Water logging

The severity of the effects of water logging on root growth and respiration depends on the plant species, developmental stages of the plant, soil properties and soil temperature in particular. Cessation of root growth and root respiration leads to a drastic drop in the uptake and transport of mineral nutrients to the shoot within a few days of water logging.

3.1.8 Alkalinity

This is characterised by a sodium absorption ratio of the soil matrix greater than 15, and they often contain sodium carbonate. Alkaline and plant growth is improved mainly by high pH, high bicarbonate and often poor aeration. In alkaline soils, poor physical conditions and correspondingly poor soil aeration are the major constraints and are often correlated with sodium and boron toxicity. Nitrogen is a growth – limiting factor for crop species better than legumes) growing in alkaline soils.

3.1.9 Salinity

Salinity is the major nutritional constraint on the growth of crops grown on wet and irrigated lands, example rice. Soils are considered saline if they contain soluble salts in quantities sufficient to interfere with the growth of most crop species. It constraint include; water deficit arising from the low water potential of the rooting medium and nutrient imbalance by depression in uptake and/or shoot transport and impaired internal distribution of mineral nutrients.

4.0 CONCLUSION

In this unit, we can conclude that a lot of factors contribute to nutrient availability in the soil for the root uptake.

5.0 SUMMARY

In this unit, you have learnt that:

- nutrient which is accessible to one plant species may not be accessible to another because of differences in root morphology.
- factors affecting mineral nutrient availability in soil varies from one to another.

6.0 TUTOR-MARKED ASSIGNMENT

Mention and explain four [4] factors that affect nutrient element availability in soils.

7.0 REFERENCES / FURTHER READING

Brady, N.C. & Weil, R.R. (2007). *The Nature and Properties of Soil*. Pearson Education Inc. p.976.

Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. (2nd ed.). San Diego, California: Academic Press Publications. p.889.

MODULE 3 SOIL ACIDITY AND BASICITY IN SOIL FERTILITY

UNIT 1 SOIL ACIDITY

CONTENTS

1.0 INTRODUCTION

An acid is a substance that gives off its hydrogen ion (H^+) to another substance. A soil is said to be acidic when the pH of that soil falls below 7.0. Such a soil is said to be acidic. Acidity varies depending on the soil pH and categorised as:

Extremely acidic	-	pH (1.0 – 2.0)
Very Strongly acidic	-	pH (3.0 – 4.0)
Strongly acidic	-	pH (4.1 – 5.0)
Moderately acidic	-	pH (5.5 – 6.0) (satisfactory for most crops)
Slightly acidic	-	pH (6.1 – 6.9) (ideal for most crops)

In the laboratory, buffers or buffer systems are used to maintain the pH of a solution to the desired pH level. Buffering is the resistance to a change in pH and some buffers used in the laboratory are acetic acid (CH_3COOH) and sodium acetate (CH_3COONa). The pH of soil together with other properties affects availability of plant nutrients and consequently soil productivity. To correct soil acidity, liming materials are used to raise the pH of the soil.

Understanding of soil acidity is necessary for good soil management of the pH and optimum productivity of both the soil and crop. In Nigeria, there are two types of acid soil which affects crop production, namely the ferrallitic soil (pH 4.5) found in high rainfall areas of the South and drained acid sulphate soils (pH 3.5) in the Delta areas and marshy coasts. Crops such as maize and cowpea that do not grow well in those areas are attributed to the acid conditions of these areas.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define soil acidity
- list the sources of soil acidity
- explain the causes of soil acidity
- describe the factors affecting soil acidity
- discuss the effect of soil acidity on crops and soils
- explain the ways to correct soil acidity.

3.0 MAIN CONTENT

3.1 What is Soil Acidity?

A soil is said to be acidic when the pH of that soil falls below pH 7.0 and varies depending on the pH of the soil reaction.

3.2 What are the Sources of Soil Acidity?

The acidity of a soil could result from organic matter, clay minerals, Fe and Al oxide (Iron and Aluminium oxides), exchangeable Al^{3+}, soluble salts and CO_2 amount present in the soil.

Organic Matter
Soil organic matter also called humus contains some carboxylic and phenolic compounds which act as weak acids. These will dissociate and release H^+ and decrease the pH of soil resulting in soil acidity. Because the organic matter content varies with the environment, vegetation core and soil type, its contribution to soil acidity also varies.

Clay Minerals
The types of clay minerals common are kaolinite (1:1) and mortmorillonite (2:1). They give off H^+ from their broken edges,

including Al and Fe oxides and organic matter. The H^+ contributes to the buffering of soil pH. High clay and organic matter will give greater buffering capacity compared to poor textures (low clay) and low organic matter soils.

Exchangeable Al^{3+}.

Hydrolysis of Al^{3+} liberates H^+ and lowers the soil pH except there is a source of basic ion to liberate OH^- to neutralise it.

Soluble Salts

Acid or basic salts in the soil solution came from weathering of minerals, decomposition of organic matter or addition of fertilisers and manures. These cations of their salts displace Al^{3+} in acid soil resulting in the decrease of the pH of the soil solution. Cations with two ions (divalent) such as Ca^{2+}, Mg^{2+} have greater lowering effect compared to those with one ion (K^+, Na^+). Band application of fertiliser causes a decrease in soil pH through hydrolysis of Aluminium.

Carbon dioxide (CO_2)

In high calcium soils, the pH is affected by the partial pressure of CO_2 in the soil. plant root respiration and organic matter decomposition causes an increase in soil CO_2 which combines with soil water to release H^+ that lower soil pH resulting in soil acidity.

3.3 Causes of Soil Acidity

A soil becomes acidic due to the fact that the basic cations (such as Ca^{2+}, Mg^{2+} and K^+) are replaced by H^+ and Al^{3+} ions resulting in the loss of these cations from soil through:

- Leaching due to high rainfall
- Removal of basic cations by the crops from the soil
- Erosion of the top soil
- Use of acidifying fertilisers (urea, ammonium sulphate)

3.4 Factors affecting Soil Acidity

Soil acidity in crop production is affected by the following:

- Use of fertilisers
- Removal of cations
- Leaching of cations
- Organic residue decomposition
- Heavy rainfall since rain has pH 5.7 or less depending on the pollutants present such as SO_2 and NO_2 (sulphur dioxide and nitrogen dioxide).

Use of Fertilisers

Nitrogen fertilisers carrying basic cations like nitrate (NO_3^-) sources have less acidifying effect compared to ammonium (NH_4^+) sources. For phosphorus fertilisers, phosphoric acid released from TSP (Triple Super Phosphate) which is a monocalcium phosphate and MAP (Mono Ammonium Phosphate) lead to acidifying the soil area in which it is applied for a short while. The former (TSP) reduced pH up to 1.5 while MAP reduces pH up to 3.5, though the amount of H+ released is small and has no long term effect on pH; but (DAP (Diammonium Phosphate) increases pH up to 8. The determination of acidity or basicity of fertilisers is based on these assumptions:

- The acid forming effect of fertilisers is caused by all of the S and Cl^- contained in them, ⅓ of the P and ½ of the nitrogen.
- The presence of basic cations (Ca, Mg, K, Na) will increase or have no effect on soil pH.
- Half of the nitrogen fertilisers are taken up as NO_3^- (nitrate) while the other half as NH_4^+ (in association with H^+ or exchanged for HCO_3^- from the root of plants). Soil acidity develops under long terms continuous application of nitrogen fertilisers. Acidity does not develop in one or two years though it varies for different soil types.

Removal of Cations

The removal of cations by crops and leaching can cause soil acidity, but can be reduced by mixed farming practices.

Ammonia Volatilisation

Ammonia volatilisation causes a reduction in nitrification process which in turn results in soil acidity build up.

Sulphur Acidification

Formation of sulphuric acid from elemental sulphur (S) and other compounds causes soil acidity

3.5 Effect of Soil Acidity on Crops and Soil

Soil that are strongly acidic cause problem for many crops such as:

- Decrease in crop yield due to manganese (Mn) and aluminium (Al) toxicity regardless of the supply of available processes causing the plant not to function properly. The solution to such crops is to increase the soil pH by adding liming materials to the soil.
- Shortage of essential cations resulting in poor growth and development. Banding of cations may furnish adequate fertility by saturating the exchange complex site.

- Some nutrients are made available under low pH while others decrease resulting in toxicity or deficiency problems at the same time. For instance, Mn may be a problem (toxicity) at low pH but molybdenum insolubility resulting in deficiency.
- Acidity of soil cause soil degradation thereby affecting land quality.
- Soil acidity causes food chain contamination thereby threatening human and animal health.
- Soil acidity effect on the availability of essential plant nutrients required by crop for growth affects yield resulting in shortage of food supply, hence increased prices of food and consequent malnutrition due to high cost of food.

3.6 Correction of Soil Acidity

Soil acidity problem can be corrected using liming materials such as limestone, hydrated lime, wood ash and quick lime, marl and slags.

4.0 CONCLUSION

In this unit, we have discussed the definition, sources, causes, factors affecting, effects on crops as well as ways to correct soil acidity. Following these discussions, it can be concluded that soil acidity causes serious effects both on crops and soil which in turn affects livelihood and crop productivity.

5.0 SUMMARY

In this unit, you learnt the following:

- An acid soil is a soil with pH of less than 7.0 and soil acidity varies depending on the soil pH.
- Soil acidity results from organic matter, clay minerals, Fe and Al oxides, exchangeable Al^{3+}, soluble salts and amount of CO_2 present in the soil.
- Soil acidity is caused by the replacement of the basic cations by H^+ and Al^{3+} ions in the soil.
- Soil acidity is affected by fertiliser use (long term), removal of cations, leaching, decomposition of organic residues and constant heavy rainfall with SO_2 and NO_2 present as pollutants.
- Soil acidity causes decrease in crop yield, soil degradation and poor land quality, food chain contamination and increase in cost of living because of increased food prices and poor health of both human and animals.

- Soil acidity does not develop in a year or two but varies from soil to soil. It may develop from 5 years (sandy soil) to 10 years (silt loam) and may reach up to 15 years or more (clay loam).

6.0 TUTOR-MARKED ASSIGNMENT

1. (a) List the sources of soil acidity.
   (b) List the causes of soil acidity.
2. How does soil acidity affect crop and soil?

7.0 REFERENCES/FURTHER READING

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UNIT 2 LIMING AND LIMING MATERIALS

CONTENTS

1.0 INTRODUCTION

Liming is one of the ways in which soil acidity is corrected as we learnt in the previous unit. Lime is a soil amendment consisting mainly of calcium carbonate used for neutralising soil acidity. Aside its role in neutralising soil acidity, it furnishes the soil with calcium and magnesium necessary for plant growth. Several works done has shown that the use of lime alone depressed plant growth and yield, compared to the combination of lime with manure and other essential micronutrients. The poor result obtained using lime alone was attributed to the inducement of micronutrient deficiencies especially zinc (Zn) resulting from excessive liming. This shows that care must be taken when lime is to be applied putting into consideration the exchangeable Al^{3+} level rather than just the pH value and the use of acid tolerant crops should be considered also.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain lime and liming
- list the various liming materials
- discuss the benefits of lime
- describe factors determining liming programme.

3.0 MAIN CONTENT

3.1 What is Lime and Liming?

Lime is a soil amendment consisting mainly of calcium carbonate ($CaCO_3$) and magnesium carbonate while liming is the process of lime application on the soil.

3.2 Liming Materials

The commonly used liming materials are the oxides, hydroxides, carbonates and silicates of calcium (Ca) and / or magnesium (Mg). The example of a liming reaction is given below:

$$CaCO_3 + H_2O \longrightarrow Ca^{2+} + HCO_3^- + OH^-.$$

The H^+ in the soil solution is removed resulting in the increase of soil pH and the precipitation of the Al^{3+} and Fe^{3+} as $Al(OH)_3$ and $Fe(OH)_3$ and they are replaced with Ca^{2+} and Mg^{2+} on the cation exchange capacity (CEC) while the soil pH increases as shown below:

Al^{3+} K^+
Ca^{2+} Ca^{2+}
Clay Mg^{2+} + $3CaCO_3$ + $3H_2O \longrightarrow$ Clay
Ca^{2+} + $2Al(OH)_3$ + $3CO_2$.
Soil K^+ Soil
Mg^{2+}
Al^{3+} Ca^{2+}
Ca^{2+}.

Fig.2.1

The above reaction shows that as pH increases the percentage base saturation increases. The liming materials must have the ability to neutralise the H^+ for them to be classified as liming agents. Some of the liming materials are:

(i) **Calcium Oxide (CaO)**

Also called lime, unslaked lime, burned lime or quick lime; it is a porter and has caustic properties hence it's shipped in bags. It is the most effective of all liming materials with a neutralising value or calcium carbonate equivalent (CCE) of 179%.

(ii) **Calcium Hydroxide ($Ca(OH)_2$)**

Also known as slaked lime, hydrated lime or builders lime. It is a white powder and difficult to handle, giving rapid result with CCE value of 136%.

(iii) **Calcium and Calcium-Magnesium Carbonate**

Calcium carbonate ($CaCO_3$) also known as calcite and calcium – magnesium carbonate ($CaMg(CO_3)_2$) known as dolomite. The CCE value ranges from 65 a little above 100%. The CCE of pure $CaCO_3$ is 100% while that of dolomite is 109%. Most agricultural limestones have CCE values between 90 and 98% due to impurities.

(iv) **Marl**

These are soft, unconsolidated deposits of $CaCO_3$ mixed with earth and usually wet. They are low in Mg and have a CCE value between 70 and 90% depending on their clay content.

(v) **Slags**

These include:

- Blast Furnace Slag ($CaSiO_3$) which is a by – product from the manufacture of pig iron. The CCE value ranges from 75 to 90% and contain good proportion of magnesium.
- Basic Slag, a by – product from pig iron produced from high phosphorus Fe ores. The impurities (Fe, Si, P) are removed with lime. The CCE value is between 60 to 70%. It is used because of its *P* content, hence, good on lo *P* acid soils.
- Electric Furnace Slag, produced from the reduction of phosphate rock for the preparation of elemental P in the manufacture of pig iron and steel. The CCE value ranges between 65 to 80%

Those not commonly used are:

- Fly ash produced from coal burning power generating plants
- Sludge from water treatment plants
- Cotrell lime or flue dust from cement manufacturing
- Sugar lime
- Pulp mill lime
- Carbide lime
- Acetylene lime
- Packing house lime

3.3 Importance of Lime in Soil

The acidity of the soil can be corrected through the application of the various liming materials mentioned above. The importance of lime:

- It supplies plants and animal essential nutrients including those of fishes
- It neutralises the acidity of the soil
- Maintains the soil in good condition for plant growth

- Helps to control plant diseases that occur in acid soils
- Helps loosen heavy soil and makes cultivation easier
- Improves or enhances crop yield of cereals, vegetables, tubers like yam and cassava, banana, plantain, soyabean and fruits (grapes, oranges).

3.4 Use of Lime in Agriculture

Lime is rarely used in areas of low rainfall where leaching occurs minimally such as the Semi- arid, aid, saline soils under irrigation and saline – alkali (saline – sodic) soils. Response to lime application is seen as a result of decrease in Al^{3+} toxicity and the benefit obtained from the Ca and Mg nutrient elements. The use of lime in agriculture can be viewed from two parts:

(a) Direct Benefit

(i) The key use of lime is for the correction of soil acidity induced by Al toxicity which inhibits nodule initiation, affects plant growth and development, absorbs P making it unavailable for plant use including other nutrients and also interferes with plant water use.

(ii) Lime is also used for the removal of excess H^+ which causes toxicity problem to both plants and microorganisms especially growth of beneficial bacteria such as *Nitrosomonas* and *Nitrobacter sp*.

Liming reduces the activity or solubility of Al^{3+} and Mn in acid soils, thereby increasing plant uptake of Ca and Mg and soil pH.

(b) Indirect Benefit

(i) Effect on P availability

Aluminium (Al) and Iron (Fe) are precipitated as insoluble Al – P and Fe – P compounds in acid soils but liming will precipitate Al and Fe as $Al(OH)_3$ and $Fe(OH)_3$ making up more available for plant use. Care must be taken so as not to reduce P availability because liming above 6.8 – 7.0 could result to Ca – P and Mg – P being precipitated.

(ii) Effect on Micronutrient availability

Apart from Molybdenum (Mo) all other micronutrient levels are increased in acid soils and this causes micronutrient toxicity problem on plants. Hence, liming will reduce or eliminate this negative effect and provide sufficient available levels of micronutrients for plant use including molybdenum.

(iii) Nitrification

The nitrifying bacteria require Ca for their metabolic activity, hence liming to pH 5.5 – 6.5 will enhance nitrification process.

(iv) Organic Matter Decomposition

Plant residue and soil organic matter decompositions are faster when acid soils are limed especially before decomposition process starts.

(v) Nitrogen Fixation

Nitrogen fixation is enhanced (symbiotic and non-symbiotic) because soil acidity suppresses nodule bacteria (Rhizobium) activity and in turn improves legume host growth.

(vi) Physical Soil Condition

The soil structure is improved due to increase in organic matter content and flocculation of Ca – saturated clay. But over liming will degrade soil structure by impeding soil water percolation. Calcium level is enhanced which in turn improves the physical condition of sodic soils.

(vii) Effect on Plant Diseases

Liming which corrects soil acidity may help in controlling some plant pathogens such as club root thereby increasing yield, but above pH 7.0 club root spores are inhibited. In some root crops, the disease incidence is increased such as scab. In wheat, infection is controlled but yield is reduced when soil is lined up to pH 7.0.

3.5 Determination of Liming Requirement (LR)

Liming requirement (LR) is the amount of liming material required to raise the pH of the soil to a specified value under field conditions. It is determined by different soil test methods.

OR

Liming requirement is the quantity of liming materials needed to neutralise the level of exchangeable Aluminium in the soil raising the pH up to 6.5. That is, Lime Requirement (LR) is the quality of lime ($CaCO_3$) needed to neutralise soil acidity. It is expressed as $CaCO_3$ equivalent in cmol kg^{-1} or meq/100g.

Factors that affect LR are:

- weathering intensity (degree of weathering)
- type of parent materials
- clay content

- organic matter content

There are two methods of determining liming requirement namely:

i. **Soil-Lime Incubation**

This is the incubation of soil with different quantities of lime and determining the amount of lime needed to achieve a specific pH.

ii. **Soil-Base Titration**

This involves titration of the acidic cations of soil with a base. To speed up this method, aliquots of a given soil is equilibrated with different amounts of a base – $Ca(OH)_2$ and then measure the quantity of base needed to increase the pH to a predetermined level.

The amount of lime required can be calculated as follows:

Every 1 meq of base consumed per100g of soil is equivalent to 2.23 tons of pure $CaCO_3$ per hectare of 300m soil depth. Thus:

$$\underset{(1)}{\frac{1.0 \text{ meq } CaCO_3}{100\text{g Soil}}} \quad \underset{(2)}{\left\{\frac{50 \text{ mg } CaCO_3}{\text{Meq}}\right\}} \quad = \quad \frac{50 \text{ mg } CaCO_3}{100\text{g Soil}} \quad = \quad \underset{(3)}{45.5 \times 10^6 \text{ kg Soil}}$$

Where 1 = Measured value

2 = Equivalent weight of $CaCO_3 = \left\{\frac{100}{2} = 50\right\}$

3 = Weight of hectare furrow slice of 30cm

Please note that (1) has a denominator of 100 which must not be ignored.

Therefore, the neutralising value of calcium carbonate equivalent is calculated as follows:

The molecular weight of $CaCO_3$ is 100

The molecular weight of $MgCO_3$ is 84

Therefore, 84g of $MgCO_3$ will neutralize the same amount of acid as 100g of $CaCO_3$. Therefore, the CCE is calculated by

$$\frac{84}{100} = \frac{100}{x}$$

$$\text{Where, } x = \frac{10{,}000}{84} = 119\% \ (\% \text{ CCE})$$

This means that $MgCO_3$ will neutralize 1.19 times as much acid as the same weight of $CaCO_3$. Therefore, the CCE is 119%.

Therefore, neutralising value or CCE is the acid – neutralising ability of a liming material expressed as a weight percentage of $CaCO_3$. Pure $CaCO_3$ is the standard with which other liming materials are measured and its CCE is considered to be 100%.

3.6 Factors Determining Type of Liming Programme

The type of liming programme to use is determined by several factors such as:

i. **Type of Crop**

Different crops react to soil acidity and liming in different ways. This is the most important factor to be considered.

ii. **Soil Organic Matter Content and Texture**

Soils with coarse texture that are low in organic matter have less need for liming. That is, their lime requirement is less compared to fine textured or high organic matter soils.

iii. **Application Time and Frequency of Liming**

Lime application should be done between 3 – 6 time before planting in crop rotations with leguminous crops, but best when wheat is planted. Room should be given to the CaO and $Ca(OH)_2$ forms (caustic forms) to spread in order not to affect seed germination.

How often to apply lime depends on the soil texture, the source of N and rate to be applied, crop removal, precipitation patterns and lime rate. Applications are more frequent on sandy soils compared to fine textured soils, and lime crushed to powder form reacts more quickly having shorter time than lime in granular or coarse forms.

iv. **Tillage Depth**

Liming is recommended on the basis of 5 – 10 furrow slice. Lime recommendation of tillage to a depth of 10 – 20 cm should be doubled.

4.0 CONCLUSION

In this unit, we have discussed the meaning of lime and liming, the various types of liming materials used and their importance, as well as the liming requirement of soil and factors that determine what liming programme to use. From the discussions, it can be concluded that liming can help correct the effect of soil acidity and enhance crop production and soil fertility.

5.0 SUMMARY

In this unit, you have learnt that:

- Soil acidity can be corrected by liming and the lime required should be measured using various strongly buffered solutions.
- Several liming materials such as calcium oxide (burned lime). Calcium hydroxide (hydrated lime), Calcium and calcium – magnesium carbonate (dolomite and calcitic limestone), marl and slags are used in the liming of soils and some of their properties are also given.
- The CCE of limes is a measure of how effective they are in neutralising soil acidity and methods to determine liming requirement (LR) were mentioned.
- Lime is one of the most essential inputs in agriculture to correct soil acidity. It has added advantages such as improving P and micronutrient availability, nitrification, N-fixation, soil structure and disease incidences of crop production.
- Selection of a liming programme depends on the LR of the crops, pH, soil texture and soil organic matter, liming material to be used, time and frequency of application and depth.

6.0 TUTOR-MARKED ASSIGNMENT

1. (a) Define the term liming requirement and name the methods of determining liming requirement of a soil.
   (b) List three types of slag used as effective liming materials.
   (c) What is the calcium carbonate ($CaCO_3$) equivalent (CCE) of sodium carbonate?
   Given the following equivalent weights.
   Ca – 40
   O – 16
   C – 12
   Na – 23 Mg – 24
   (d) Define neutralising value or calcium carbonate equivalent of liming materials.
2. (a) List the several indirect benefits of adding lime to soil?
   (b) What ions are the principal sources of soil acidity?

7.0 REFERENCES / FURTHER READING

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UNIT 3 SOIL BASICITY/ALKALINITY

CONTENTS

1.0 INTRODUCTION

Soluble salts accumulation is one of the long term major problems facing crop production in dry regions and requires attention urgently and specially. Acid soils are found mainly in humid regions and this possesses both agricultural production and environmental problems in these soils. However, in the arid and semi – arid regions, the soils are mainly alkaline, having a pH greater than 7.0. Some of the soils also accumulate soluble salts (saline soils) or sodium ions (sodic soils) or both. The chemical reactions with alkalinity, both salinity and sodicity affect negatively the fertility of the soil and its physical properties. Some plants and animals that are native to the deserts and range (graze) lands have adapted to all except for severe levels of alkalinity, salinity and sodicity.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain alkalinity and alkaline soil
- discuss the causes of soil alkalinity
- explain the sources of soil alkalinity
- state the factors affecting alkalinity of soils
- describe the characteristics of an alkaline soil
- explain the problems associated with soil alkalinity.

3.0 MAIN CONTENT

3.1 What is an Alkaline Soil and Alkalinity?

The terms an alkaline and alkalinity are often seen as having one and the same meaning, and people commonly use it to characterise soils that have high levels of soluble salts or sodium. Alkaline soils are soils that have a pH above 7, while alkalinity is the concentration of the OH^- ions just as we have for acidity with H^+ ions.

3.2 Cause of Alkalinity in Soils

Soil alkalinity occurs generally in the semi – arid and arid regions where precipitation is less than potential evapotranspiration, having rainfall amounts is less than 500mm (20 inches). In these soils the cations released during mineral weathering tends to accumulate due to lack of adequate rain to leach them away, causing the pH to increase to 7 and above. Hence the cause of alkalinity is high soil pH.

3.3 What are the Sources of Soil Alkalinity?

Leaching occurs minimally in arid and semi-arid environment, hence soil acidification or soil acidity is reduced, hence on the exchange complex site and in soil solution, you have Ca^{2+}. Mg^{2+}, K^+ and Na^+ ions. These cations do not produce H^+ in reaction with water (like Al^{3+} and Fe^{3+} ions), nor OH^- ions. Hence they are said to be non-hydrolysing. They are neutral in water except in the presence of some anions. The anions that give off the OH^- ions are mainly the carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions. The sources of these anions are from calcite ($CaCO_3$) and carbonic acid (H_2CO_3) when dissociate or dissolved in water. Therefore, carbonate and bicarbonate are sources of alkalinity because they act as bases by reacting with water to form OH^- ion (hydroxyl) which increase soil pH.

3.4 Factors that Influence Alkalinity

The factors that affect alkalinity are as follows:

(i) **Influence of carbon-dioxide (CO_2) and carbonates.**
The way the overall reaction goes, determines whether the OH^- ions are taken up or produced and this in turn is controlled by precipitation or dissolution of calcite and production or loss (volatilisation to atmosphere) of carbon-dioxide. Concentration of CO_2 in soil air could be up to 0.5% due to root respiration and microorganisms but microbial activity lowers the soil pH.

Another process that affects increase in soil pH is the precipitation of $CaCO_3$ when the soil solution is saturated with Ca^{2+} ions, removing calcium from the soil solution, thereby lowering the pH. The pH at which $CaCO_3$ precipitates is pH 7-8 depending on CO_2 concentration increase by microbial activity. This indicates that if there are other more soluble carbonate minerals in soil like (Na_2CO_3) sodium carbonate, the pH will increase. This is the case with calcerous soils where calcite dominated soils have pH 7 – 8.4 (tolerable by most plants) while sodic soils (sodium carbonate dominated) have pH 8.5 – 10.5 (levels toxic to most plants).

(ii) **Role of Na^+ and Ca^{2+}Cations**

As earlier mentioned, cations associated with carbonate and bicarbonate anions affect soil pH level. Calcium (Ca) and sodium (Na) are the main cations responsible. When Na^+ dominates the exchange complex site and soil solution, more OH^- ions are produced resulting in increased pH. This is because Na_2CO_3 and sodium bicarbonate are more water soluble than calcium carbonate ($CaCO_3$). With high levels of carbonate ions (CO_3^{2-}) in solution, the pH can go up to 10 or more. It is therefore, more advantageous that Ca^{2+} and Na^+ ions dominates the soil.

(iii) **Effect of Soluble Salt Level**

High levels of neutral salts in the soil solution lower the pH by moderating the alkalinising reaction. Such neutral salt is calcium sulphate ($CaSO_4$), sodium sulphate(Na_2SO_4), sodium chloride (NaCl) and Calcium chloride (CaCl). When the concentration of Ca2+ or Na+ is increased, the reaction results in common ion effect. Common ion effect is the shift in equilibrium which results from the addition of an ion that is already part of the equilibrium reaction. For instance, Ca^{2+} and Na^+ ions added from other sources (not $CaCO_3$ or Na_2CO_3) causes less carbonates to be dissolved, hence, less CO_3^{2-} and HCO_3^- ions being in solution. This causes a reduction in pH as compared to when less salt is added.

(iv) **Effect of Soil Physical Properties**

The soil physical properties are affected by salts. For instance, high amounts of soluble salts increase the total ionic strength in soil solution. This in turn enhances the soil physical condition by increasing the aggregation of clays.

3.5 Characteristics and Problems of Alkaline Soils

Alkaline soils as previously mentioned are high in pH and rich in carbonate, hence they exhibit many characteristics and problems different from those in acid soils.

(a) Nutrient Deficiencies

(i) Micronutrient Elements

The availability of nutrients is affected by pH. Micronutrients (Zn, Cu, Fe, Mn) are readily available in acid soils. Iron (Fe) and manganese (Mn) may even reach toxic levels and are not so soluble at pH above 7. For this reason, in alkaline soils plant growth is affected by the deficiencies of these nutrient elements. Iron (Fe) solubility is very low at alkaline pH levels that plants and microorganisms have to depend on mechanisms for accessing these micronutrients in order to survive. Addition of chemical fertilisers to alkaline soils that contain Fe and other micronutrients, do not correct the deficiency problems at times because the added elements are adsorbed and rendered insoluble. The addition of chelates helps meet the nutrient needs of plants on these soils. In other to avoid the interaction of these micronutrients in alkaline soils, foliar applications are advised or the addition of acid forming chemicals like sulphur to change the pH.

(ii) Boron and Molybdenum

Boron availability is a problem in alkaline soils because it forms complexes on surfaces of Fe and Al oxides and silicate clays. Adsorption increases as the pH increases up to 9. Clay soils adsorb boron more compared to sandy soils. While loose soil (sandy) loses boron due to leaching. Plants have higher deficiency is common in alkaline soils. Molybdenum (Mo) availability on the other hand is high in alkaline soils. It could reach toxic levels causing problem to both plants and animals. Irrigation water high in Mo can cause Mo toxicity.

(iii) Phosphorus

Phosphorus is a macronutrient and next to nitrogen in importance. It is deficiency is common in alkaline soils because it is fixed to Ca^{2+} and Mg^{2+} ions in the soil solution. Phosphorus applied fertiliser like single superphosphate (SSP) is very soluble but soon reacts to form Ca – P compounds that are insoluble but easily attacked by acids.

(b) Cation Exchange Capacity (CEC)

The CEC of alkaline soils are usually high compared to acid soils. This is because:

i. The 2:1 clay types (e.g. montmorillonite clays) have high amounts of permanent charge.
ii. The high pH levels stimulate high pH – dependent charges on soil colloids such as humus.

(c) Calcium – rich Layers

A common characteristic of soils in low rainfall areas is the accumulation of $CaCO_3$ in the soil profile. Micronutrient and P deficiencies can occur on plants not adapted to this calcareous soil condition. Calcareous soils are soils with free carbonates. Petro calcic or duripans are formed in alkaline soils. These are subsoils cemented into hard, concrete like horizons. Some are rich in gypsum (Calcium sulphate) which is more soluble than calcium carbonate. The soil oxides found mainly in alkaline soils are Aridisols and Entisols.

(d) Soil Water Supply

The subsoils of low rainfall alkaline soils are dry except where ground water table is near the surface. Low moisture levels to competition among plants for water determine the nature and productivity of the natural vegetation and the capacity to support animals.

In arid regions, clumps or aggregates or floccules of natural grasses and shrubs are spaced, leaving patches of bare soil in between. In some areas, patches not covered by vegetation are not bare but covered by crusts developed by fungi and algae associations. While in some areas, the surface is covered by layers of pebbles. These surfaces help to conserve water, but soils of rangelands are easily degraded due to overgrasing.

4.0 CONCLUSION

In this unit, we have discussed the difference between alkaline soil and alkalinity, causes and sources of alkalinity, factors affecting alkalinity and characteristic features and problems of alkaline sails. Following our discussions, it can be concluded that alkaline soils dominate arid and semi-arid regions. These soils have pH above 7, rich in calcium carbonate (calcic) or gypsum at some depth in the horizon. These soils are usually used for grasing or as rangeland and for dry land farming in the arid and semi-arid regions. Irrigation of alkaline soils results in the accumulation of salts; hence care must be taken when applying irrigation water. The high pH of these soils results in some micronutrient deficiencies (Fe and Zn) and phosphorus. Boron and molybdenum may be very much available to accumulate in plants that will cause problem to animals that graze on them.

5.0 SUMMARY

In this unit, you learnt that:

- Alkaline soils are soils that have pH above 7, while alkalinity is the concentration of OH^-ions just as we have acidity with H^+ ions.
- Alkaline soils are rich in calcium carbonate and gypsum.
- Soil alkalinity is a major problem in the arid and semi-arid regions where precipitation is less than potential evapotranspiration having rainfall less than 25cm per year.
- These soils are used as rangelands and for dry land farming
- Irrigation induces alkalinity especially if the irrigation water has high Na^+ ions compared to Ca^{2+} and Mg^{2+} and also if the HCO_3^- ion is present.
- The anions that give off the OH^- ions are the CO_3^{2-} and HCO^- ions and the source of these anions are calcite ($CaCO_3$) and carbonic acid (H_2CO_3) when they dissociate in water.
- Soil alkalinity is influence by CO_2 and carbonates, Na^+ and Ca^{2+}cations, soluble salt level present in soil and in turn affects the soil physical properties.
- Boron and molybdenum nutrient elements are very much made available while Fe, Cu, Zn and Mn are less available resulting in their deficiencies in alkaline soils.
- Phosphorus deficiency is common in alkaline soils due to being fixed to Ca^{2+} and Mg^{2+} ions in the soil solution forming Ca – P insoluble compounds.
- Cation exchange capacity of alkaline soils are high compared to acid soils because of the high amounts of permanent charge of 2:1 clays and high pH dependent charges on soil humus.

6.0 TUTOR-MARKED ASSIGNMENT

1. (a) What are the main sources of soil alkalinity?
   (b) Analysis of micronutrient Fe (Iron) in an arid region soil showed high level of Iron (Fe), yet crop growing on the soil showed serious Iron deficiency symptoms. What is the likely explanation?
   (c) List the factors that influence soil alkalinity.

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UNIT 4 SOIL SALINITY AND SODICITY

CONTENTS

1.0 INTRODUCTION

As mentioned in the previous unit, rainfall is not sufficient to cause leaching, usually about 15 – 20 inches per year in the arid and semi-arid regions. Hence, water collected in holes and depressions from runoff evaporate and leave behind salts in these regions. Even in shallow water tables, water moves upwards, and evaporates resulting in salt accumulation forming saline, saline – sodic or sodic soils. These soils are formed also in irrigated areas where poor drainage and irrigation systems are used. These soils can be found in tropic mangrove swamps-marshy areas close to salt lakes in the temperate regions.

Dry season farming using irrigation has resulted in soil degradation due to salinity problem. In India, large areas of land have become unproductive due to salt accumulation and poor water management, therefore making salinity a major problem in wetland rice production. Salinity also is becoming a problem on non-irrigated crop and rangelands of the United States of America. These accumulated soils contain cations (Na^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}). Soluble salts can result from rock mineral weathering and parent material and accumulate in areas where precipitation is very low to cause leaching.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- discuss the causes of salinity and sodicity
- describe how to measure Salinity and Sodicity of a soil
- explain the effect of salt-affected soils on plants
- discuss how to reclaim a Saline, Saline-Sodic and Sodic soil
- explain how to manage the reclaimed soils.

3.0 MAIN CONTENT

3.1 What is Soil Salinity and Soil Sodicity?

Soil salinisation is the accumulation of neutral soluble salts in the soil. These salts are mainly chlorides (Cl^-) and sulphates (SO_4^{2-}) of calcium, magnesium, potassium and sodium. When the concentrations of these salts are good enough to affect plant growth and produce an electrical conductivity (EC) greater than 4dS/m (4mmhos/cm) in the saturation extract. This process is called soil salinity. While sodicity is the process of accumulation of natural salts at low EC (less than 4mm hos/cm) but have high levels of Na on the exchange complex where the Exchangeable Sodium Percentage (ESP) is more than 15J and Sodium Adsorption Ratio (SAR) is more than 13 in the saturation extract.

3.2 Types of Salt-Affected Soils

Salt-affected soils can be classified into three types or classes based on their EC, ESP (or SAR) and soil pH. They are classified as:

(i) Saline Soil

- Formerly called white alkaline due to deposits of salts on the soil surface
- Have EC value greater than 4mm hos/cm.
- Have pH below 8.5
- ESP less than 15%
- SAR less than 13
- Exchange complex site dominated by Ca^{2+} and Mg^{2+} not Na^+.
- The soluble salts sufficient enough to affect plant growth, though plants differ in their level of salt tolerance.

(ii) Sodic Soil

- Formerly called black alkali because organic matter is deposited along with salts on the soil surface.

- EC less than 4mm hos/cm indicating that level of the neutral soluble salts are low.
- pH greater than 8.5 up to 10 or more because sodium carbonate is more soluble than Ca or Mg carbonates thus maintaining high of CO_3^{2-} and HCO_3^- ions in soil solution.
- ESP greater than 15%
- SAR greater than 13
- Exchangeable Na^+ disperses soil colloids which clog soil pores as they move down the profile resulting in the breaking of soil aggregates due to lack of large pores. This lowers hydraulic conductivity and water infiltration rate causing water to form puddles. This is a major characteristic of sodic soils.
- Unproductive and difficult to manage.

(iii) Saline-Sodic Soils

- The neutral soluble salts have EC greater than 4mm hos/cm to qualify as saline.
- Have ESP greater than 15% and SAR greater than 13 to qualify as sodic. Thus they are called saline – sodic soils.
- Have pH less than 8.5
- When the salts are leached out, the exchangeable Na^+ hydrolyses leading to increase in pH resulting in a sodic soil.
- Exhibit soil physical conditions intermediate between saline and sodic soils.
- The salts help to keep the soil colloids together in aggregates.
- This soil type is subject to rapid change especially if the soluble salts are leached from soil especially if SAR is high. This will reduce salinity but ESP % will increase and this soil will become sodic.

3.3 Causes of Salinity and Sodicity

Salinity and sodicity as mentioned have resulted from accumulation of salts in the soil of the semi-arid and arid regions. One of the causes of these salt-affected soils is high evaporation of soil water more than precipitation. These soils are common in the arid and semi-arid regions where rainfall per annum is less than 25 cm or 15 – 20 inches. In these regions the rainfall is not sufficient enough to cause leaching instead salt accumulation results due to high evaporation rate forming saline, saline-sodic and sodic soils.

Another cause of salinity and sodicity is the use of irrigation water especially where improper irrigation and drainage methods are used. The build-up of salts has become a serious problem on almost all the irrigated lands in the semi-arid and arid regions all over the world. The use of irrigation water high in *Na* results in sodicity problem due to Na^+ ion saturation of the exchange complex site. These salts accumulated being mainly cations of Ca^{2+} and Mg^{2+} and anions of Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}. Salt accumulation also results from the weathering rocks and parent materials where precipitation is very low to cause leaching.

In salt-affected soils, Ca^{2+} and Mg^{2+} ions dominate most of the exchange complex site, though in some soils Na^+ dominates the exchange complex sites especially where the ESP and SAR are greater than 15% and 13 respectively and EC less than 4mm hos/cm.

3.4 How do We measure Salinity and Sodicity?

Salt affected soils have good negative effect on plant growth and development and also affect the structure of the soil. This is as a result of the high accumulation of salts (salinity) and Na^+ ions (sodicity) in the soil. in order to ascertain and be able to manage these salt affect soils, various parameters that are characteristic of each type of salt affects soils is determined or measure to know what type of soil it is and how to manage or reclaim it. These parameters are namely:

i. **Electrical Conductivity (EC)**

This measures the total dissolved salt (TDS) in the soil solution and given as:

EC x 10 = total soluble cations (TDS) in milli-equivalent per litre (meq/l)

TDS can be converted to ECw for Na salts as TDS = 640 x ECw; For Ca salts, TDS = 800 x ECw

Where

TDS = Total Dissolved Salts in water or solution extracted from water saturated soil paste measured on bulk soil.

ECw = Conductivity of the solution extracted from a 1:2 ratio soil – water mixture.

ii. **Exchangeable Sodium Percentage**

$$ESP = \frac{\text{ExchangebleNa}^{+}\text{cmol/kg}}{\text{Cation Exchange Capacity cmol/kg}} \times 100$$

Or

$$ESR = \frac{\text{Exchangeable } Na^{+} \text{ (in meq/100g)}}{\text{Exchangeable } (Ca^{2+} + Mg^{2+}) \text{ (in meq/100g)}}$$

Where
$[Na^{+}]$ $[Ca^{2+}]$ and $[Mg^{2+}]$ are concentrations (in milli-equivalent of charge per 100g) of Na, Ca and Mg ions in soil solution.

ESR = Exchangeable Sodium Ratio. This is so because the relation between solution and exchangeable cations in soils. That is Sodium Adsorption Ratio (SAR) is related to the quantity of Na^{+} on the cation exchange capacity (CEC).

iii. **Sodium Adsorption Ratio (SAR)**
This is the next more measured parameter after EC of soil and it is given as:

$$SAR = \frac{[Na+]}{\sqrt{\frac{[Ca2+ \ + \ Mg2+]}{2}}} \text{ (meq/l)}$$

Or

$$SAR = \frac{[Na+]}{(0.5)[Ca2+] + 0.5 \ [Mg2+]) ½} \text{ (nmol/litre)}$$

Where: $[Na^{+}]$ $[Ca^{2+}]$ $[Mg^{2+}]$ are concentrations of Na, Ca and Mg ions in millimole per litre in the soil solution.

The SAR of soil takes into account the negative effect of Na^{+} being mild or moderate in the presence of Ca^{2+} and Mg^{2+} ions. This method is used to characterize irrigation water supplied to soil. The ESR is related to SAR and ESP as follows:

$$ESR = 0.015 \text{ (SA)}$$

$$ESP = \frac{100 \text{ (ESR)}}{1 + ESR}$$

3.5 Effect of Salt-Affected Soils on Plants

The different classes or types of salt – affected soils affect plant growth in different ways.

- Nutrient deficiencies result due to high pH resulting in stunted growth. Some plants show dark – blue green leaf colour with dull surfaces. Scorching or necrosis of leaf margins and tips. Also premature leaves fall.
- Increase in osmotic pressure leading to the movement of the salts from higher concentration to lower concentration. This causes the movement of salt into soil solution water, and when the plant root cells get in contact with the soil solution, the solute (salts)

are transported through the plant roots into the plant tissues or cells resulting in plasmolysis (cell collapses). Plants are more susceptible to salt damage at the early stages of growth.

- Seed germination is prevented or delayed under saline condition. But older plants of same species may be able to tolerate this saline condition.
- The type of salt present in the soil solution can determine how the plants will respond. Ions such as Cl^-, Na^+, $H_4BO_4^-$ (borate) and HCO_3^- are toxic to most plants. This is called specific ion effect. For instance, high Na^+ levels cause nutrient imbalance. It competes with K^+ during up take or transport in the cell membrane and make K not sufficient or available for plant. This reaction is characteristic of saline – sodic and sodic soils, but in saline soil the presence of Ca^{2+} nullifies the effect of Na^+ and making K^+ ion available. This is a benefit of saline soil to plants.
- Effect on Soil Physical Properties: The soil structure is adversely affected under sodic soil conditions hence the choice of plant to grow matters here because sodicity causes dispersion of soil colloids. This affects oxygen leading to poor soil aeration. Secondly, reduced water infiltration and percolation rates.

3.6 Reclamation of Saline Soils

Soil reclamation is the restoration of both the chemical and physical conditions of the soil to the highly productive level. The reclamation of saline soils is relatively easier compared to saline – sodic or sodic soils. In saline soil reclamation, the following must be made possible:

1. There must be effective drainage (internal and surface).
2. Good quality irrigation water low in salt content (low salt irrigation water) must be applied to enable salts be leached from the surface down beyond the root zone and out of contact with the roots.
3. Use of deep – rooted vegetations in areas where irrigation water is not available. These deep – rooted vegetation will lower the water table thereby reducing the uptake of salts by roots (reduce movement of salts upwards).
4. Installation of artificial drainage network where natural soil drainage is inadequate, but application of excess irrigation should be done from time to time in order to reduce the salt content level to the desired one. The amount of water required to remove the excess salt from the soil or the amount of irrigation water to be applied to leach the salts down beyond the root zone is called leaching requirement and can be calculated using the equation below:

$$LR = \frac{EC_{iw}}{EC_{dw}}$$

Where LR = Leaching Requirement
EC_{iw} = EC of Irrigation Water
EC_{dw} = EC of Drainage Water

It tells you the volume of water required to reduce the salts in the soil.

The LR depends on the following:

- Characteristics of the crop to be grown. That is the EC_{se} which depends on the salt tolerance of the crop to be grown.
- Irrigation water quality (EC_{iw})
- Rooting or leaching depth of soil
- Water holding capacity of the soil

3.7 Reclamation of Saline-Sodic and Sodic Soils

In this case, the exchangeable Na^+ and or EC_{se} must be lowered. This is more difficult compared to saline because the soil clay may be disposed leading to low infiltration rate or completely hindering soil infiltration. In the saline-sodic soil, leaching of the soil may lead to increase in exchangeable Na^+ as well as the soil pH. Therefore, it is advisable to first reduce the level of exchangeable Na^+ ions before tackling the removal of excess soluble salts. The removal of Na^+ ions can be achieved by the addition of gypsum ($CaSO_4.2H_2O$) which releases Ca^{2+} ions that occupies the exchange complex site or H^+ ions causing Na^+ ions to be leached beyond the root zone as Na_2SO_4 (sodium sulphate). The use of gypsum is more common in this process, the soil must be well moistened to enhance reaction and the gypsum well mixed by cultivation and followed up with application of irrigation water to leach most of the Na_2SO_4.

3.8 Management of Reclaimed Soils

This is important in the arid and semi-arid regions. In order to manage these reclaimed soils, it is necessary to use:

(i) Methods of management that will minimise or reduce the LR and the quantity of drainage water applied.

Limitations of Leaching Requirement (LR) Method

(i) Maintain soil water near field capacity. This dilutes the salts making it not harmful to plants.

(ii) Light leaching or light irrigation after planting. This moves the excess salt below the planting and early rooting zone.

(iii) Periodic application of water when available will leach the salts out of the rooting zone, in the form of precipitates of

$CaSO_4.2H_2O$, $CaCO_3$ or $MgCO_3$ during dry periods making them not to react as soluble salts, though Na^+ ions in the soil solution may increase.

(iv) Under ridge tillage systems, planting on the shoulders or edge of the ridges helps to reduce or avoid excess salt problems.

(v) Requires additional leaching to reduce excess concentrations of some nutrient elements like boron.

(vi) LR does not put into consideration increase in water table resulting from increased leaching leading to waterlogging and increase in salinity.

(vii) Over application of irrigation using simple LR method. This is because the whole field is treated to avoid or reduce salt damage.

(viii) LR does not take into account salts that may be taken up from fossil salt deposits in the soil strata and substrata.

(ix) It assumes that the EC of drainage water is known. This is because the drainage water sample today may be that of several months ago. Therefore, a repeated measurement across the field using EM sensor or far – electrode methods is recommended. This is a complex method, but recommended when combined with site – specific management method.

4.0 CONCLUSION

In this unit, we have discussed the different salt-affected soils and their characteristics; their effects on plants and soil organisms as well as the ways to reclaim and manage these soils. Following these discussions, it can be concluded that salt-affected soils could be saline, saline-sodic and sodic soils and all these soil types have adverse effects on plants and soil organisms including humans to some extent. But these soils can be reclaimed to make them productive again with good management methods.

5.0 SUMMARY

In this unit, you learnt that:

- Salt-affected soils occur in the arid and semi-arid regions where evaporation leaves salts behind on the soil surface.
- Irrigation water can cause salt problems where drainage is inadequate.
- These salts are mainly Ca^{2+}, Mg^{2+} and Na^+cations while the anions are Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}.
- Saline soils have EC greater than 4mm hos/cm, ESP < 15% and SAR < 13; sodic soil have EC < 4mm hos/cm, ESP > 15% and SAR > 13 while for saline – sodic soils combination of the two.

- Saline soils can be easily reclaimed compared to sodic soils through leaching, but in the reclamation of sodic soils, disposition of soil colloids will result and can cause low infiltration or permeability.
- Gypsum is commonly used for soil reclamation including the use of salt tolerance crop species with good management practices.

6.0 TUTOR-MARKED ASSIGNMENT

i. What are the main cations in saline, sodic and saline – sodic soils?
ii. Explain how a sodic soil becomes impermeable.
iii. Why is $CaSO_4.2H_2O$ effective in reclaiming saline soils.

7.0 REFERENCES / FURTHER READING

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MODULE 4 SOIL FERTILITY EVALUATION

UNIT 1 WHAT IS SOIL FERTILITY EVALUATION

CONTENTS

1.0 INTRODUCTION

Soil fertility involves the status and availability of essential nutrients in soil under various soil conditions while evaluation has to do with their level of availability and balance in soil. This also includes ways or approaches for determining these factors such as soil tests, plant analysis, soil survey, climatic conditions. After the soil has been evaluated, recommendations are made which involves addition of amendments such as fertilisers, Farm Yard Manure (FYM), poultry litter and other amendments. These amendments are added on recommended quantities and applied at the time in the season in ways to give optimal required nutritional environment for plant growth. Therefore, soil fertility evaluation and recommendations are site specific and condition specific.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explaine soil fertility evaluation
- state the difference between soil fertility and soil fertility evaluation
- discuss the importance of soil fertility evaluation.

3.0 MAIN CONTENT

3.1 What is Soil Fertility Evaluation?

Soil fertility evaluation is the process of finding out or diagnosing nutritional problems of soil and making further recommendation.

3.2 Importance of Soil Fertility Evaluation

Soil test results obtained from Soil Fertility Evaluation (SFE) are:

- fast and the needs of the soil are known before the crops are planted.
- the results obtained is used to maintain the fertility level of that soil.
- helps to predict the possibility of obtaining a profitable response to fertiliser application.
- helps to provide the basis for recommendation of amount of fertiliser and/or soil amendment to be applied.
- to evaluate or know the fertility status of the soil.

3.3 Difference between Soil Fertility and Soil Fertility Evaluation

Soil fertility mainly has to do with the mineral nutrient elements and their soil conditions while evaluation is concerned with the availability status or level and nutrient balance in soil including the various approaches for assessing or determining these factors.

3.4 How do we know that a Soil is Fertile?

The criteria for rating soil fertility classes are as shown below:

(i) Low-this means that the fertility status is below critical level.

(ii) Medium-this is the range above the critical level where there are different responses as expected to fertiliser application.

(iii) High-this is the range where response is unlikely to occur and fertilisation may not be necessary.

Below are soil fertility rating for some soil parameters:

Table 1.1: Soil Fertility Rating

Parameters	**Ratings**		
	Low	**Medium**	**High**
Nitrogen (Total N g kg^{-1})	0.6 – 1.0	1.6 – 2.0	2.1 – 2.4
Available Phosphorus (Bray – 1P mg kg^{-1})	3.0 – 7.0	8.0 – 20.0	> 20
Potassium (Exchangeable K^{+})	0.21 – 0.3	0.31 – 0.6	0.61 – 0.73
Organic Carbon (g kg^{-1})	4.0 – 10.0	10.0 – 14.0	14.0 – 20.0
Exchangeable Ca^{2+}	2.0 – 5.0	5.0 – 10.0	10.0 – 20.0
Exchangeable Mg^{2+}.	0.3 – 1.0	1.0 – 3.0	3.0 – 8.0
Exchangeable Na^{+}	0.1 – 0.3	0.3 – 0.7	0.7 – 2.0
Organic Matter (%)	< 2.0	2.0 – 3.0	> 3.0
Available Micronutrients (mg kg^{-1})			
Zinc (Zn)	< 1.0	1.0 – 5.0	> 5.0
Available Boron (B)	< 0.35 – 0.5	0.5 – 2.0	>2.0
Available Copper (Cu)	< 0.2	0.2 – 10.0	> 10.0
Available Manganese (Mn)	< 1.0	1.0 – 5.0	> 5.0

Source: Chude et al. (2011)

4.0 CONCLUSION

In this unit, we have discussed the definition, importance as well as approaches employed in fertility evaluation. Following these discussions, it can be concluded that soil fertility evaluation is essential in predicting the possibility of obtaining a profitable response to fertiliser or other soil amendments which will result in enhanced fertility status leading to improved crop productivity.

5.0 SUMMARY

In this unit, you have learnt that:

- soil fertility evaluation deals with levels of nutrient availability and balance in soil including the ways for assessing them.
- soil fertility evaluation is necessary because it helps to know the soil needs/requirements before the crops are planted and maintain the fertility status of the soil.

- evaluation is also necessary to make fertiliser or soil amendment recommendation.

6.0 TUTOR-MARKED ASSIGNMENT

1. (a) What is the difference between soil fertility and soil fertility evaluation?
   (b) What is the importance of soil fertility evaluation?

7.0 REFERENCES / FURTHER READING

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UNIT 2-APPROACHES / WAYS TO SOIL FERTILITY EVALUATION

CONTENTS

1.0 INTRODUCTION

Before fertilisers and/or soil amendment recommendations can be made, there is the need to evaluate the fertility status of the soil; in order to achieve this, there are various methods used or employed to assess these factors which are site specific and condition specific too before recommendations are made.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- state the various approaches in fertility evaluation
- explain the approaches.

3.0 MAIN CONTENT

3.1 Approaches Used in Soil Fertility Evaluation

Various methods are in use, world over, to diagnose fertility status of soil. The most common are based on:

(a) Soil testing
(b) Plant analysis
(c) Missing element technique
(d) Simple Fertiliser Trials (SFT)
(e) Combination of all above
(f) Microbiological test
(g) Nutrient deficiency symptoms on plants

(a) Soil Testing

The soil tests used in soil fertility evaluation are mainly those that involve the chemical properties of the soil. There are six (6) inter related facets, namely:

- Sampling of plant and soil
- Laboratory analysis of plant and soil
- Correlation between analysis and yield
- Interpretation and recommendation
- Putting information into use.
- Research works to be carried out.

(i) Soil sampling is the first and most important step in soil and plant analysis. It is also the highest source of error in soil fertility evaluation because there is a lot of variability on the field. A representative soil sample is composed of 10 – 20 sub soil samples per hectare from the rooting zone within the field which is relatively homogenous. After collection, the samples are mixed thoroughly to minimise non uniformity in the field. Sampling depth and time of season to sample are important considerations when sampling. The rooting zone for arable crops is 0-15cm, tree crops 0-30cm or further. How often to sample, depends on the intensity of the use of fertiliser, and economic value of the crop. For intensively managed areas, sampling can be done annually, while for the average managed areas, every three years is adequate.

(b) For plant sampling avoid plant parts damaged by insects and diseases. Nutritionally, healthy and unhealthy parts should be sampled for comparative analysis. Younger leaves should be sampled first for micronutrient determination because they show deficiency symptoms first.

(ii) Laboratory analysis of plant and soil

This involves mainly analysis of chemical properties such as:

- pH
- Organic Carbon
- Total and Available Nitrogen
- Available Phosphorus
- Cation Exchange Capacity (CEC)
- Exchangeable Bases (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+})
- Exchangeable Acidity
- Extractable Micronutrients (Fe, Zn, Mn, Cu, B)

Some physical parameters of importance in soil fertility evaluation includes:

- Soil Texture

- Infiltration Rate
- Soil Colour (this is physical observation)

Selecting extractants for soil test laboratory analysis must meet the following conditions:

- It must be able to extract all or good proportion of the available forms of nutrients with different properties.
- It must be rapid and accurate
- Amount extracted must correlate with growth and response of all crop to the nutrient in question under different conditions.

(iii) Correlation, interpretation and recommendation are one of the most difficult areas of soil fertility evaluation because of the complicated phenomenon involved.

Correlation between analysis and yield response to crop involves how to use these chemical properties in assessing the fertility of the soil. For instance, if the Critical Level (CL) value of an element is not known, given a value is meaningless. The critical level of an element is that below which crops will respond to the application of the element in fertiliser form and above which there may be no response to fertiliser. Hence, values of elements determined in the laboratory are compared against the critical level.

If such values are lower than the critical level, it suggests that the nutrient(s) is deficient in the soil. However, if higher than the critical level, it suggests sufficiency but exceedingly higher levels suggest toxicity.

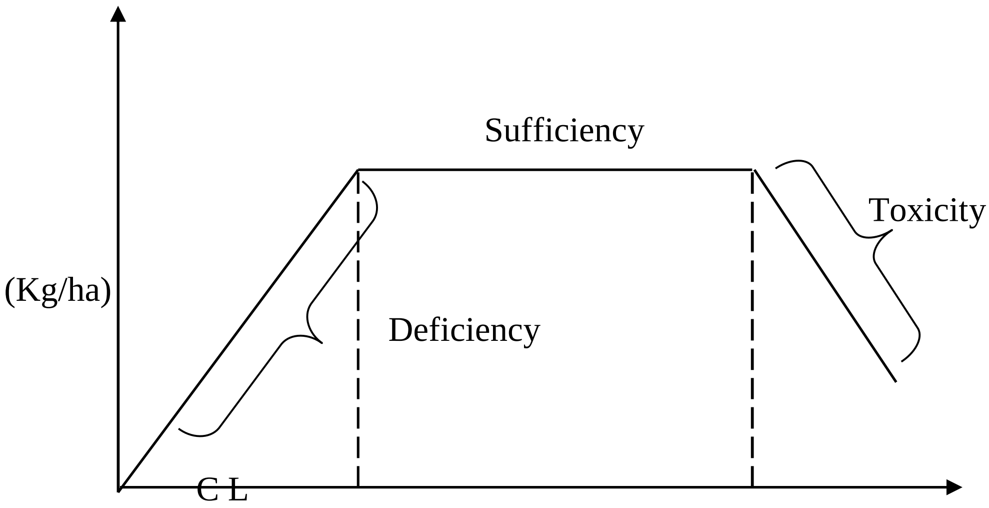

Fig. 2.1:Total P Concentration in Plant

(iv) Interpretation and recommendation is done from the result of correlation between soil tests values and plant analysis with crop yield. If established that nutrient is deficient, it suggests that fertiliser must be applied to sustain growth. For instance, under this situation the maximum dose of nitrogen (120kg N/ha) should be applied. If fertility is medium of the recommended rate, about 60kgN/ha should be approved, but where high, only a quarter (¼ - 30kgN/ha) of the recommended rate should be applied (in the case of N). This is called maintenance dose and is given because losses during growth due to erosion, leaching and burning.

Putting the information into use is done after establishing the optimum fertiliser requirement through soil testing. The information is then passed on to the farmers through Extension Agents. It is necessary to monitor the effect of those extension messages on the productivity of the farmers through follow-up visits to identify problems arising from the recommendations. This is called impact assessment. Where there are problems, solutions should be found like modifying your recommendations.

(v) Then research works should be carried out.

(c) Missing Element Technique

This is also known as minus (-) 1 technique. This involves growing a plant in one plot with all nutrients applied and growing same plant in another plot with one nutrient missing (the nutrient in question). If no differences between the plants in plot 1 and plot 2, it means that the nutrient (example N) is not essential for this particular crop. That is, it is not deficient in plot 2. But if differences occur, it suggests the opposite. Under such condition there will be need to apply N fertiliser to plot 2. The amount to apply depends on the amount of N present in the soil. Where amount is low than CL, you apply maximum; where medium you apply half and where higher you apply maintenance dose.

For legumes, if high and medium no fertiliser (N) application except when critically low, you apply starter dose (10–20kgN/ha). The disadvantage of this technique is that the plants are harvested at an early growth, so data obtained on nutrient deficiencies may be exaggerated due to small volume of soil weight is better for participatory screening in research or for additional information on soil for which poor results on soil test yields are obtained.

(d) Simple Fertiliser Trials (SFT):

This is similar to the missing element technique, but here larger numbers of simple un-replicated fertiliser trials are conducted on the farmers' field, which are chosen randomly before analysis. Here, the fertility response is evaluated on the farmers' field and not under greenhouses or screen houses under controlled conditions. The advantage of this approach is seen mainly on the findings that for application of moderate fertiliser rates, moderate yield increases are obtained. Also, various crops show whether or not those areas are deficient in nutrients like Nitrogen, Phosphorus and potassium. Different yield potentials of different regions are shown or indicated; but it overlooks the local soil variability and hence, site specific recommendations cannot be made.

(e) Combination of all Methods

Here you sample the soil first, and then analyse and get the result. After that, you know whether to apply low, medium or high or give maintenance dose.

(f) Microbiological Test

This involves the use of microorganisms. The microorganisms pick up nutrients and then you kill them and analyse the amount of nutrient in them. Others that can be utilised are laboratory incubator and trip tests.

(g) Nutrient Deficiency Symptoms on Plants

This involves visual observation on the growing plant where deficiency of an element may result in abnormal growth of the plant. If a plant is lacking an element, the deficiency symptoms will manifest. This method is cheap and simple or easy but requires experience. Insect attack and diseases limit the use of nutrient deficiency symptom as a tool. A major disadvantage of this method as a SFE is that the damage would have been done before symptoms appear or show, because symptoms show when nutrient supply is low that the plants cannot function well. But if the symptoms are seen early this can be corrected by application of the right fertiliser treatment.

4.0 CONCLUSION

In this unit, we have discussed in detail the approaches of soil fertility evaluation and some of their benefits and disadvantages. Following these discussions, it can be concluded that SFE approaches are necessary to help diagnose nutritional problems and fertiliser recommendations are made where the fertility status (if established) is low, medium or high or just to apply maintenance dose while for legumes only starter doses are applied when N levels are low.

5.0 SUMMARY

In this unit, you learnt that:

- Soil testing, plant analysis, missing element technique, simple fertiliser trial, nutrient deficiency symptoms, combination of all methods and microbiological test are some of the soil fertility evaluation approaches employed.
- Soil fertility evaluation is site specific and condition specific.
- Soil sampling in soil and plant analysis is the highest source of error in soil fertility evaluation.
- For micronutrient determination, younger leaves are sampled because they show deficiency signs first.
- Nutrient deficiency symptoms on plants are cheap, simple and rapid but requires experience.
- Soil testing is rapid and the needs of the soil are known before planting commences.

6.0 TUTOR-MARKED ASSIGNMENT

1. Why is soil sampling the largest source of error in evaluating soil fertility?
2. Does yield advantage (of the best) pay for the extra fertiliser added and at the same time leave some profit for the farmer?

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UNIT 3 FACTORS AFFECTING SOIL FERTILITY EVALUATION

CONTENTS

1.0 INTRODUCTION

As earlier mentioned, soil fertility evaluation involves many approaches as given by International Soil Fertility Evaluation and Improvement Program (ISFEIP). As indicated soil fertility has to do with mineral nutrient element of plants and the condition of the soil while evaluation talks about the level of availability of these nutrients and their balance in the soil, including the various approaches or methods used for assessing the factors such as soil test, plant analysis, climatic conditions and so on. Therefore, factors which affect the various soil fertility evaluation methods will definitely affect soil fertility evaluation, which will in-turn affect interpretation of results and recommendations.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- identify the various factors that affect soil fertility evaluation
- list the factors affecting soil fertility evaluation.

3.0 MAIN CONTENT

3.1 Factors Affecting Soil Fertility Evaluation

It is important to note that soil fertility evaluation interpretation and recommendations are site and condition specific. The factors are therefore based on the methods of assessment.

1. Lack of experience when using the visual observation on the growing plant method which is based on nutrient deficiency symptoms. This is because incidences of diseases and insect attack can also affect this method.

2. Time of analysis – This is usually observed using the method of plant analysis. By the time the analysis shows nutritional problem it may be too late to correct the deficiency resulting in plant loss.
3. Variability in soil samples collected. This has to do mainly with soil fertility evaluation based on soil tests. The field has a lot of variability, so when sampling be sure that samples collected are representative of the area in question in order to give a good evaluation of the area or site, putting into consideration the depth, time of season to sample, intensity of fertiliser use in the area and the economic value of the crop being planted.
4. Improper handling of the soil samples collected to avoid some chemical and physical changes that may affect result and also
5. Use of bad extractants that will not be able to extract a good proportion of the available forms of the nutrients in soil under different properties.
6. Using data of early growth hence nutrient deficiencies may be exaggerated due to small value of soil being used compared to large numbers of soil from farmer's fields. This is seen in the method based on missing element technique.
7. Lack of site – specific recommendation made. This is because evaluation is done in farmer's field and not under controlled condition resulting in showing different yield potential or ability of different regions / areas thereby not putting into consideration local soil variability. It is expensive and less suitable to individual resource thereby limiting farmers. This is observed mainly on soil fertility evaluation based on fertiliser trials.

4.0 CONCLUSION

In this unit, we have discussed the factors affecting soil fertility evaluation. Following these discussions, it can be concluded that the disadvantages of each of the approaches in turn affect the fertility evaluation.

5.0 SUMMARY

In this unit, you learnt the factors affecting soil fertility evaluation, namely:

- lack of experience
- time of analysis
- variability in soil samples collected
- bad handling of soil samples collected
- use of bad extractants
- data collected at early growth of plant

- lack of site-specific recommendations made affect soil fertility evaluation leading to wrong interpretation and finally wrong recommendations made.

6.0 TUTOR-MARKED ASSIGNMENT

List the factors affecting soil fertility evaluation.

7.0 REFERENCES / FURTHER READING

Chude, V.O; Olayiwola, S.O; Osho, A.O & Daudu, C.K.(Ed.). (2011). *Fertiliser Use and Management Practices for Crops in Nigeria.*. Federal Fertiliser Department (FFD) in Collaboration with National Special Programme for Food Security, FAO, Abuja, Nigeria. p.45.

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UNIT 4 MAINTENANCE OF SOIL FERTILITY

CONTENTS

1.0 INTRODUCTION

In most cropping systems (especially small holder), soil fertility improvement and maintenance are essential for increasing crop productivity. This is a big issue in the Northern Guinea Savanna (NGS) agro-ecology where farmers practice intensive continuous farming, with little improvement in crop productivity. These soils are tropical soil generally low in organic matter and nutrient retention ability. Their texture is generally coarse, and hence, percolation rates are higher resulting to greater nutrient losses. Rainfall is either too high or too low. High total rainfall with high intensity under short period causes surface runoff, leaching and heavy losses of soil and plant nutrient. Temperatures are high mainly and speed up the mineralisation rate of soil organic matter and applied fertilisers thereby increasing the chances of nitrate (NO_3^-) losses through leaching.

A healthy soil is therefore needed to produce quality food which will enhance the health of those who eat the food produced from it, especially to encourage microbiological growth. This can be achieved by producing the microorganisms with organic matter for food and in turn they protect the soil, maintain and enhance its fertility status.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- discuss the characteristics of tropical soils and how to manage them

- explain the benefits of soil organic matter in soil fertility improvement and maintenance
- describe the role of microorganisms in soil fertility maintenance.

3.0 MAIN CONTENT

3.1 Various Ways of Maintaining Soil Fertility

There are many ways of maintaining the fertility of a soil. These include both physical and chemical management practices.

Physical Maintenance Practices

1. **Tillage or cultivation practices**

In porous or sandy soils, tillage increases loss of moisture hence the use of zero or minimum tillage should be observed.

2. **Use of Cover Crops or Mulching**

Conserve loss of moisture by mulching and cover crops

3. **Minimum use of machineries on the soil**

Tropical soils are fragile, so caution should be maintained in the use of machineries so as not to compact the soil too much and to minimise exposure which will lead to loss of top rich soil to erosion.

4. **Soil Structure Improvement**

In heavy clay soils, the use of organic matter to improve soil structure to make them workable is encouraged.

5. **Surface Drainage**

Due to poor drainage, surface drainage should be introduced.

Chemical Maintenance Practices

1. Liming of acid soils and reclamation of alkaline soil by acidifying the soil.
2. **Crop Mixture**

Choice of crop is important. In a depleted soil put a legume that will improve the soil and leave the stubble so that the nitrogen fixed will be there and not all removed.

3. **Mixed Farming**

This involves the grazing of animals (example cattle) on the crop residue in the field and then keeps the animals on the field for some days to deposit manure (cow dung); which in turn improves the fertility of the soil. Also multiple cropping of two or more crops on same piece of land to complement one another and in turn help to improve the fertility level of soil. Examples are intercropping or crop rotation.

4. **Use of Fertilisers**

Fertiliser use aids the production of biomass which is subsequently used as manure to improve the maintenance of organic matter.

5. **Cation Exchange Capacity Improvement**

Cation exchange capacity (CEC) is the ability of the soil to exchange cations and this is affected or influenced mainly by organic matter content. Improvement of cation exchange capacity:

a. Will improve the ability of the soil to meet the needs of high nutrient demanding crops.
b. Enhance nutrient imbalance from use of fertilisers.
c. Reduce leaching effect of nutrients applied from surface soil such as cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}).
d. It acidifies the soil when acid inducing soil amendments are applied like urea.

3.2 Importance of Organic Matter in Soil Fertility Improvement and Maintenance

The level of organic matter in the soil is mostly associated with soil productivity. The roles of organic matter in soil fertility improvement are thus:

(i) It helps to bind the soil aggregates together thus helping to maintain and improve soil health (tilt).
(ii) Soil aeration is improved and water percolation thus reducing the risk of soil erosion.
(iii) Water and nutrient holding capacity of soil are increased. In this way, nutrients are protected from losses due to leaching.
(iv) Supplies a number of micro elements and growth promoting substances.
(v) Organic matter acts as a food source for soil microbes and thus maintains microbial activities and release of nutrients from the organic form to plant available forms.

3.3 Importance of Soil Organisms in Soil Fertility Maintenance

A healthy soil is required to improve microbial growth and achieved by organic matter supply as food which in turn will protect the soil. The importance of soil organisms includes:

- Decompose organic materials
- Help to fix nitrogen from the atmosphere in nitrogen fixation and nitrification
- Recycle nutrients and make them available for plant use.
- Bind soil particles together into aggregates thereby improving soil structure and help moderate the soil pH.
- Help improve soil aeration and water holding capacity.

4.0 CONCLUSION

In this unit, we have discussed the various ways of maintaining the fertility of the soil as well as the roles of organic matter and microorganisms in soil fertility maintenance. Following these discussions, it can be concluded that organic matter and soil microorganisms play essential roles in improving and maintaining the fertility status of the soil for sustainable production. These criteria for soil fertility ratings given below do not apply to nitrogen and organic matter because these two parameters are not regularly used in interpreting the nitrogen fertiliser needs of soil.

5.0 SUMMARY

In this unit, you learnt that the following:

- Soil fertility maintenance includes both physical and chemical management practices.
- The physical management practices in maintaining soil fertility includes tillage practices, mulching, use of cover crops, minimum use of machinery on the soil and soil structure enhancement.
- Chemical management practices include liming of acid soil and reclamation of alkaline soils, use of crop mixtures and mixed farming, use of fertilisers and cation exchange capacity improvement.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the various ways to maintaining soil fertility
2. Why is having a biologically active soil important for soil fertility?
3. Mention the importance of organic matter in soil fertility maintenance?

7.0 REFERENCES/FURTHER READING

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MODULE 5 CROP AND SOIL MANAGEMENT PRACTICES

UNIT 1 SOIL AND CROP PRODUCTIVITY

CONTENTS

1.0 INTRODUCTION

In the previous module, we discussed, in details, the mineral nutrition of crops. In this unit, you will be exposed to how soil and crop productivity can be maintained. The goal of any soil and crop management program is sustained profitable production. For any civilisation to be sustained for a long period of time, it will depend on the ability to sustain the productive capacity of its agriculture.

2.0 OBJECTIVE

By the end of this unit, you will be able to:

- explain how crops and soil productivity can be sustained, maintained or enhanced.

3.0 MAIN CONTENT

3.1 Soil and Crop Productivity Management

For agriculture to be sustainable, it encompasses soil and crop productivity, economics and environment and is defined by the integration of agricultural management technology to produce quality food and fiber while maintaining or increasing soil productivity, farm profitability and environmental quality. From soil productivity-soil fertility view point, soil conservation is important for long term sustainability. Soil management practices that contribute or encourage soil degradation will reduce soil productivity and impair progress toward sustainability.

You should not confuse increasing crop yields with increasing soil productivity because yield increases are mainly due to technological innovations in crop breeding and genetics, fertiliser and fertiliser management and other agronomic technologies. Soil conservation and good soil management enhance more than just the prevention of soil losses. Soil erosion is a symptom or indication of poor soil management, be it inadequate plant nutrients or improper cropping systems.

The problems of declining soil productivity are not new and have been recognised ever since soil organic matter and native nutrient supply especially *N* has decreased. The nutrients removed have generally been greater than the amounts returned to the soil in manure and commercial fertilisers.

Adoption of many agronomic technologies developed will increase crop productivity e.g. *N* fertilisation, breeding/genetics, weed control and other cultural practices. Soil productivity can be improved by soil conservation practices e.g. conservation tillage, crop rotations, improved drainage, terracing, contour farming, organic fertilisers, improved systems to match cultivars, soil and climate.

4.0 CONCLUSION

In this unit, we can conclude that the aim of crop and soil management should be to realise a sustained maximum profit from cropping programme. Effects on water intake and erosion, plant nutrient supply, tilth and pest control must be considered.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- Sustainable agriculture demands the effective integration of agricultural management technology to produce quality food and fiber while maintaining soil productivity, farm profitability and environmental quality.
- Agronomic technologies should be adopted in order to increase crop productivity.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is soil and crop productivity management?
2. What is the aim of a crop and soil management program?

7.0 REFERENCES/FURTHER READING

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UNIT 2 IRRIGATION

CONTENTS

1.0 INTRODUCTION

In the arid and semi-arid regions where temperature levels are high resulting in high evaporation of soil water leading to low soil moisture levels that cannot sustain plant growth. In these regions also, rainfall amount is not sufficient for plant growth and only lasts for a few months. This causes plants to suffer drought periods leading to poor growth and development and then very low yield or may be death of the crop. The rainfall amount is usually less than 500mm per year. In order to sustain crop growth and development and maintain yield in these regions, irrigation water application is one of the soil and water management practices employed to improve and manage the fertility of these soils. Irrigation therefore is the artificial application of water to the soil for the benefit of growing crops.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define Irrigation
- explain the importance of irrigation
- state the various types of irrigation systems
- discuss the advantages of using irrigation.

3.0 MAIN CONTENT

3.1 What is Irrigation?

As mentioned in the introduction, irrigation is the artificial application of water to the soil for the benefit of growing crops or agricultural production. It is also the artificial application of water to overcome deficiencies in rainfall for growing crops. Therefore, it is the determining factor in agricultural production in the arid and semi-arid regions because the low soil water content is a major constraint to increase agricultural crop production. Most irrigation water are pumped directly from a water source such as river, creek, channel, drag line, well water (hole or underground water), dam or bore hole.

3.2 Importance of Irrigation

Proper application of water (irrigation) will affect positively the whole growing process of crops from planting to harvest (maturity). The growing processes are from preparation of the seed bed, germination, root growth and development, nutrient availability and up take, quality of grain or fruiting (fruit development) and yield. In order to get the maximum benefit from irrigation, there must be uniformity in water application by the producer, knowing how much water to supply and when to apply. Thus, the importance of irrigation in agriculture can be viewed from two main points name the effect on soil and crops and to the producer. These are as follows:

- Helps the growth and maintenance of agricultural crops in dry areas with low rainfall average throughout the growing season.
- Used for cooling live-stocks and reducing dust circulation.
- For the disposal of sewage and in moving.
- Allows the producer to grow more and quality crops and pasture.
- Provides the opportunity to grow crops all year round thereby overcoming the problem of seasonal variability and drought.
- More animals are stocked making grazing management tighter because they are sure of pasture supply throughout the season.
- Takes market incentives advantage for the production of unseasonal crops.
- Because of the constant or consistent supply of pasture, there is less reliance on hay and grasses (supplementary feeding).
- Improves the producers' income because more crops are produced throughout the year, that is greater returns.
- Maintains the soil moisture level at field capacity.

3.3 Types of Irrigation Systems

The time and quantity of water to be applied to the crop by the irrigator is called irrigation scheduling. This depends on the crop water requirement at different growth stages and climatic conditions. The various methods and ways of applying the water are as follows:

(i) Furrow Systems
The water is applied to the row crops in ditches made by using tillage implements. It is made up of small, shallow channels that are used to guide or direct water down a slope across a paddock.

(i) Flood or Border Check Systems
Here the systems divide or separate the paddock into bays separated by parallel ridges or border checks. Water then flows down the paddock's slope as a sheet guided by the ridges.

(ii) Level Basin Systems
This system differs from the flood or border check in that the slope of the land is level and the area ends are closed. High volume of water is applied to achieve an even, rapid (fast) ponding of the depth desired with basins.

(iii) Center-Pivot Sprinkler Systems
This is self -propelled. A single pipeline is supported by a row of towers that are mobile and suspended 2 – 4 meters above ground. Water is then pumped into the central pipe as the towers rotate slowly around the pivot resulting in a large circular areas being irrigated.

(iv) Hand Move Sprinkler Systems
They are a number of light weight pipelines moved manually for successive irrigations. Lateral pipelines are connected to the mainline which may be portable or buried.

(v) Solid Set / Fixed Sprinkler Systems
This is a stationary (fixed) sprinkler system. The water supply pipeline is fixed (stationary) and sprinkler nozzles lifted above the surface. This is used mainly in orchards and vineyards for frost protection and crop cooling.

(vi) Traveling Gun Sprinkler Systems
Uses a larger sprinkler mounted on a wheel or trailer with a flexible rubber-hose. It is self-propelled while applying water moving in a cable guided land requiring high pressures to operate.

(vii) Side-Roll Wheel Move Systems
These systems have large wheel diameter mounted on a pipeline to enable the line roll as a unit to successive positions across the field. Crop types is considered since pipeline is about 1 (one) meter above ground.

(viii) Linear or Lateral Move Systems
Similar to the center-pivot except that the lateral line and towers move in a continuous straight path across the field.

(ix) Low-Flow Systems (including Drip and Trickle)
They use small diameter tubes that are placed above or below the soil surface. water is applied slowly to the soil through smooth holes or emitters.

(x) Sub-Irrigation Systems
Water is applied in open ditches or tile lines until the water table is raised enough to wet the soil.

Therefore, in choosing an irrigation system several things should be considered:

- Differences in soil type
- Differences in topography (varying topography)
- Power source availability
- Water availability and source
- Period or time of system installation
- Size of irrigation area
- Capacity of water storage on farm
- Labour availability and financial resources

3.4 Advantages of Irrigation

Some of the benefits in using irrigation are:

- Prevents disease infestation and growth of weeds.
- Water and time are conserved
- Soil structure and nutrients are preserved
- Farming flexibility
- More crops are grown like cash crops that bring returns.
- Ground water storage is enhanced.
- Crop yields are enhanced, hence more income.
- Encourages fishery development.
- Protects from drought / famine

3.5 Problems of Irrigation

The main challenge or problem in irrigation is knowing the crop water requirement at various growth stages and the climatic conditions. This helps to avoid either over or under watering using irrigation. Therefore, to avoid these two problems (over and under watering) you need to know how much is available to the plant and how efficiently the plant can use it. The way to measure this includes:

- Plant observation
- Feel and appearance of soil
- Using of soil moisture monitoring devices
- Estimating available water from weather data.

Thus, the drawbacks or disadvantages of over and under watering include:

(i) Under Watering
  * Yield reduction resulting in loss in market value
  * Fruit size and quality are also reduced.

(ii) Over Watering
  * Excessive vegetative growth
  * Water lost to the water table
  * Enhances or encourages erosion resulting in the displacement of top soil, thereby affecting and crop yield.

- Enhances pathogen spread and effect of pesticide and weed growth.
- Runoff is encouraged
- Loss of operational cost such as labour and pumping cost
- Leaching of nutrient elements, resulting in soil salinity
- Course Nitrate build which results in poisoning surface and underground water.
- Reduces the product quality and yield
- Increases operational cost
- Results in high demand due to shortage of water for urban dwellers.

4.0 CONCLUSION

In this unit, we have discussed what irrigation is, importance, types, benefits as well as problems associated with irrigation. Following these discussions, it can be concluded that irrigation is of great benefit to the soil, crops and the farmer, because soil fertility is enhanced and more crops are grown all year round.

5.0 SUMMARY

In this unit, you have learnt that:

- Irrigation is the application of artificial water to the soil for crop production.
- It improves soil structure and nutrient availability thereby enhancing the soil fertility.
- Irrigation types are furrow, flood (border – check), level basin, sprinkler (center – pivot, hand move, solid set (fixed) and travelling gun), side roll wheel, linear (lateral) move and low flow irrigation systems.
- Irrigation water source are mainly river, creeks, channel, drag line, dam, hole and bore.
- Challenges or problems result mainly from under or over watering though of great benefit also.

6.0 TUTOR-MARKED ASSIGNMENT

1. (a) Define Irrigation.
   (b) Mention some common types of irrigation systems you know.
   (c) What are the sources of irrigation water?
   (d) What is irrigation scheduling?

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UNIT 3 SOIL TILLAGE

CONTENTS

1.0 INTRODUCTION

In our previous units, you learnt that sustainable agriculture demands the effective integration of agricultural management technology to produce quality food and fiber, while maintaining soil productivity, farm profitability and environmental quality. In this unit, we shall look into the growing interest in developing tillage practices to give greater protection to the soil against soil and water losses. The amount of surface residues and surface roughness, both have an effect. Crop residue management has been developed to leave more of the harvest residues, leaves and roots on or near the surface.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define soil tillage
- discuss its advantages and disadvantages
- explain and differentiate the types of tillage

3.0 MAIN CONTENT

3.1 Soil Tillage

In this unit, we shall look into the growing interest in developing tillage practices to give greater protection to the soil against soil and water losses. The amount of surface residues and surface roughness, both have an effect. Crop residue management has been developed to leave more of the harvest residues, leaves and roots on or near the surface.

3.1.1 What is Soil Tillage?

It is the mechanical manipulation of soil for any purpose, but in agriculture it is usually restricted to the modifying of soil conditions for crop production. The surface forms of soil manipulation performed by the application of mechanical forces to the soil with a tillage tool, such as cutting, shattering, inversion or mixing.

3.1.2 Advantages and Disadvantages of Tillage

Advantages

- Improves infiltration and more efficient use of water.
- Increases hectrage of sloping land that can safely be used for row crops.
- Improves crop yield
- Reduces soil erosion by water and wind
- Minimises labour, machinery and fuel costs.

Disadvantages

- More potential for farm animals (rodents), insects and diseases
- Skilled manpower is needed

3.1.3 Types of Soil Tillage

i. **Clean Tillage:** A process of frequent cultivation or plowing to prevent growth of all vegetation, except the particular crop derived during the growing season.

ii. **Conservation Tillage:** Any tillage sequence which reduces loss of soil or water relative to conventional tillage.

iii. **Conventional Tillage:** The combined primary and secondary tillage operations normally performed in preparing a seed-bed for a given crop grown in a given geographical area.

iv. **Minimum Tillage:** The minimum soil manipulation necessary for crop production or meeting tillage requirements under the existing soil and climatic conditions.

v. **Mulch Tillage:** Tillage or preparation of the soil in such a way that plant residues or other materials are left to cover the surface, also mulch farming, trash farming, stubble mulch tillage, plow less farming.

vi. **Zero Tillage:** A procedure whereby a crop is planted directly into a seedbed; not tilled since harvest of the previous crop; also no – tillage system.

3.1.4 Effects of Tillage

Effects of tillage vary greatly, depending on soil, crop and weather conditions.

- **Surface Residues** – The amount of surface residues remaining after one tillage operation varies with the implement. Subsurface implements leave most of the residue on the soil surface to help protect the surface against erosion. Also, the quantity of residue incorporated or left on the surface after tillage also depends on type of crop given.
- **Soil Loss** – The amount of residue required to prevent soil erosion depends on the following factors: soil characteristics (texture, organic matter, structure, depth, slope, length), residue characteristics, rainfall characteristics and wind characteristics (velocity, direction to mention but two).
- **Soil Temperature** – Soil temperature early in the growing season are generally lower under conservation tillage than under conventional tillage due to the insulating effect of the unincorporated crop residues on the surface.
- **Soil Moisture** – Increasing residues on the surface by reducing tillage residues, runoff and soil erosion while increasing infiltration, water conservation increases with maintenance of surface residue cover.
- **Soil Microbial Activity** – The interaction of soil temperature and moisture with tillage will dramatically influence microbial activity. When the soil is tilled, increased aeration encourages microbial activity and mineralisation of organic matter, which essentially releases Nitrogen and other nutrients. Microbial activity is lower early in the season because of lower temperature however; it is slightly higher later in the season because of greater soil moisture.

4.0 CONCLUSION

In this unit, we can safely conclude that tillage have both favourable and unfavourable effects on aggregation. If the soil is not too wet or too dry when the tillage is performed, the short term effect of tillage is generally favourable. Tillage implements break up large clods, incorporate organic matter into the soil, kill weeds and generally create a more suitable seedbed. Soon after plowing, the surface soil is loosened (its cohesive strength is decreased) and total porosity is increased.

5.0 SUMMARY

In this unit, you have learnt that:

- Soil tillage is the mechanical manipulation of soil for any purpose but in agriculture it is usually confined to the modifying of soil conditions for crop production.
- Soil tillage improves infiltration, crop yield, minimises soil erosion.
- Soil tillage requires skilled manpower
- There are different types of soil tillage namely; clean tillage, conservation tillage, conventional tillage, mulch tillage, minimum tillage and zero tillage.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is soil tillage?
2. List the types of tillage practices you know.
3. What is the difference between:
   a) minimum and zero tillage?
   b) conventional and conservation tillage?

7.0 REFERENCES / FURTHER READING

Brady, N.C. & Weil, R.R. (2007).*The Nature and Properties of Soils.*(13th ed.). Upper Saddle River, NJ : Prentice Hall. P. 881.

Tisdale, S.L.; Nelson, W.L.; Beaton, J.D. & Havlin, J.L. (2003). *Soil Fertility and Fertilisers*. (5th ed.). New Delhi,India: Prentice-Hall.p.634.

UNIT 4 ORGANIC MATTER IN THE SOIL

CONTENTS

1.0 INTRODUCTION

Plant residue serves as the major substrate for SOM formation. In this unit, the definition, beneficial impact and decomposition of SOM will be considered. In addition to other factors, the organic matter (OM) content of a soil is intimately related to its productivity. The production of large quantities of residues and their subsequent decay is necessary for good soil productivity.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- define soil organic matter
- justify its importance in productivity
- explain its rate of decomposition (aerobic and anaerobic conditions)
- discuss how it is maintained for sustainable farming.

3.0 MAIN CONTENT

3.1 Definition of Soil Organic Matter

Soil organic matter can be defined as a complex, varied mixture of organic substances. Soil organic matter comprises decomposed plant and animal residues. It plays an important role in carbon balance which is a major factor affecting global warming.

3.2 Importance of Soil Organic Matter

Some of the functions are as follows:

- It increases cation exchange capacity
- It improves soil structure
- It reduces the effect of compaction
- It reduces crusting and increases infiltration
- It increases water holding capacity
- It provides energy for microbial activity
- It acts as a reservoir for nutrients
- It aids in buffering the soil pH.

3.3 Rate of Decomposition

Organic matter composes of decomposed plant and animal residues hence organic compounds are listed below in terms of ease of decomposition as follows:

Rapid decomposition

- Sugars, starches and simple proteins
- Crude proteins
- Hemicelluloses
- Cellulose
- Fats, waxes, oils
- Lignins andphenolic compounds

Very slow decomposition

3.3.1 Decomposition of Soil Organic Matter

Aerobic Conditions

Humus decomposition rate ranges between 2% - 5% per year depending upon climatic conditions. Increase upon soil temperature will result in increasing humus decomposition up to about 45^{o}C. Tropical conditions favour rapid SOM decomposition and nitrogen deficiencies commonly result following SOM depletion. Adequate soil aeration favours oxidative decomposition and results in a faster decomposition rate, much more than anaerobic conditions. The presence of adequate available nitrogen will increase the rate of decomposition. Tillage of the soil exposes new surfaces of organic matter to microbial oxidation and thus increases the rate of SOM decomposition. The practice of no – till or minimum – till, crop production increases SOM levels compared to conventional tillage management due to less soil cultivation and inherently lower levels of residue incorporation.

Anaerobic Conditions

When plant and animal residue is added to an anaerobic environment (example: swamp or marsh), decomposition is greatly reduced and organic residue typically accumulates often in layers. These layers represent various degrees of decomposition of residues. When the soil pores are filled with water, oxygen supplies are reduced because the pores filled with water prevent the diffusion of oxygen into the soil from the atmosphere. The products of anaerobic decomposition include:

- Partially oxidised organic compounds like organic acids, alcohols and methane gas.
- This releasing little energy for the organisms involved, with the end products still containing much energy.

3.4 Maintenance of Soil Organic Matter

The need to maintain organic matter in soil is important for sustainable agricultural production. The improvement or maintenance of organic matter include:

- Compost application
- Use of green manure
- Crop or plant residue
- Incorporation of farm yard or animal manure
- Reduced tillage
- Rotation / intercropping with legumes

4.0 CONCLUSION

In this unit, we can conclude that organic matter involves tilth, increases moisture retention, provides surface protection, serves as a store house for nutrients, increases cation exchange capacity, provides energy for micro-organisms, releases CO_2. All of these functions except surface protection depend on decomposition. Therefore, organic matter accumulation in the soil is not an end in itself. The important point is the production of high quantities of organic matter and its subsequent decay.

5.0 SUMMARY

In this unit, you have learnt that:

- Soil organic matter plays an important role in the chemistry of soils
- Cropping systems affect the amount of sol organic matter largely by the amounts of residue produced as added plant nutrient increase yield, larger amounts of residues are obtained.
- Decomposition of soil organic matter in aerobic and anaerobic conditions differs.
- Soil organic matter can be maintained for increased productivity.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the importance of soil organic matter in soil fertility
2. How can you maintain organic matter in soil to enhance fertility?

7.0 REFERENCES/FURTHER READING

Brady, N.C. & Weil, R.R. (2007). *The Nature and Properties of Soils*. (13th ed.). Pearson Education Inc. p.976 .

Pierzynski, G. *et al*. (2005).*Soils and Environmental Quality*. (3rd ed). Taylor and Francis Group.

Sylvia, D.M., Hartel, P.G., Fuhrmann, J.J. & Zuberer, D.A. (2005). *Principles and Applications of Soil Microbiology*.(2nd ed.) Upper Saddle River, New Jersey: Prentice Hall. P.640.

UNIT 5 ROTATION AND CONTINUOUS CROPPING

CONTENTS

1.0 INTRODUCTION

In our previous units, we discuss the role, decomposition and maintenance of organic matter in the soil with respect to crop and soil management. In this unit, we will be discussing on rotation and continuous cropping. Improved management of low yielding systems, particularly in the tropics is essential for the well-being of the populace. Cropping systems that improve nutrient cycling and that protect the soils from erosion are an important part of the solution.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- differentiate between rotation and continuous cropping
- discuss the effect of both systems.

3.0 MAIN CONTENT

3.1 What is Rotation and Continuous Cropping?

Crop rotation is a planned sequence of crops growing in a regularly recurring succession on the same area of land while continuous cropping is the continuous culture of one crop or growing different crops on haphazard order or scattered order.

3.2 Rotation versus continuous cropping

Research has shown that rotation increases long-term crop productivity compared to continuous cropping. The reason for the rotation effect advantage with rotation cropping compared to continuous cropping may likely be due to a crop having a harmful effect on the following crops, be it another crop or the same crop. There is some evidence that substances released from roots or formed during the decomposition of residues are responsible for the toxicity. Allelopathy is the term used to refer to the antagonistic action of one plant on another.

3.3 Effect of both Rotation and Continuous Cropping

Rotation

- There more continuous vegetative covers with reduced erosion and water loss
- Weed and insect control are favoured
- Erosion is minimised
- Changing the crop residues encourages competition among soil organisms and may help reduce the pathogens
- Deep rooted legumes may be grown periodically over all fields.

Continuous Cropping

- The climate may favour one crop.
- Soil may be especially suitable for one crop.
- Profits may be greater, but depends on the crops involved.
- Machinery costs may be lower.
- The farmer may not wish to be fully occupied with farming all year round.

4.0 CONCLUSION

At the end of this unit, we can conclude that adoption of improved crop management practices can increase yields and reduce runoff and erosion.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- The aim of a crop management programme should be to realise a sustained maximum profit from the cropping programme.
- Cropping systems affect the amount of soil organic matter solely by the amounts of residue produced. As added plant nutrients increase yields, larger amounts of residue are obtained.

- Rotation is a planned sequence of crop growing in a regularly recurring succession on the same area of land.
- Monoculture is the continuous culture of one crop or growing different crops in a scattered order.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by crop rotation and continuous cropping?
2. What is the effect of rotation and continuous cropping in soil fertility management.

7.0 REFERENCES/FURTHER READING

Brady, N.C. & Weil, R.R. (2007).*The Nature and Properties of Soils.*(13th ed.). Upper Saddle River, NJ : Prentice Hall. P. 881.

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UNIT 6 ANIMAL MANURE

CONTENTS

1.0 INTRODUCTION

The use of farm manure has been synonymous with an efficient and stable agriculture. Manure only does not supply organic matter and plant nutrients to the soil, but it is often associated with the production of soil conserving forage crops used to feed animals. Crop and animal production and soil conservation are enhanced by its use on the land.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain what animal manure is and their sources
- discuss the benefit, management and storage of animal manure.

3.0 MAIN CONTENT

3.1 What is Animal Manure?

Animal manure are by-products of the livestock industry and greater attention is being given to effective disposal of animal manures because of the increased use of confinement production systems and associated manure handling problems as well as their environmental concerns with regards to contamination of ground water or surface water by NO_3^- originating from the manure.

3.2 Sources of Animal Manure

The sources of animal manure include:

- Dairy cow manure
- Poultry manure
- Sheep manure
- Horse manure
- Goat manure
- Swine manure
- Donkey manure.

3.3 Benefits of Animal Manure

Reasons for the favourable action of manure remains unclear but they perhaps include one or more of the following:

- An additional supply of NH_4 – N.
- Availability of P and micronutrients due to complexation
- Increased moisture retention
- Increased soil organic matter
- Complexation of Al^{3+} in acid soils.
- Improved soil structure

3.4 Management of Animal Manure

Four main management systems are used to handle manure including;

- The manure can be collected and spread daily.
- The manure may be stored and packed in piles where it is allowed to partially decompose before spreading
- The manure can be stored in aerated ponds that are sufficiently shallow to permit fairly ready oxidation of the organic materials, or oxygen is stirred into the slurry.
- Deep anaerobic lagoons can be used in which the manure is allowed to ferment in the absence of elemental oxygen.

3.5 Storage of Animal Manure

In ameliorating manure problem, methods of manure handling that both prevent pollution and preserve nutrients in a form that can be easily made accessible and available will be a major contribution. Several options include;

- Heat-dry and pelletise – this technology dries the manure with heat and then compressed the dried product into small pellets that can be handle like commercial fertiliser.
- Commercial Composting – In the case of poultry manure, dried birds are composted along with the manure and the final product

is a very stable, run offensive, relatively high analysis, slow – release fertiliser that is also easy to handle. Composting is a natural aerobic decomposition process and is much less energy and capital intensive than heat – drying and pelleting. However, it does require considerable labour and management to obtain a quality product.

- Anaerobic digestion with biogas production – In this method, the manure is made into liquid slurry and adhered to become anaerobic.

4.0 CONCLUSION

At the end of this unit, we can conclude that farm manure is a valuable by-product of the livestock industry. Animal manure is receiving increasing attention. It supplies large amounts of most essential elements. The possible toxic effects are still to be determined.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- Animal manure are by – products of the livestock industry
- They have different sources
- Their benefits include-improving soil structure, increasing SOM etc.
- Management of animal manure include – spreading daily, packing in piles for partial decomposition, storage in aerated ponds and storage in anaerobic lagoons for fermentation.
- Storage of animal manure will include the following procedure – heat-dry and pelletise, commercial composting and anaerobic digestion with biogas production.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the sources of animal manure you know?
2. What are the benefits of animal manure in soil fertility?

7.0 REFERENCES / FURTHER READING

Brady, N.C. & Weil, R.R. (2007).*The Nature and Properties of Soils*.(13th ed.). Upper Saddle River, NJ : Prentice Hall. P. 881.

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UNIT 7 GREEN MANURE / COVER CROPS

CONTENTS

1.0 INTRODUCTION

In our last unit, we discussed on animal manure and its benefits, in this unit we will discuss on green manure and cover crops and their importance to crop production. Instead of being harvested, a cover crop is grown to provide vegetative cover for the soil and then is either killed and left on the surface as a mulch, or tilled into the soil as a green manure.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain what green manure / cover crops are
- discuss their importance to crop production.

3.0 MAIN CONTENT

3.1 What is Green Manure?

These are plant materials incorporated with the soil while green or immediately after maturity for improving the soil.

3.2 What is a Cover Crop?

This is a close growing crop grown solely for the purpose of protecting and improving soil between periods of regular crop production or between trees in orchards.

3.3 Benefits of Green Manure / Cover Crops

Growing a cover crop provides numerous benefits compared to leaving the soil bare for the off – season. Their benefit includes:

- Increase the available nitrogen in the soil
- Increase moisture retention
- Improves soil structure
- Increase soil organic matter
- Increase soil pH and buffering capacity

4.0 CONCLUSION

In this unit, we can conclude that the importance of green manure / cover crops cannot be over emphasised. Cover crops will supply residues and *N* if they are legumes. They are most useful in cropping systems in which few residues remain on the land after harvest.

5.0 SUMMARY

At the end of this unit, we have learnt that:

- A cover crop is a close growing crop sown mainly for the purpose of protecting and improving soil between periods of regular crop production (mostly leguminous crops).
- Green manure is plant materials incorporated within the soil, while green or sown after maturity for the essence of improving the soil fertility status.
- Manure increases moisture retention capacity, available nitrogen in the soil, improves soil structure, increases soil organic matter and soil pH.

6.0 TUTOR – MARKED ASSIGNMENT

1. What are cover crops?
2. What are the benefits of cover crops in soil fertility improvement?

7.0 REFERENCES / FURTHER READING

Brady, N.C. & Weil, R.R. (2007).*The Nature and Properties of Soils.*(13th ed.). Upper Saddle River, NJ : Prentice Hall. P. 881.

Tisdale, S.L.; Nelson, W.L.; Beaton, J.D. & Havlin, J.L. (2003). *Soil Fertility and Fertilisers*. (5th ed.). New Delhi,India: Prentice-Hall.p.634.