NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: AGR 203

COURSE TITLE PRINCIPLES OF CROP PRODUCTION

AGR203
PRINCIPLES OF CROP PRODUCTION

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CONTENTS **PAGE**

INTRODUCTION

PrinciplesofCropProduction:Is a two-credit course for 200 level students of B.Sc. (Agricultural Extension and Management). The course consists of 13 units in3 modules which deal with the basic principles and practice of crop production.This course guide tells you briefly what the course is all about, and how you can work through these units. It suggests some general guidelines for the amount of time you are likely to spend studying each unit in order to complete it successfully. It also gives you some guidance on your tutor-marked assignments.

WHAT YOU WILL LEARN IN THIS COURSE

The main aim of this course is to introduce the fundamental principles upon which crop production practices are based. By studying the principles of crop production you will be able to understand the interaction between the plant, the environment and how and why plants grow and develop. This will enable you to manipulate the plants and their external conditions for better growth and development and crop yield.

COURSE AIMS

The aim of the cause is to acquaint you with the basic principles of crop production.

This will be achieved through:

- introducing you to the basic principles of crop production
- creating a better understanding of plants, their classification and nomenclature, their response to various conditions
- developing a clear understanding of the role of the surrounding condition of the plant in growth and development and distinguish the effect of these factors in order to have precise control of growth process
- introducing you to the various cultural practices upon which is laid successful crop production enterprise
- identification of competitive pests, weeds and diseases so that you can select appropriate method of control
- identifying the best practices of harvesting, processing and storage of field crop.

In order to achieve the course aims, certain overall objectives have been set. In each unit specific objectives are set. These are usually stated at the beginning of the unit. You should pay attention to the objectives of each unit before starting to go through them. You can always refer to the unit's objectives to check your progress. You should also look at them after completing a unit. By so doing you can be sure that you have achieved what the unit expects you to acquire.

COURSE OBJECTIVES

Below are the wider objectives of the whole course. By meeting these objectives, the aims of the course as a whole would have been achieved. These are:

- state classification of plants based on botanical similarities, usefulness, growth cycle, indigenous, introduced and response to some climatic conditions
- understand the pattern in which crops are grown in a given area over a period of time and the technical and managerial resources that are utilised in the process of crop production
- identify the most appropriate fertiliser to apply on a particular crop in a given area and recommend the right time and quantity of fertiliser to apply
- describe the various tillage practices, state their roles and implements for carrying them out
- identify the most critical periods in the life of plant in relation to moisture and recommend irrigation programmes that are most appropriate
- understand the importance of drainage and the use of the different methods of drainage
- describe the various soil and water conservation methods
- identify the different types of weeds and their characteristics and recommend the most appropriate measure of weed control
- describe the common types of pests and their characteristics, nature of damage to crop plants and identify the most appropriate control measures for effective control of pests

- identify the various kinds of plant diseases, symptoms of plant diseases and the general principles of disease control
- describe harvesting, thrashing, and processing of field crops
- identify and describe a quality grain and state measures of ensuring good grain quality
- identify the common rodent and pests of crop in storage and describe the control measures to effectively tackle the problems of rodents and pests of storage.

WORKING THROUGH THIS COURSE

To complete this course you are required to read the study units, read other recommended materials. You will be required to answer some questions based on what you have read in the text to reaffirm the key points.

There are some tutor-marked assignments (TMAs) at the end of each unitwhich you are expected to submit for marking. The TMA forms part of continuous assessment.

At the end of the course is a final examination. The course should take you 12 to 13 weeks to complete. You will find listed the component of the course, what you have to do and how you should allocate your time to each unit in order to complete the course successfully on time.

COURSE MATERIALS

The main components of the course are:

1. Course Guide
2. Study Units
3. References
4. Tutor-Marked Assignments

STUDY UNITS

Module 1

Unit 1 Development of Crop Production
Unit2 Cropping Systems
Unit3 Fertilisers and their Uses
Unit4 Tillage Practices

Module 2

Unit 1 Seeds and Seedlings
Unit 2 Soil and Water Conservation
Unit 3 Irrigation and Drainage
Unit 4 Weeds
Unit 5 Weeds Control

Module 3

Unit1 Pests and Diseases
Unit 2 Crop Improvement
Unit 3 Harvesting and Processing of Field Crops
Unit 4 Storage of Field Crops

TUTOR-MARKED ASSIGNMENTS (TMAs)

There are fourTMAs in each unit. You will have to do the TMA as a revision of each unit. This will help you to have broad view and better understanding of the subject.

Your tutorial facilitator will inform you about the particular TMA you are to submit to him for marking and recording. Make sure your assignment reaches your tutor before the deadline given in the presentation schedule and assignment file. If, for any reason, you cannot complete your work on schedule, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstances. You will be able to complete your assignment questions from the texts contained in this course material and references; however, it is desirable to search other references, which will give you a broader view point and a deeper understanding of the subject.

FINAL EXAMINATION AND GRADING

The final examination for the course will be fortwo hours and consists of Section A which contains 20 objectives questions all of which you are expected to answer; and Section B which consists of fourtheory questions out of which you are expected to answer two questions. The total mark for the final examinations is 70 marks; that is, 20 marks from Section A and 50 marks from Section B. The examination will consist of questions, which reflect the TMAs that you might have previously encountered. All areas of the course will be covered by the assessment.

Use the time you have between finishing the last unit and sitting for the examination to revise the entire course. You will find it useful to review your tutor-marked assignments before the examination. The final examination covers information from all parts of the course.

Table1

Assessment	Marks
Tutor-Marked Assignment 1-4	10 marks each, the best three would recorded to give you 30%
Final Examination	70%
Total	100% of course marking scheme

COURSE OVERVIEW

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

Table2 Course Organiser

Unit	Title of work	Period of activity	TMA at the end of the unit
	Course Guide	1	
1	Development of Crop Production	1	4
2	Cropping Systems	1	4
3	Fertilisers and their Uses	1	4
4	Tillage Practices	1	4
5	Seeds and Seedlings	1	4
6	Soil and Water Conservation	1	4
7	Irrigation and Drainage	1	4
8	Weeds	1	4
9	Weeds Control	1	4
10	Pest and Diseases	1	4
11	Crop Improvement	1	4
12	Harvesting and Processing of Crops	1	4
13	Storage of Field Crops	1	4
	Revision	2	
	Total	16	52

HOW TO GET THE MOST FROM THIS COURSE

In distance learning the study units replace the university lectures. This is one of the great advantages of distance learning; you can read and work through specially designed study materials at your own pace, and at a time and place that suit you best. Think of it as reading the lecture instead of listening to the lecturer. In the same way that a lecturer might set you some reading to do, the study units tell you when to read your set books or other materials. Just as a lecturer might give you an in-class exercise, your study units provide exercise for you at appropriate points.
Each of the study units follows a common format. The first item is introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. 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 or not. If you make a habit of doing this you will significantly improve your chances of passing the course.

The main body of the unit guides you through the required reading from other sources. This will usually be either from your set books or the reading list.

When you need help, don't hesitate to call and ask for your tutors' assistance.

1. Read the course guide thoroughly.

2. Organise a study schedule. Refer to the "Course Overview" for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units. Important information details of your tutorials and the date of the first day of the semester is available at the study centres of National Open University of Nigeria. You need to gather all these information in one place, such as your diary or wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working on each unit.

3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course work. If you get into difficulties with your schedule, please let your tutor know before it is too late.

4. Turn to unit 1 and read the introduction and the objectives for the unit.

5. Assemble the study materials. Information about what you need for a unit is given in the introduction and objectives of the course at the beginning of each unit.

6. Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow.

7. Keep in mind that you will learn a lot by doing the assignments carefully. They have been designed to help you meet the objectives of the course and, therefore will help pass the exams.

8. Review the objectives for each unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult your tutor.

9. When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed from unit to unit through the course and try to pace your study so that you keep yourself on schedule.

10. When you have submitted an assignment to your tutor for marking, do not wait for its return before starting on the next. Keep to your schedule. When your assignments are returned, pay particular attention to your tutor's comments. Consult your tutor as soon as possible if you have any question or problems.

11. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives and the course objectives listed in the course guide.

SUMMARY

This course intends to introduce you to the principles of crop production. Upon completion of this course, you would be equipped with basic knowledge and understanding of the various areas that make up crop production. After successfully going through this course you would be able to answer the following questions:

- classify crops based on botanical similarities and use
- group crops based on centre of origin

- identify the problems militating against the development of crop production in Nigeria and suggest the most appropriate measures of containing them
- describe the various cropping systems used in crop production
- describe the different types of fertilisers and their uses and make recommendation on the type, method and time of fertiliser application
- state the uses of different types of fertiliser and identify the deficiency symptoms of each type of fertiliser
- identify the different tillage practices and explain the advantages and disadvantages of each type of tillage
- discuss the different methods of soil and water conservation
- describe the various methods of irrigation and drainage and state the advantages and disadvantages of each method
- describe a good quality seed and state factors affecting quality of seeds
- describe the various methods of overcoming seed dormancy and seed treatment methods before planting
- define weeds and describe the characteristic of weeds that enable them to compete with field crops
- discuss the effects of weeds and why it's important to control weeds
- describe the various methods of weed control
- give a classification of herbicides used in weed control
- define pest and identify pests of significance affecting the production of field crops
- state the effect of pests and methods of pest control
- identify diseases of crops and describe the methods of controlling them

- define crop improvement and state its importance
- describe the various methods of crop improvement
- describe the various methods of harvesting and processing of crop
- give the characteristic of a good quality grain
- discuss the methods of storage of field crops
- describe the various methods of rodent control.

You should be able to use the knowledge acquired in this course in planning and executing successfully crop production of any field crop in your locality. I wish you success in this course and hope that you find it interesting and useful.

Good luck!

MODULE 1

UNIT 1 DEVELOPMENT OF CROP PRODUCTION

CONTENTS

1.0 INTRODUCTION

In this unit you will be studying the historical development of crop production from the incipient stage to modern day crop production. The origin and distribution of indigenous and exotic field crops and its classifications are treated. This unit will give you a general overview of the historical development of crop production, its development and contribution in food and raw material supply, the place of Nigeria in world food production, constraints to crop production in Nigeria and measures that could help increase field crop production in the country are highlighted and discussed.

2.0 OBJECTIVES

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

- identify the centres and origin of most field crops
- identify crops that are indigenous to Africa and those that are introduced into Africa
- classify crops based on agronomic and special-purpose
- identify the major cereals produced in Nigeria and the place of each cereal in total cereal production in the country
- state the contribution of each of the geographical zone in Nigeria to the total national cassava production
- identify those crops in which Nigeria occupies a premier position in terms of total global production figures of such crops.

3.0 MAIN CONTENT

3.1 Historical Development of Crop Production

Early man lived on wild game, leaves, roots, seeds, berries and fruits. As the population increased, the food supply was not always sufficiently stable or plentiful to supply his needs. This probably led to the practice of crop production. Therefore, crop production began at least nine thousand (9000) years ago when domestication of plants became essential to supplement natural supplies in certain localities. The art of crop production is older than civilisation, and its essential features have remained almost unchanged since the dawn of history. These features are:

1. gathering and preservation of seeds of the desired crop plants

2. destroying other kinds of vegetation growing on the land

3. stirring the soil to form a seedbed

4. planting when the season and weather are right as shown by past experience

5. destroying weeds

6. protecting the crop from natural enemies, and

7. gathering, processing and storing the product.

The early husbandman cultivated a limited number of crops, the cereals being the first to be grown in most parts of the world. The same crop was often produced continuously on a field until low yields necessitated a shift to new land. This practice is still common in parts of Africa. A modification of this practice was the introduction of bare fallow every two or three years. The primitive husbandman removed by hand the destructive insects in his fields and appeased the gods or practiced mystic rites to drive away the evil spirits he believed to be the cause of plant diseases. With advancing civilisation, materials such as sulphur, brine, ashes, white-wash, soap and vinegar were applied to plants to suppress diseases or insects attack.

Cultivated plants are products of human achievement and discovery which has enable man to provide his food and fiber needs with progressively less labour.

The first successful domestication of plants by man has recently been suggested to have occurred in Thailand in Neolithic times.

The value of lime, marl, manures, and green manures for the maintenance of soil productivity was recognised 2000 years ago. Books on agriculture written by the Romans about the 1st century A.D. describe the growing of common crops including wheat, barley, clover, and alfalfa by procedures very similar to those in use today except that more of the work was done with hand and the implements then used were crude.

The old art of crop production still predominates in farm practice throughout the world. Plant pathologists and entomologists have found ways to control plant diseases and insect pests more effectively. Chemists and agronomists have found supplements for manure and ashes formally used as fertilisers. Rotations perhaps are slightly improved. Many new crop hybrids and varieties (cultivars) have been developed. The control of weeds with herbicides was realised in the 20th century.

Improved cultural methods, doubtless, followed observations made by primitive farmers. They discovered that crops yield better where manure, ashes or broken limestone had been dropped, or where weeds were not allowed to grow, or where soil is darker, deep, or well watered or where one crop followed certain other crops. Observations or empirical trials quickly revealed, roughly, the most favourable time, place, and manner of planting and cultivating various crops. These ideas were handed down through the generations.

Eventually, the exchange of ideas, observations, and experiences, through agricultural societies and rural papers and magazines, spread the knowledge of crops.

3.2 Origin of Cultivated Crops

All cultivated plants were domesticated from their wild species. However, the exact time and place of origin and the true ancestry of many crops are still as highly speculative as the origin of man. Man has domesticated some crop species that met his needs before the dawn of recorded history. Most of the domesticated crops were introduced into new areas far from their centres of origin by migrating human populations in prehistoric as well as in recorded times. As a result, both indigenous and introduced crops are grown everywhere in the world.

a. Centres of Origin of Cultivated Crops

The centres of origin of both agriculture and culture were in populated areas favoured by a more equitable climate. Nicolai Ivanovic Vavilov (1926) concluded that a centre of origin was characterised by dominant alleles while towards the periphery of the centre, the frequency of recessive alleles increased and the genetic diversity decreased. He reported the following centres of origin:

- China

- India/Indo-Malayan
- Central Asia
- Near East
- Mediterranean Sea coastal and adjacent regions
- Ethiopia or Abyssinia
- South Mexico and Central America
- South America (Peru, Ecuador, Bolivia, Chile, etc.).

b. Contribution of the Different Centres

The following are the important crops that originated in the different centres. Some crops may have two centres of origin, (primary and secondary centres of origin):

i. Chinese centre

China is one of the richest centres of crop origin contributing to many important crops such as *Brassica campestris* and related species, *Camellia sinenses*, *Colocasia esculenta*, *Corchorus sinensis*, *Glycine max*, *Panicum miliaceum*, *Raphanus sativus* and *Setaria italica*. It is secondary centre for *Oriza sativa spp. japonica*, *Zea mays* and other crops.

ii. Indo-Malayan centre

This region is important for such crops such as *Cocos nucifera*, *Colocasia esculenta*, *Dioscoria spp.*, *wild Oryza spp.* and *Saccharum officinalis.*

iii. Indian centre

Important crops from this centre include*; Oryza sativa*, *Phaseolus mungo*, *Piper spp.*, *Saccharum sinensis*, *Vigna sinensis* and *Cucurbita sativa.*

iv. Central Asia centre

Among the important crops of this centre include*; Allium cepa*, *Daucus carota*, *lathyrus sativa*, *Spinacea oleracea* and *Vicia faba.*

v. Near Eastern centre

This is the centre of origin of *Brassica olearacea, Hordeum Vulgare, Lens esculanta, Medicago spp., Secale spp., Triticum spp., Vicia sativa* and *Vitis vinifera.*

vi. Mediterranean centre

Many field crops have been domesticated in this region; *Avena spp., Beta vulgaris, Brassica napus, B. oleracea, Lathyrus spp., Olea europaea, Raphanus sativus, Trifolium spp.* and *Vitis vinifera.*

vii. Ethiopian or African centre

Brassica juncea, Ceiba pentandra, Coffea spp., Cola spp., Cucumis spp., Gossypium spp., Hibiscus spp., Lablab purpureaus, Oryza spp., Pennisetum spp., Phoenix spp., Ricinus communis, Sesamum indicum, Setaria spp., Sorghum bicolor and Vigna unguiculata are all important crops of African centre of crops origin.

viii. Central American and Mexican centre

Few important crops were domesticated in this region*; Agaves pp., Capsicum spp., Gossypium spp., Ipomoea batatas, Phaseolus spp*. and *Zea mays.*

ix. South American centre

This centre accounts for most of the tuberous crops such as *Solanum spp., Oxalis tuberose and Ullucus tuberous. Amaranthus spp., Arachis hypogaea, Capsicum spp., Lycopersicum spp., Lupinus spp., Manihot esculenta, Nicotina spp., Phaseolus spp., Solanum spp.* and *Theobromw cacao* all have their origin from this centre. This centre also serves as secondary centre of diversity of *Zea mays.*

3.3 Spread of Cultivated Crops

The spread of crops from their centre of origin to other parts of the world was either by natural means or by agency of man.

i. Natural dispersal of crops

Coconuts may have floated across the Pacific Ocean from Asia to the western coast of Central America, and the capsules of sweet potatoes crossed the Pacific Ocean in the same way.

ii. Human migrations

As people migrate, they take along with them cultivated plants to ensure a permanent food supply and support their culture.

iii. Expansion of world trade

With the expansion of world trade, crops indigenous to the Americans such as: maize, groundnuts, sweet potatoes, potatoes, tomatoes and cassava were spread to other parts of the world. During the eighteenth and nineteenth centuries, the development of agricultural enterprises in the tropics was stimulated by the demand from Europe for agricultural raw materials for use in industry. As a result of these developments, many crops spread from one area to the other. For example: rubber from Brazil became popular in Malaysia, Sri Lanka and West Africa; American cotton became popular in the Old World and sugar cane became an economic crop of the new world.

iv. International agricultural research collaboration

This has included the exchange of seeds or germ plasm between agricultural research institutions in different parts of the world in their programmes. Thus, encouraging crop transfers across the globe.

3.4 Indigenous Crops of Africa

The following are most important crops that are indigenous to Africa:

	Cereals	
Bulrush millet	-------------------	*Pennisetum typhoides*
Guinea corn	-------------------	*Sorghum bicolor*
Finger millet	-------------------	*Eleusine coracana*
Rice	-------------------	*Oryza glaberrima*
Hungary rice	-------------------	*Digitaria exillis*
	Grain legumes	
Cowpea	-------------------	*Vigna unguiculata*
Pigeon pea	-------------------	*Cajanus cajan*
	Oil seeds	
Oil palm	-------------------	*Elaeis guineensis*
Niger seeds	-------------------	*Guizotia abyssinica*
Castor	-------------------	*Ricinus communis*
Bambara groundnut	-------------------	*Voandzeia subterranean*
Shea butter	-------------------	*Butyrospermum paradoxum*
	Yam	
White guinea yam	--------------------	*Dioscorea rotundata*
Yellow guinea yam	-------------------	*Dioscorea cayenensis*
	Fibre crops	
Cotton	-------------------	*Gossypium herbaceum*
Kenaf	-------------------	*Hibiscus cannabinus*
Bow-string hemp	-------------------	*Sansevieria spp.*
Kapok	-------------------	*Pentandra var. caribea*
	Coffee	
Coffee	-------------------	*Coffea arabica, Coffea liberica*

Kolanut

Kolanuts Gbanja Kola	-------------------	*Cola nitida*
Abata kola	-------------------	*Cola acuminata*

Vegetable

Water melon	-------------------	*Citrullus lanatus*

3.5 Crops Introduced into Africa

There are many crops widely grown in Africa that are introduced from other regions of the world. The most notable among them include the following:

Cereals

Rice	---------	*Oryza sativa*
Wheat	---------	*Triticum aestivum*

Grain legumes

Groundnuts	---------	*Arachis hypogaea*
Common bean	---------	Phaseolus vulgaris
Field pea	---------	*Pisum spp.*

Roots and tubers

Cassava	---------	*Manihot esculanta*
Cocoyam	----------	*Colocasia esculenta*
Water yam	---------	*Dioscorea alata*
Tannia	---------	*Xanthosoma sagittifolium*
Sweet potato	---------	*Ipomoea batatas*

Oil-seed

Sesame	---------	*Sesamum indicum*

Fiber crops

Cotton	---------	*Gossypium barbadense*
		Gossypium hirsutum
Sisal	---------	*Agave sisalana*

Sugar crops

Sugar cane	---------	*Saccharum officinarum*

Drug crops

Tobacco	---------	*Nicotiana tobaccum*

Beverage crops

Tea	---------	*Camellia sinensi*
Cocoa	---------	*Theobroma cacoa*

Latex crops

Rubber --------- *Hevea braziliensis*

3.6 Classification of Crops

There are two major methods of classifying crops plants:

1. Botanical classification which is based on the morphological similarity of plants parts.

2. Economic classification is based on their uses.

a. Botanical classification

This classification is based upon similarity of plant parts. Field crops belong to the **spermatophyte** division of the plant kingdom, in which reproduction is carried on by seeds. Within this division the common crop plants belong to the subdivision of **angiosperms**, which are characterised by having their ovules enclosed in an ovary wall. The angiosperms are divided into two classes, the monocotyledons and the dicotyledons. All the grasses, which include the cereals and sugar cane, are monocotyledonous plants. The legumes and other crop plants except the grasses are classified as dicotyledonous plants because the seeds have two cotyledons. These classes are subdivided into **orders**, **families, genera, species, subspecies**, and **varieties.**

i. The grass family

This includes about three fourth of the cultivated forage crops and all cereals crops. They are either annuals, or perennials. Grasses are almost all herbaceous plants, usually with hollow cylindrical stems closed at the nodes. The stems are made of nodes and internodes. The leaves are two-ranked and parallel-veined. The roots are fibrous. The small greenish flowers are collected in a compact or open inflorescence, which is terminal on the stem. The flowers are usually perfect, small, and with no distinct perianth. The grain or caryopsis may be free, as in wheat, or permanently enclosed in the floral bracts as in oats.

ii. The legume family

Legumes may be annuals, biennials or perennials. Leaves are alternate on the stems, stipulate with netted veins, and mostly compound. The flowers are almost always arranged in racemes as in the pea. The flowers of leguminous field crops are butterfly-like. The irregular flowers consist of five petals, a standard, two wings, and a keel that consists of two petals that are more or less united. The calyx is normally four or five toothed. The fruit is a pod that contains one or several seeds. The root system is taproot. Often, the roots have an abnormal growth called nodules caused by the activities of bacterium *Rhizobium.*

iii. Other crop families

Among the other botanical families that contain crop plants are:

1. *Cannabaceae* (hops and hemp)
2. *Polygonaceae* (buckwheat)
3. *Chenopodiaceae* (sugarbeets, mangels and wormseed)
4. *Cruciferae* (mustard, rape, and kale)
5. *Linaceae* (flax)
6. *Malvaceae* (cotton)
7. *Solanaceae* (potato and tobacco)
8. *Compositae* (sunflower, safflower and Jerusalem artichoke).

b. Agronomic/economic classification

i. Cereal or Grain crops

Cereals are grasses grown for their edible seeds, the term cereal being applied either to the grain or to the plant itself. Cereals include wheat, oats, barley, rye, rice, maize, sorghum, millets, etc.

ii. Legumes

These include pea nuts, field beans, cowpeas, soybeans, lima beans, mug beans, chickpeas, pigeon peas, broad beans and lentils. They all belong to the family Leguminosae and are grown for their edible seeds.

iii. Oil crops

The oil crops include soya bean, peanuts (groundnuts), sunflower, safflower, sesame, castor bean, mustard, cotton seed, corn and grain sorghum, rape, flax and perilla, the seeds of which contain some useful oils.

iv. Root and tuber crops

These include sugar beets, carrots, sweet potatoes, yams, cassava, potatoes and cocoyam.

v. Fiber crops

These are grown for their fiber. They include cotton, jute, kenaf, hemp, ramie and sisal.

vi. Sugar crops

These are crops that are grown for their sweet juice from which sucrose is extracted and crystallised. They include sugar cane and sugar beet.

vii. Forage crops

These are vegetable matters fresh or preserved that are utilised as feeds for animals. They include grasses, legumes, crucifers and other cultivated crops.

viii. Vegetable crops

This group includes potatoes, tomatoes and onions.

ix. Rubber crops/latex crops

These crops which include Para rubber are grown for the milky sap, or latex which they produce.

x. Beverage crops

These crops are also sources of stimulants. They include tea, coffee and cocoa.

c. Special-Purpose Classification

i. Cover crops

These are crops planted to provide a protection to the soil against direct beating of rainfall. When crops are turned under while still green, they are termed green manure crops. Important green manure crops include alfalfa, soya beans, cowpeas, rye, and buckwheat.

ii. Catch crops

Catch crops are substitute crops planted too late for regular crops or after the regular crop have failed. Short season crops such as millet and buckwheat are often used as catch crops.

iii. Soiling crops

These are crops that are cut and fed green and may include legumes, grasses, kale, and maize.

iv. Silage crops

Silage crops are those cut and preserved in succulent condition by partial fermentation. They include corn, sorghum, forage grasses and legumes.

v. Companion crops

These are crops that are grown with a crop such as alfalfa or red clover in order to secure a return from the land in the first year of a new seeding. Grain crops and flax are often used for this purpose.

vi. Trap crops

These are crops planted to attract certain insects or parasites. Trap crops are plowed under or destroyed once they have served their purpose.

3.7 Trends in Crop Production Nationally and Globally

i. Cereals

World cereal production in 1999 is forecast at 1 870 million tons (including milled rice). While on the supply side, the estimates are becoming firmer, the demand-related issues have yet to be determined. Global cereal utilisation in 1999/2000 is forecast to rise only slightly, just less than one percent. Overall, the growth in direct food consumption of cereals is expected to keep pace with population increase. Nigeria with a total cereal production of18 million tones representing only 1% of the world cereal as reported by the Food and Agricultural Organisation of the United Nation (FAO) year book of 2002 and presented in Table 1 and Fig. 1.

Table 1.1: Cereal Productions in Nigeria 1990-2000 in 000, Metric Tones

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Fonio	65	72	78	81	93	108	125	127	131	134	133
Maize	5104	5142	5223	5309	5426	5472	4273	4200	3884	3965	3999
Millet	4778	4560	4367	4850	5007	5107	5356	5487	5596	5603	5914
Rice, Paddy	1208	1652	1664	1564	1714	1796	1784	2048	2044	2191	2199
Sorghum	4185	5538	5474	5605	5738	6095	6191	6589	6635	6678	6885
Wheat	60	50	30	14	15	20	23	25	49	50	52
Cereals, Total	15400	17014	16836	17423	17993	18598	17752	18476	18339	18621	19182

Source: FAO Yearbook 2002

In sub-Saharan Africa, 1999 was another disappointing year in terms of agricultural output, as overall agricultural production lagged behind population growth rates for the third consecutive year. Output increased by 2.1 per cent in 1999, after increasing by 0.4 and 2.3 per cent in 1997 and 1998, respectively. In Nigeria, production growth slowed from more than 4 per cent in 1998 to slightly less than 3 per cent. The preliminary estimates for 2000 suggest no improvement in the sluggish performance of the last few years and overall agricultural production appears to have expanded by only 0.5 percent.

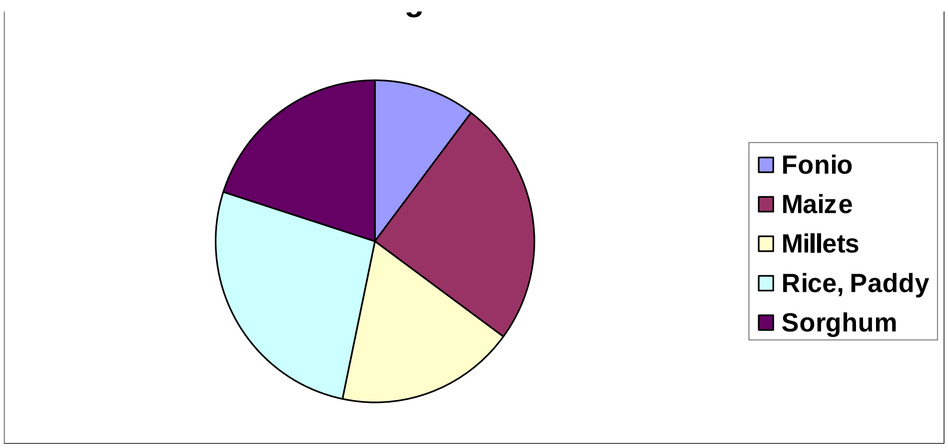

Fig. 1.1: Production Percentage of Different Cereals in Nigeria in the Year 2000

Table 1.2: Nigeria - Statistics on Cereals - Imports/Exports

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Exports - Qty Mt	3	270	0	56697	82600	76218	2000	44000	46757	46757
Exports - Val 1000$	2	98	0	3673	8550	8352	180	3960	4250	4250
Imports - Qty Mt	476920	813977	1073019	1712290	1178072	1022942	1259345	1882181	2132391	2226259
Imports - Val 1000$	113368	186010	233612	351818	229600	210274	287572	460602	473796	509115

Source: FAO Yearbook 2002

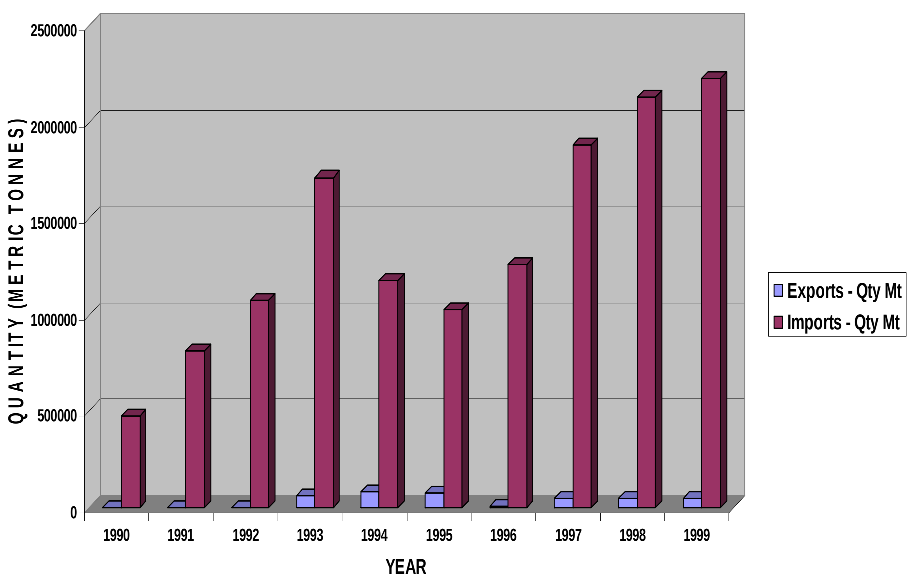

Fig. 1.2: Export and Import of Cereals in Nigeria

The steady rise in the imports and decline in export of cereal crops in Nigeria from 1990 to 2000 is as evidenced in Table 2 and Fig. 2. These are direct indications that food crop production in the country is lagging behind the demand for food. The rapid increase in the Nigerian population (3.5%) annually which is considered among the highest in the world has necessitated the need to massively import food to feed the teaming population. Agricultural production within the same period recorded a modest growth rate of 1.5%, but the growth is mostly associated with cassava production which is currently enjoying a boom.

This scenario of massive importation of cereals and sharp decline in export could be attributed not only to growth in population and stagnation of internal production levels but also on other equally important factors such as natural and socio-economic factors.

Natural factors in form of drought and flooding that affected the major crop producing areas of the country within the reported period. Drought which affected the Northern Savanna zone where the bulk of country's cereals is produced, thereby, leads to shortages of major foodstuff which necessitated massive importation of cereals to supplement the shortfall.

The growth of poultry industry in the country also lead to increased demand for cereals to be used in the production of feeds, this triggered massive importation of maize to be processed into poultry feeds.

The shift in government policy that do not accord food production the priority it deserved in terms of adequate funding and supply of needed inputs to sustain the current production levels. The fiscal and monetary systems enforced by structural adjustment policy have adversely affected food production especially cereals in the country by making importation of food stuff very attractive and internal production of food becomes less attractive.

Lack of stability in the farm prices and poor marketing system of major cereal crops in the country discourage farmers from making investment to produce more. These and many more socio-economic factors have contributed to the present scenario of massive food importation by Nigeria.

ii. Cassava Production

Nigerian cassava production is by far the largest in the world; a third more than production in Brazil and almost double the production of Indonesia and Thailand. Cassava production in other African countries - the Democratic Republic of Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda appears small in comparison to Nigeria's substantial output.

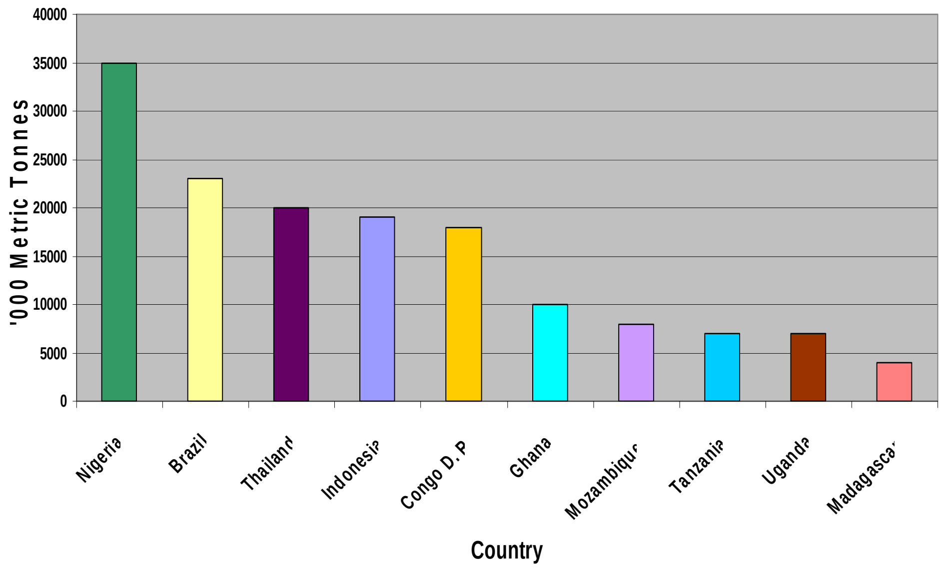

Fig. 1.3: Leading World Producers of Cassava
Source FAO Yearbook 2004

The Food and Agriculture Organisation of the United Nations (FAO) in Rome (FAO, 2004a) estimated 2002 cassava production in Nigeria to be approximately 34 million tonnes. The trend for cassava production reported by the Central Bank of Nigeria mirrored the FAO data until 1996 and thereafter it rises to the highest estimate of production at 37 million tonnes in 2000 (FMANR, 1997; Central Bank of Nigeria). The third series provided by the Projects Coordinating Unit PCU (PCU, 2003) had the most conservative estimate of production at 28 million tonnes in 2002. PCU data collates state level data provided by the ADP offices in each state. Comparing the output of various crops in Nigeria, cassava production ranks first, followed by yam production at 27 million tonnes in 2002, sorghum at 7 million tonnes, millet at 6 million tonnes and rice at 5 million tonnes (FAO, 2004a).

Expansion of cassava production has been relatively steady since 1980 with an additional push between the years 1988 to 1992 owing to the release of improved IITA varieties.

By zone, the North Central zone produced over 7 million tonnes of cassava a year between 1999 and 2002. South South produces over 6 million tonnes a year while the South West and South East produce just less than 6 million tonnes a year. The North West and North East are small by comparison at 2 and 0.14 million tonnes respectively (Table 3).

Table 1.3: Cassava Production by Nigerian Geographical Zones 2000-2002 (Tonnes)

Regions	**2000**	**2001**	**2002**
South West	4 993 380	5 663 614	5 883 805
South South	6 268 114	6 533 944	6 321 674
South East	5 384 130	5 542 412	5 846 310
North West	2 435 211	2 395 543	2 340 000
North Central	7 116 920	7 243 970	7405640
North East	165 344	141 533	140520
Total	26 363 099	27 521 016	27938049

Source: *PCU, 2003

On a per capita basis, North Central is the highest producing region at 720kg/per person in 2002, followed by South East (560kg), South South (470kg), South West (340kg), North West (100kg) and North East (10kg). National per capita production of cassava is 320kg/per person. Benue and Kogi state in the North Central Zone are the largest producers of cassava in the country, while Cross River, Akwa Ibom, Rivers and Delta state dominate cassava production in the South South. Ogun, Ondo and Oyo dominate in the South West and Enugu and Imo dominate production in the South East. Kaduna state alone in the North West is comparable in output to many of the states in the southern regions at almost 2 million tonnes a year. The production in the North East is currently very little.

* (Projects Coordinating Unit, Federal Ministry of Agriculture 2003)

Table 1.4: Ranking of Nigeria in the World Production of some Field Crops in 2005

Commodity	Nigeria	World	Ranking in the World
Cassava	41,565.000 MT	208,559,340 MT	1
Yams	34,000.000 MT	44,276,130 MT	1
Cowpeas	2,815000 MT	22,880,290 MT	1
Melon seeds	451,000.00 MT	691,605.00 MT	1
Taro	5,068000 MT	11,538,705 MT	1
Citrus fruits	3,545,841.00 MT	6,999,186 MT	1
Green maize	4,779000 MT	9,216,770.00 MT	2
Millet	6,282000 MT	30,522,860 MT	2
Sorghum	8,028000 MT	59,153,380 MT	2
Okra	730,000 MT	5,357.927 MT	2
Groundnuts in shell	3,478.000 MT	37,763.330 MT	3
Sweet potatoes	3,205.000 MT	123,271.111 MT	3
Papaya	834,040.00 MT	6,666.540 MT	3
Cashew nuts	594,000. MT	2,864.270 MT	4
Cocoa beans	366,000 MT	3,924.770 MT	4
Ginger	110,000 MT	1,270.400 MT	4
Vegetables	4,285,000 MT	261,732.740 MT	5
Pineapple	976,920,000 MT	17,692.310 MT	6
Sesame seed	100,000 MT	3,322.080 MT	6

Source: FAO Yearbook 2005

According to FAO Yearbook 2005, Nigeria account for more than 77% of world yam production as well as occupied first position in the world production of cassava, taro, citrus fruits, melon seeds and cowpeas. During the same year under review, Nigeria rank second in the world production of millet, sorghum, okra and green maize and came third in sweet potatoes, groundnuts, and papaya. The tremendous rise in the status of food crop production in the country from the year 2000 upwards could be attributed to recent shift in government policy that favours massive food production programme internally with the hope of attaining sustainable food security status and meet up with Millennium Development Goals of the country.

3.8 Constraints to Crop Production in Africa

Many factors have been cited as limiting the growth and development of crop production in tropical Africa. Here, we concern ourselves more with social, economic and political constraints.

i. Poverty

Poverty is indicated both by the few capital resources and the low cash incomes of African farming families. The small size of farm holdings (typically 1-5 ha.) represents very little collateral on a loan, and unless the family owns livestock there may be little prospect of raising money to buy equipment or meet emergencies. Income from the sale of farm produce is typically inadequate to meet essential family expenses such as taxes, school fees, medicine, clothing and house hold items. Rarely is enough left over for seed, fertiliser or chemicals, let alone for large capital items such as oxen, ploughs and water pumps. Thus, the key components of Green Revolution Technology (seed, fertiliser, pesticides) are not generally accessible.

ii. Seed

The adoption of improved varieties in Nigeria is minimal in the case of principal food crops. This is partly due to poor performance of the seed service agency in terms of production, quality assurance, and distribution of improved seeds.

iii. Agro-chemicals

The use of fertilisers and pesticide among the peasant farmers in Nigeria is low; this could be due to high cost or poor availability or both. The use of herbicide, insecticide and fungicides is minimal. Farmers generally lack spraying equipment and technical skills for the timely and effective application of pesticides, which if wrongly applied pose dangers to people, crops and wider environment. It is often not recognised that decisions concerning what, when and how much to spray are very complex, and sufficient guidance is rarely available to the farmer. Products are often sold without proper recommendations for use and threshold levels of insects' infestation are rarely defined. The repeated application of the same chemicals may lead to rapid development of resistance to it. For this reasons, pesticides represent a risk to small-scale farmers.

iv. Labour constraints

Labour constraints are particularly serious because of the low level of adoption of animal traction in the humid zones of Nigeria. The presence of tsetse fly is one major reason for this but often it is poverty that prevents farmers from buying and using oxen and ploughs. Without animal traction, the area of land that can be cultivated by one adult is about 0.5 ha. Such small scale cultivation rarely provides a surplus of food or other crops for sale- a prerequisite for economic development.

The use of oxen allows several hectares to be ploughed and perhaps weeded, opening up the possibility of marketing surpluses to fund the purchase of further equipment, new seeds and other inputs.

3.9 Measures of Improving Field Crop Production in Nigeria

i. Development of infrastructure

To achieve accelerated development in food crops production in Nigeria there is need to have a market orientation approach toward production process. Without selling their produce, farmers cannot usually raise enough cash necessary for farm maintenance and improvement, whether in form of a new plough, seed or fertiliser, extra labour or insecticide nor provide for his family. Markets and prices depend on access to sale points by traders and farmer. A good road transport system is vital in this respect. The fewer and poorer the roads, the lower will be the gain of the farmer, because the cost of moving the farm products will be too high. Farming communities also need better water supplies. Bringing good quality water nearer the farm reduces the time spent in collecting it. Provision of health care facilities closer to the farmers would enhance their health status and productivity. Development of infrastructure does not in itself produce more food but it strengthens and encourages the farming population and also helps to create an enabling environment for crop production to thrive and prosper.

ii. The incentive approach

Government need to put in place incentives that would ensure stable prices high enough to stimulate and encourage farmers to produce more. Farm price support has proved very successful in the EU - to the point of over production. It is hoped that if implemented here, would produce similar results. Because inputs are very expensive for most peasant farmers, incentives are usually necessary if they are to be adopted on a significant scale. Incentives can take the form of direct subsidy, improved access to credit and granting ownership of land to peasant farmers. However, subsidies need to be implemented with care to avoid corruption.

iii. The institutional approach

Government agricultural development agencies are created to help the farmers through training and extension, to implement government policies and monitor performance. But unfortunately such government staffs are poorly motivated and ill-equipped. Extension services are frequently ineffective due to low morale among extension officers. This may be due to a top-down approach, under-funding, recommendation that is too complex or costly. In addition there are severe logistical problems in disseminating information to the large numbers of small-scale farmers scattered over the vast areas in the Savanna. Most of the programs for accelerated food production programme are typically designed top-down approach instead of bottom-up planning. That is why most of these programmes remain out of touch with farmers' real constraints and abilities. A 'them-and us' mentality develops, so that soon, staff and beneficiaries have different attitudes to and expectation from the project. There is little identification by the people with the objectives of the programme, and no local enthusiasm to take it over and develop it. These are not inevitable results, but avoiding them needs great imagination, careful planning and inspired leadership.

iv. Transfer of technology and green revolution

Transfer of technology could be described as an attempt to overcome local problems with exotic technology. The typical example of transfer of technology is the green revolution. More accurately referred to as the seed-fertiliser revolution, has centred on the simultaneous adoption of high-yielding varieties and greatly increased levels of chemical fertilisation. Pesticides, especially insecticides, have been required to counteract the greater susceptibility to pest and diseases associated with this combination, and improvements to irrigation and husbandry have frequently been added to the package. The seed-fertiliser revolution is based, then, on a package of inputs, most of which represent technology transferred from elsewhere but adapted to local condition through regional or national research programmes. Very large increases in production have resulted from rapid adoption of this technology in a number of countries in Asia and Latin America but with limited successes in Africa south of the Sahara. This is partly due to scarce resources and poorly developed infrastructure to take full advantage of the new technology. To take advantage of this technology in sub-Saharan Africa the following need to be put in place:

i. appropriate plant breeding or selection from existing material, concentrating on yield stabilisation

ii. establishing efficient and effective seed multiplication system, especially for food crops

iii. strengthening communication and infrastructure for marketing of crops and inputs

iv. increased use of animal plough in order to overcome labour and timing constraints

v. involving the farmers more effectively in farming system research and programme formulation, implementation and appraisal

vi. greater and consistent commitment to increased food production by national government

vii. incentives for trained personnel to stay and work in their own countries.

4.0 CONCLUSION

As you studied this unit, the historical development of crop production from the stage of hunting and gathering to intensive methods of production would be clear to you. Classification of crops based on botanical similarities and uses, the various centres of origin of important field crops were treated. Also, trends, problems and prospects of crop production in Nigeria and globally are highlighted and explained.

5.0 SUMMARY

Crop production practices are intimately associated with cultural evolution of human beings and have undergone tremendous transformation and development from hunting and gathering stage to modern day intensive field crops production. Many crops of significance in Nigeria i.e. cassava, maize, sweet potatoes, taro, rice, groundnuts, sugar cane, cocoa and rubber had their origin from other continents but were introduced into Nigeria many years ago. In this unit, field crops were classified according to their botanical similarities, their uses and some special peculiarities. The present condition of field crop production, import and export of cereals in Nigeria, and ranking of the country in world production of some crops was presented. The cassava revolution in Nigeria was equally treated. Constraint and prospects of field crop production in Nigeria were examined and analysed.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. State five centres of crop origin.
   b. For each centre mention two crops that originated from there.
   c. List five crops that are indigenous to Africa.
   d. Mention five crops (introduced) grown in Africa but have their origin from other continent.
2. a. Describe the botanical classification of field crops with examples.
   b. Give the agronomic classification of field crops.

3. a. Describe the factors that constitute constraints to crop production in Nigeria.
   b. What are the measures to increase food crop production in Nigeria?

7.0 REFERENCES/FURTHER READING

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UNIT 2 CROPPING SYSTEMS

CONTENTS

1.0 INTRODUCTION

Cropping system is not only interested in the types of crops grown, but also on how those crops are distributed on the field at any given time and how this distribution changes over time. In addition, the level of management and amount of resource inputs are integral aspects of a cropping system.

This unit will explain to you the various cropping systems and the conditions that give rise to such cropping systems. The advantages and disadvantages of each cropping system are also treated.

2.0 OBJECTIVES

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

- describe shifting cultivation the factors governing its rise and why it is no longer tenable
- identify practices that could enhance soil fertility while practicing continuous cropping
- state the advantages and disadvantages of each cropping system
- select the best cropping system in a given area based on the environmental conditions, crop growing pattern, nutrient status of the soil, sloppiness of the land, etc.

3.0 MAIN CONTENT

3.1 Definition of Cropping System

The term cropping system is used to describe the pattern in which crops are grown in a given area over a period of time and includes the technical and managerial resources that are utilised. In short, when we talk about the cropping system of a given area, we are not only interested in how those crops are distributed on the field at any given time but also how this distribution changes over time. In addition, the level of management and amount of resource inputs are integral aspects of a cropping system.

Cropping systems are classified based on the following criteria

1. The distribution of crops in time, i.e. whether shifting cultivation, continuous cropping, monoculture, or crop rotation is practised.

2. The distribution of the crops in space on the field, i.e. whether intercropping or sole cropping is practised.

3. The level of management and resources utilised to produce the crop, i.e. whether production is intensive or extensive.

4. The type of crop grown, i.e. whether orchard, arable cropping, pasturing, forestry, etc. is practised.

3.2 Shifting Cultivation

In this system, the farm is not at a permanent location. Instead, a piece of land is cleared, farmed for a few years and then abandoned in preference for a new site. While the new site is being farmed, natural vegetation is allowed to grow on the old site. Eventually, after several years of bush fallows, the farmer returns to the original location. The practice of moving the home along with the farm is discontinued and in its place the practice of making home stationary is common in tropical Africa.

Common features of shifting cultivation

1. The farmer first selects a site which has been under bush fallow for several years.

2. Clears the vegetation by burning.

3. Crops are then grown on the field for one, two or three years, starting with crops with high nutrients requirement and ending with crops that has low nutrients requirement.

4. Low levels of technology, input and management.

5. Most of the operations are carried out using simple hand tools and the labour requirements are high while the yields are correspondingly low.

Factors necessitating shifting cultivation

1. Declining of soil fertility and increasing population.

2. Unusually high incidence of diseases and pests.

3. Social or religious customs may dictate the abandonment of site before its fertility level has become marginal.

Disadvantages of shifting cultivation

1. It tends to discourage high level of inputs.

2. Because the farms stays in one location only for a short while, there is no incentive to invest in permanent structures such as store sheds, irrigation and even certain pest control soil erosion or soil conservation measure that may have a long-term benefits.

3. It requires a great deal of land to maintain the system.

4. Low efficiency in land utilisation.

5. Low efficiency in labour utilisation.

3.3 Continuous Cropping

In contrast to shifting cultivation, continuous cropping implies the cultivation of the same piece of land year after year. Fallowing may occur, but it never occurs more than a season or two. The absence of a protracted fallow periods means that other soil management practices must be employed in order to maintain high soil fertility.

Agricultural practices for maintaining soil fertility under continuous cropping

1. Application of fertilisers and other soil amendments in order to boost fertility.

2. Judicious selection of the crops and crop combinations to be grown. Crop rotations and carefully planned intercrop combination are indispensable.

3. Introducing short term fallow periods in to the cropping cycle. A leguminous cover crop can be planted on the fallow land so as to aid the fixation of nitrogen by legumes during the fallow period and through increasing the soil organic matter content when the fallow crop is ploughed under

Advantages of Continuous Cropping

1. Land utilisation under continuous cropping is extremely efficient. A very high percentage of land is under crops at any given time.

2. It is possible and economically feasible, to erect permanent structures on the farm site.

3.4 Crop Rotation

The practice of growing different kinds of crops, one at a time, in a definite sequence on the same piece of land is referred to as **crop rotation.** In designing a good crop rotation, the farmer must decide what crops to have in the rotation, in what sequence the crops should occur, and for how many years or season each cycle of the rotation must run.

A good rotation that provides for maintenance or improvement of soil productivity usually includes a legume crop to promote fixation of nitrogen, a grass or legume sod crop for maintenance of humus, a cultivated or intertilled crop for weed control and fertilisers. Perennial legumes and grasses may leave two to three tons of dry weight per acre of roots residues in the soil when plowed down.

Factors that affect crop rotation

The choice of a rotation for a particular farm depends upon the following:

1. adaptation of the crops to a particular soil, climate, and economic conditions

2. prevalence of weeds, plant diseases, and insect pests may also limit the kinds of crops that can be grown in a locality

3. crops may be selected for rotation so as to spread labour throughout the year.

Factors to consider in deciding the sequence of crops (principles of crop rotation)

1. The target crop (the main crop) should be planted immediately after the legumes or fallow period. At this time the fertility of the soil is at its peak and the optimum realisable yield of the target crop is possible. Crops which are known to have a high demand for nutrients are also timed for the first season after the fallow.

2. Crops which are deep feeders should alternate with shallow feeders. In this way, nutrient removal occurs uniformly from the various soil layers rather than occurring in only one layer.

3. Crops that are botanically similar or are likely to be attacked by the same diseases and pests should not normally follow each other in the rotation. Yams, for example, should not follow cowpeas in rotation if the root-knot nematode is prevalent, as the nematodes left over from the cowpea crop will severely reduce yam yields. However, if the nematode problem does not exist in the area, yam could conveniently follow cowpeas.

4. The number of years for which each cycle of the rotation should run is determined by the number of crops in the rotation, the length of their growing seasons and how frequent the farmer can grow the target crop without running into problems of disease and soil fertility. For example, the time interval between the harvesting of the target crop and its being planted again on the same piece of land should be long enough to prevent the carry-over of pathogens in crop residues from one cycle to the next.

Types of Crop Rotation

In planning crop rotation, the farmer may decide to consider his entire field as one plot. He then rotates the crops in sequence on the field. At any given time, there is only a crop on the field, and that crop would not return again until the next cycle some years later. This is commonly practiced in Northern Nigeria.

Table 2.1: Example of a 3-Year Crop Rotation as Practised in Savanna Zone of Nigeria

	Year 1	Year 2	Year 3
Winter (with irrigation)	Rice	Vegetables	Wheat
Summer (Rainy season)	cotton	Groundnut/maize	Beans/millet

This system, however, has certain disadvantages**:**

1. The growing of one crop means that the demand for labour occurs in peaks. Labour demand is more evenly spread if many crops are grown simultaneously.

2. The risk of crop failure is ever present, and the risk is greater where only one crop is grown.

3. Since each crop occurs on the farm only once every several years, specialised facilities for the target crop, can only be utilised once in several years, a situation which is definitely inefficient.

Most farmers who practice crop rotation find it more convenient to divide their field into as many plots as there are years in the rotation. The farmer then starts with a different crop on each plot and progress through the rotation. In this scheme, all the crops are present on the farm at any given time. Example of such type of rotation is given below.

Table 2.2: Example of a 3-Year Crop Rotation Found in

	Year 1	Year 2	Year 3
Plot A	Cotton	Guinea corn	Groundnuts
Plot B	Guinea corn	Groundnuts	Cotton
Plot C	Groundnuts	Cotton	Guinea corn

Advantages of Crop Rotation

1. It is an effective means of controlling diseases and pests. The pathogens and pests of a particular crop are more likely to die off when their host crop is followed by a completely different non-host crop. Many insects are destructive to only one kind of crop. The life cycle is broken when crops grown are unfavourable to the development of the insect pest. Cotton root-knot can be reduced by the growth of immune crops in the rotation.

2. Crop rotation is the most effective practical method for controlling many farm weeds. Some weeds are particularly adapted to cultivated crops, the absence of such host crop in the field for many years due to rotation, effectively control the weeds. Rotation may include smother crop as a means of controlling certain weeds.

3. The type of crop rotation where the field is divided into several plots, offers the farmer some insurance against crop failure, and enables him to spread out his labour needs.

4. Crop rotation is an effective means of reducing erosion in comparison with continuous cropping. Grass legumes mixtures in a rotation have been very effective in the reduction of erosion.

3.5 Monoculture

This is the practice of incessantly cultivating the same type of crop on the same piece of land year after year. For example, sugar cane farming in Bachita, Kwara State, Nigeria.

Disadvantages of monoculture

1. In monoculture diseases and pests of the particular crop always have their host present, and therefore have the opportunity to build up over the years.

2. Monoculture encourages rapid depletion of soil nutrients and destruction of the soil structures.

3. The risk of crop failure is great and ever present.

Advantages of monoculture

The main advantage of monoculture is that it permits maximum concentration of production effort on a single target crop.

3.6 Intercropping

The practice of growing one crop variety in pure stands on a field is referred to **as sole cropping.** In this practice, only one crop variety occupies the land at any one time. The alternative practice of growing two or more crops simultaneously on the same field is called **intercropping. T**he various crops in the intercrop do not necessarily have to be sown or harvested at the same time; the main requirement is that they are on the field at the same time for a significant part of their growing periods.

Types of intercropping

1. Row intercropping: This is when the various crops are grown in separate rows.

2. Mixed cropping: This is when the various crops are grown intermingled more or less at random with each other.

3. Relay inter-cropping: This is when a second crop variety is sown between the stands of an existing sole crop just before the first crop is harvested. As such, both the first and second crops spend most of their field lives as sole crop, and grow together on the field for only a brief period.

Factors that determine the crops combination and spatial arrangement

1. Tillage practices: When ridges have been made, the spatial arrangement of the various crops may be determined by particular needs of each crop. For example, yam which requires a deep layer of tilled soil, is planted at the top of the mounds, while rice because of its high moisture requirement, is planted in the lower ground between the mounds. Other crops such as maize, pumpkins and melons are planted at intermediate positions between the rice and the yams.

2. The crop the farmer considers as target crop and which one is considered a subsidiary influence the proportion of the crops.

3. Nature of the crops themselves: A few strands of pumpkin or melon occupy a lot of land and have high economic yield, whereas rice strands, for example, would have to be much more numerous to be meaningful.

Evaluating yield from intercropping

The relative yield of each component crop in an intercropping situation is the yield of that component in the intercropping situation divided by what that crop would have yielded as a sole crop, covering the same area as the intercrop and managed at the same level. Suppose, for example, that a field with a crop combination of maize and cowpeas yields 1.5 tonnes/hectare of maize and 0.25 tonnes/ha. of cowpeas. If the expected sole crop yield of maize is 2.0 t/ha and that of cowpeas is 0.5 t/ha. Then the relative yield of maize is 1.5/2.0 = 0.75 and the relative yield of cowpeas is 0.25/0.50 = 0.50.

The sum of the relative yields of the various component crops in the intercrop is sometimes called the **relative yield total.** A little reflection of how many times the land area used for intercrop would be required to produced the same yields of the component crops when they are grown as sole crops. The relative yield total is therefore more conventionally referred to as **land equivalent ratio (LER)**.

Mathematically:

LER = relative yield of crop A and relative yield of crop B + relative yield of crop n

In the maize/cowpeas combination considered above the LER = 0.75 + 0.25 = 1.25. An LER greater than 1.0 implies that for that particular crop combination, intercropping yielded more than growing the same number of stands of each crop as sole crops. An LER of less than 1.0 implies that the intercropping was less beneficial than sole cropping.

LER can also be calculated based on the monetary value of the yield obtained from the various intercrop and sole crop situation and make comparisons on this basis.

Calculating LER by comparing the total energy value of the yield in kilo calories in various situations and compared the values to determine which arrangement was most beneficial.

Advantages of intercropping

1. In a carefully planned intercropping the LER is usually greater than one. This means that there is yield advantage in growing crops together than growing each one separately. This advantage may rise from several sources.

2. The crops may complement one another in their use of field time. The periods of their peak demands for light, water, nutrients and other resources may differ, so that in general there is a more efficient utilisation of the resources available. For example, during the two or three month that yam takes to sprout and establish adequately on the field, a quick intercrop of maize or melon would beneficially utilise the field resources during this period.

3. The component crop may complement each other in their use of space. For example, an intercrop of a deep rooted crop can exploit various horizons of the soil.

4. An intercrop may be able to utilise resources which the main crop may not be able to utilise or which may even be disadvantageous to it.

5. Certain crops may exert specific beneficial effect on others. For example, plantains intercropped with young cocoa seedlings provide shade for the seedlings. Similarly, in an intercrop of a legume with a cereal crop, the cereal would benefit from the nitrogen fixed by the legumes.

6. By having many crops growing simultaneously on the field the farmer is more or less buffered against failure of one of the crop.

7. Intercropping allows for a more uniform distribution of labour throughout the year.

8. When one component of an intercrop combination fails, the other combinations are able to utilise the resources that would have been available to the failed crop and so yield better than they would have done otherwise. In other words there is yield stability.

9. The spread of diseases and pests is less rapid than in sole cropping. This is probably because the mean distances between the plants of the same component crops are greater. In many instances, the other component crops are not susceptible to the particular disease or pest afflicting one component and may act as physical barriers to the spread of diseases and pest.

Disadvantages of intercropping

1. Since many crops exist together on the field, it is not possible to tailor production practices to the needs of any particular crop.

2. Control of pests and diseases is particularly difficult because pesticides which have been developed to control a disease on one particular component crop may have deleterious effect on other crops in the combination.

3. It is difficult to mechanise operations such as planting, weeding and harvesting.

3.7 Cropping Systems in Africa

Shifting cultivation and intercropping are the predominant practice among the peasant farmers of Tropical Africa while the large scale farmers of East and Southern Africa as well as irrigated agriculture of the Nile valley in Egypt practice sole cropping with crop rotation. In each of these cases continuous cropping is the rule rather than shifting cultivation.

Plantation agriculture mainly practices sole cropping such as oil palm, cocoa, rubber, coffee and tea. In some instance, they may be intercropped with food crops when the plantation is still young. For arable cash crop such as tobacco and groundnuts, sole cropping is the rule but the sole crop may be subjected to shifting cultivation, or to continuous cropping with rotation.

4.0 CONCLUSION

Cropping systems is basically concerned with the distribution of crops in time and space as well the resources expended in the production of crop and the types of crops that are grown. Cropping system of a given area is influenced by climatic conditions, resources available and level of management skills of the farmer. The principles of crop rotation, advantages and disadvantages of various cropping systems were highlighted in this unit.

5.0 SUMMARY

This unit treats the distribution of crops in time, i.e. whether shifting cultivation, continuous cropping, monoculture, or crop rotation and the distribution of the crops in space on the field, (i.e. whether intercropping or sole cropping) as well as the level of management and resources utilised to produce the crop, (i.e. whether production is intensive or extensive) and the type of crops grown, (i.e. whether orchard, arable cropping, pasturing, or forestry). The advantages and disadvantages of each cropping systems and the principles of the rotations were also discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. Explain briefly the criteria used in classifying cropping systems.
   b. Describe shifting cultivation and state its advantages and disadvantages.

2. a. What is crop rotation?
   b. State the principles of crop rotation.
   c. Mention the advantages of crop rotation.
   d. Draw a three year crop rotation with the following crops, maize, cowpeas, cassava, and cotton.
3. a. What are the factors that determine crop combination and special arrangement in intercropping?
   b. Describe the advantages of intercropping.
   c. State the disadvantages of intercropping.

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UNIT 3 FERTILISERS AND THEIR USES

CONTENTS

1.0 INTRODUCTION

According to the World Bank's population projections, the world's population will increase from 6 billion people in 1999 to 7 billion in 2020. All these people will have to be housed, dressed, and above all, fed. Up to 90 percent of this necessary increase in food production will have to come from fields already under cultivation. Fertilisers will continue to play a decisive role in increased food production. It is estimated that, globally, roughly 40% of the world's dietary protein supply in the mid-1990 originated in synthetic nitrogen. Therefore, in order to obtain high yields, fertilisers are needed to supply the crops with the nutrients the soil is lacking. With fertilisers, crop yields can often be doubled or even tripled.

In this unit, fertilisers and their types, importance of each fertiliser in crop nutrition, deficiency symptom of each fertiliser, methods of calculating fertiliser rates, methods of fertiliser application and determining fertiliser needs are treated.

2.0 OBJECTIVES

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

- explain the role of nutrients in plant growth and development

- state the role of inorganic fertiliser in increasing the quantity and quality of field crops
- identify the deficiency symptom of each type of fertiliser
- calculate the rate of fertiliser in a concrete crop in a given locality
- discuss the different factors affecting fertiliser use and efficiency.

3.0 MAIN CONTENT

3.1 Plant Nutrients - their Roles in Plant Growth and their Sources

For proper plant growth, a regular supply of plant nutrients especially the essential ones, is necessary. Plants absorb a large number of elements from the soil, air and water during their growth period, but not all of these are essential. Only 16 elements have been found to be essential for all plants and four others have been found to be essential for some plants.

Essential elements for plant growth

For element to be so classified, it has to fulfill the following criteria:

1. a deficiency of the element makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle

2. the deficiency symptom of the element in question can be prevented or corrected only by supplying that element

3. the element must have a direct influence on the plant, and must be directly involved in the nutrition of the plant, quite apart from its possible effect in correcting some microbiological or chemical condition in the soil or culture medium.

Essential elements like carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur are the elements of which proteins and hence protoplasm are composed. The other ten elements which are essential for plants are potassium, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, and chlorine. The four elements which are essential only for some and not for all plants are sodium, cobalt, vanadium and silicon.

Sources of nutrients

The following elements are derived:

a. from air; carbon (C) as CO_2 (carbon dioxide)

b. from the water: hydrogen (H) and oxygen (O) as H_2O (water)

c. from the soil, fertiliser and animal manure: nitrogen (N) a considerable amount of nitrogen is also fixed by leguminous plants through root nodule bacteria.

Macro and Micronutrients

Macronutrients are needed by the plants in large amount, and large quantities have to be applied if the soil is deficient in one or more of them. Within the group of macronutrients, which are needed for plant growth in large amounts, the primary nutrient such as nitrogen, phosphorus and potassium. Calcium, magnesium and sulphur are sometimes called secondary nutrients due to their secondary importance in plant nutrition.

In contrast with macronutrients, micronutrients or trace elements are required in only minute amounts for correct plant growth and have to be added in very small quantities when they cannot be provided by the soil.

Functions of nutrients

Nitrogen (N)

1. Nitrogen is the motor of plant growth. It makes up to 1 to 4 percent of dry matter of the plant. It is taken up from the soil in the form of nitrate (NO_3^-) or ammonium (NH_4^+).

2. In the plant it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins.

3. Being the essential constituent of proteins, it is involved in all the major process of plant development and yield formation.

4. A good supply of nitrogen for the plant is important also for the uptake of the other nutrients.

Phosphorus (P)

1. It constitutes 0.1 to 0.4 per cent of dry matter of the plant.

2. It plays a key role in the transfer of energy.

3. It is essential for photosynthesis and other chemical-physiological process in the plant.

4. It is indispensable for cell differentiation and for the development of the tissues, which form the growing points of the plant.

Potassium (K)

1. Potassium makes up 1 to 4 percent of the dry matter of the plant.

2. It activates more than 60 enzymes.

3. It plays a vital part in carbohydrate and protein synthesis.

4. Potassium improves the water regime of the plant and increases its tolerance to drought, frost and salinity.

5. Plants well supplied with K are also less affected by diseases.

Magnesium (Mg)

1. It is a central constituent of chlorophyll, the green pigment of the leaves which functions as acceptor of the energy from the sun, thus, 15 to 20 per cent of the magnesium found in plant is contained in the leaves.

2. Mg is also involved in enzyme reactions related to the energy transfer of the plant.

Sulphur (S)

1. It is an essential constituent of protein and also involved in the formation of chlorophyll.

2. In most plants it makes up to 0.2 to 0.3 per cent of dry matter.

Calcium (Ca)

1. Calcium is essential for root growth

2. It is a constituent of cell wall materials.

Micronutrients or Trace elements

These are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B). They are part of the key substances in plant growth and are comparable with vitamins in human nutrition. Being taken up in minute amounts, their range of optimal supply is very small.

3.2 Addition of Plant Nutrients to the Soil

Plant nutrients can be supplied to the soil by adding the following:

1. organic manure
2. green manures and other crop residues
3. concentrated organic manures
4. commercial fertilisers
5. soil amendments

a. Organic fertilisers/manures

Farm yard manure, compost, sludge, green manures and other bulky sources of organic matter are known as bulky organic manures. These manures supply plant nutrients in small quantities and organic matter in large quantities. These manures have a direct effect on plant growth, on the humus content of the soil, so improving its physical properties, and on microbial activities in the soil.

i. Farmyard manures

The term farmyard manure (FYM) refers to the refuse from all animals of the farm although as a general rule the bulk of this is produced by cattle. The richest and most concentrated manure is poultry manure which is particularly good for vegetable production. Farm yard manure consists of two components- solids and liquids in a ratio of approximately 3:1. The solid portion is made up straw that has been used for bedding and dung. Dung is mostly undigested food and urine is a fluid waste product. More than 50% of the organic matter in dung is in form of complex products, often of lignin and protein, which are similar to humus. FYM contain on the average 0.5%N, 0.25% P_20_5, and 0.5% K_20. Generally, 30% of N, 30% of the P_20_5 and 50% of the K_20_5 in farm manure are available to plants.

Importance of farmyard manure

1. Farmyard manure is source of nutrient especially nitrogen, potash and some trace elements.
2. It influences the physical properties of the soil.

3. Farmyard manure increases the humus content and consequently the water holding capacity of the soil.

4. It improves the structure of the soil by making it more granular, better aerated and better drained. The manure also tends to reduce soil compaction which is often associated with continuous cultivation.

ii. Compost

Compost is well-rotted vegetable matter which is prepared from farm and town refuse. Compost is prepared in trenches of various sizes and shapes. The accumulated refuse is well mixed and then spread in the trench in a layer of about 0.3 m. this layer is then well moistened by sprinkling over it slurry of cow dung and water, or earth and water. Subsequent layers of the same thickness of mixed refuse are then spread on the heap and moisten. After about three month it is now fully decomposed and should be taken out of the trenches formed into conical heaps above ground and covered with earth. After one or two months, the compost will be ready for use. The N, P and K contents of farm compost are on the average 0.5%, 0.15%, 0.5%, respectively, while those of the town compost are 1.4%, 1.0%, 1.4%, respectively.

Advantages of composting organic matter

1. The carbon: nitrogen ratio is improved because carbon dioxide is released to the air by micro-organisms.

2. Improve the structure of the soil by making the soil friable, crumbly and easier to handle and work upon.

3. The heat generated may kill weed seeds and other pathogenic organism.
4. It is the cheapest source of organic manure.

iii. Green manures

This is the practice of growing and ploughing in green crops to increase the organic matter content of the soil. Green manure crops are usually fast growing annual legumes and grasses. They are usually incorporated in the soil when they are green and succulent. Crops which grow rapidly even on poor soils and produce an abundant mass of green leaves and tops can be used as a green manure crop.

Advantages of green manure

1. It increases the organic matter content of the soil.
2. It improves soil structure.
3. Makes phosphorus and certain trace elements available to plants.
4. Checks erosion and leaching.
5. Helps to control weeds by acting as a smother crop.

b. In-organic/commercial fertilisers

What is a fertiliser? Any natural or manufactured material, which contains at least 5 percent of one or more of the three primary nutrients (N P K), can be called fertiliser. Industrially manufactured fertilisers are called mineral fertilisers. Fertiliser may contain one or more of the essential nutrients. Those that contain only one of the major elements are described as single, simple or straight fertilisers. Those that contain two or more of the major elements are classified as mixed or compound fertilisers. Nitrogen, phosphorous, and potassium are the main plant nutrients and these three provide the basis for the major groups of fertilisers.

With the rapid increase in population and rise in standard of living there is increasing demand for food and feed grains. To meet up with the food demand it is necessary to intensify field crop production. Achieving and sustaining high crop yield of desired quality is only possible through the use of commercial fertilisers.

Although there have been tremendous increases in fertiliser using in tropical Africa over the years, utilisation is still on a very small scale relative to the total needs. There is a wide gap between the national requirements for fertilisers and their actual use by farmers.

3.3 Chemical Fertilisers

a. Nitrogenous fertilisers

The nitrogen in many straight and compound fertilisers is in the ammonium (NH_4 ions) form, but this is quickly changed by the bacteria in the soil to the nitrate (NO_3 ions) form. Most crop plants such as cereals take up and respond to the NO_3 ions faster than to the NH_4 ions, but some crops, such as rice, potatoes and grasses, are equally responsive to both forms.

On the basis of the chemical form in which nitrogen is combined with other elements in a fertiliser, nitrogenous fertilisers may be classified into four groups:

i. Nitrate fertilisers

In these fertilisers, nitrogen is combined in nitrate (NO_3) form with other elements. Such fertilisers are sodium nitrate (N_aNo_3), having 16 percent N, calcium nitrate [Ca $(NO_3)_2$], having 15.5% N, and potassium nitrate (KNO_3), having 13.4% N and 44% K.

Nitrate fertilisers are quickly dissociated in the soil, releasing the nitrate ion for plant absorption. As such they are readily absorbed and utilised by the plants. The great mobility of the nitrate ions in the soil has the advantage that, even when applied to the surface of the soil, the nitrogen quickly reaches the root zone. They are therefore very often used as side and top dressings. However, there is also the increased danger of leaching of these fertilisers.

All the nitrate fertilisers are basic in their residual effect on the soil and their continued use may reduce soil acidity.

ii Ammonium fertilisers

In these fertilisers, nitrogen is combined in ammonium (NH^+_4) form with other elements examples of such fertilisers:

1. Ammonium sulphate [$(NH_4)_2SO_4$], having 20% N,
2. Ammonium phosphate ($NH_4H_2PO_4$) having 20% N and 20% P or 16% N and 20% P;
3. Ammonium chloride (NH_4Cl), having 24-26% N,
4. Anhydrous ammonia, having 82% N and
5. Aqueous ammonia having 28% N.

When added to the soil, the ammonium ion is temporarily retained by the colloidal fraction of the soil until it is nitrified. These fertilisers are much more resistant to loss by leaching because the ammonium ions are readily adsorbed on the colloidal complex of the soils. Most ammonium fertilisers have acidic residual effect on the soil.

iii. Nitrate and ammonium fertilisers

These are fertilisers that contain nitrogen in both ammonium and nitrate forms. Examples of such fertilisers:

1. Ammonium nitrate (NH_4NO_3), having 32.5% N,
2. Ammonium sulphate nitrate (ASN)[$(NH_4)_2SO_4 \cdot NH_4NO_3$], having 26% N,
3. Calcium ammonium nitrate (CAN) [Ca $(NH_4NO_3)_2$], having 25% N.

These fertilisers are readily soluble in water and suitable for use under variety of soils and cropping conditions. The nitrate nitrogen of these fertilisers are readily available to plants for rapid growth and the ammonium nitrogen resists leaching losses and can be utilised by the plants at a later stage. These fertilisers are acidic in their residual effect on the soils.

iv. Amide fertilisers

These fertilisers are carbon compounds, and so are called organic fertilisers. Important fertilisers in this group are:

1. Urea [$Ca(NH_2)_2$], having 46% N and
2. Calcium cyanamide ($CaCN_2$), having 22% N.

These fertilisers are readily soluble in water and easily decomposed by micro-organisms in the soil. In the soil they are quickly changed into ammonical nitrogen and then to nitrate form.

General recommendation on the use of nitrogen fertilisers

a) For rice, it is recommended to use ammonia-forming fertilisers such as ammonium sulphate, ammonium chloride and urea. In case these fertilisers are not available, ammonium-nitrate fertilisers such as ammonium sulphate nitrate, ammonium nitrate and calcium ammonium nitrate should be used. For the rest of field crops, all nitrogenous fertilisers are equally effective.

b) Continuous use of ammoniacal or ammonium-forming fertilisers on acidic soil should be avoided as it tends to make the soil more acidic.

c) All nitrate fertilisers are best suited for side and top dressing.

d) Since they are easily leached, they should not be applied in large quantities in light sandy soils or during heavy rains.

e) The entire recommended dose of nitrogen should be applied in 2 or 3 splits.

b. Phosphorus fertilisers

Crop plants absorb phosphorus in the form of negatively charged ions such as HPO_4^{2-} or $H_2PO_4^-$

Phosphorus fertilisers can be classified into three groups depending on the form in which phosphoric acid is combined with calcium.

Phosphorus fertilisers containing water-soluble phosphoric acid or monocalcium phosphate [Ca $(H_2PO_4)_2$]: such fertilisers are super phosphate, ordinary or single, having 16-18% P_2O_5; double super phosphate, having 32% P_2O_5; triple super phosphate, having 46-48% P_2O_5 and ammonium phosphate, having 20% N and 20% P_2O_5 or 16% N and 20% P_2O_5.

These fertilisers are quickly absorbed by the plants, since plants absorb phosphorus as H_2PO_4 ions. Water-soluble phosphoric acid is rapidly transformed in the soil into a water-insoluble form. As such there is no danger of loss of nutrients by leaching.

This group of fertilisers should not be used in neutral or alkaline soils and not inacidic soils. Under acidic condition, phosphoric acid is converted into monocalcium phosphate, and there is less chances of the phosphate being fixed as iron or aluminum phosphate.

Fertilisers containing citric-acid, soluble phosphoric acid or dicalcium phosphate [$CaHPO_4$]; such fertilisers are basic slag, containing 14- 18% P_2O_5: dicalcium phosphate, containing 34-39% P_2O_5 and rhenania phosphate, containing 25-76%. These fertilisers are particularly suitable for acidic soils.

Fertilisers containing insoluble phosphoric [$Ca_3(PO_4)_2$]: such phosphatic fertilisers are rock phosphate, having 20-40% P_2O_5: raw bonemeal, having 20-25% P_2O_5 and 3-4% N and steamed bone-meal, having 22% P_2O_5. These fertilisers are well suited for strongly acidic soils or organic soils which require large quantities of phosphorus fertilisers to raise the soil fertility.

Principles of effective utilisation of phosphorus fertilisers

a) Granular fertilisers with a high degree of water-solubility are more effective on acid and neutral soils than powdered fertilisers.

b) On acid and neutral soils, band application of powdered fertiliser with a high degree of water solubility will give better results than mixing the fertilisers with the soil.

c) Water soluble fertilisers give the greatest response when applied in band.

d) To get optimum response from addition of phosphorus fertilisers other nutrients must be in adequate quantities.

c. Potassium fertilisers

All potassium fertilisers consist essentially of potassium in combination with chloride, sulphate, or nitrate. Almost all potassium fertilisers are water soluble. The following are examples of potassium fertilisers:

a) Potassium chloride [KCl] or muriate of potash, having 60-63% K_2O

b) Potassium sulphate [K_2SO_4], having 50 – 53 % K_2O_5 and 18% of sulphur

c) Potassium-magnesium sulphate [K_2SO_4. $MgSO_4$] having 22% K_2O_5

d) Potassium nitrate [KNO_3], having 13% nitrogen and 44% K_2O_5

e) Potassium metaphosphate [KPO_3] having 40% K_2O and 60% P_2O_5.

Principles of effective utilisation of potassium fertiliser

1. All potassium fertilisers are equally available to plants because all of them are readily soluble in water.

2. Potassium fertilisers containing sulphur, magnesium or sodium have some additional agronomic importance on some soil because of the presence of other elements.

3. Potassium fertilisers containing chlorine or sulphur should be used with caution as they may be injurious to some crops.

d. Compound fertilisers

Compound fertilisers supply two or three of the major plant nutrient elements (i.e. nitrogen, phosphorus, and potassium). They are produced by mixing the straight fertilisers such as ammonium nitrate, ammonium phosphate and muriate of potassium or by more complex chemical processes. The chemical composition of compound fertilisers is usually given as the ratio of nitrogen, phosphorus and potassium expressed as elemental N, P_2O_5 and K_2O respectively. A 15:20:10 compound fertiliser therefore contains 15% N, 20% phosphorus P_2O_5 and 10% potassium expressed as K_2O.

Advantages of compound fertilisers

a) The mixture is usually dry, fine and well mixed and can be applied by hand as well as through a fertiliser drill.

b) The mixture usually contains all major plant nutrients.

c) It saves the farmer time and labour.

d) It does not form lumps or deteriorate in any way if it is not used immediately.

Grades of compound fertiliser

Low grade mixtures are 6:12:6, 5:10:10, and 9:9:0 etc. and high grade mixtures are15:15:15, 20:20:20. Using high grade fertilisers have some advantages like:

1. Low cost per unit of plant nutrient

2. Lower cost of transportation, labour, and storage

3. Increased the speed of application in the field.

e. Slow release fertilisers

Slow or controlled release fertilisers contain a plant nutrient (usually nitrogen) in a form, which after application delays its availability for plant uptake significantly longer than a common fertiliser. This effect is obtained either by coating a common (nitrogen or NPK) fertiliser with sulphur or with a semi-permeable polymer material or by special chemical nitrogen compound formulations.

Advantages of slow release fertiliser

1. Labour saving, instead of several split application only one for the whole growing periods.

2. Reduces toxicity to seedlings even with high application rates.

Disadvantages of slow release fertiliser

The cost per unit of nutrient is considerably high than that in common fertilisers.

f. Nitrification and urease inhibitors

Nitrification inhibitors are compounds which, when added to nitrogen fertilisers (containing the nitrogen in form of ammonia (NH_4^{+}) causes delay in the transformation of the ammonium-ion (NH_4^{+}) held by the adsorption complex into nitrite (NO_2) and further to nitrate (NO_3^{-}) through the activities of soil bacteria, thus preventing leaching of nitrate not taken up immediately by the crop.

Urease inhibitors are compounds that depress the transformation of the amide-N in urea into ammonium for about 10 to 12 days; thus preventing, or reducing, evaporation losses of ammonia to the air when the weather stays dry or the urea cannot be incorporated into the soil immediately after application.

Both nitrification and urease inhibitors are strongly mixed with the nitrogen fertilisers before spreading and then spread together in the mixture.

3.4 Calculating the rate of fertiliser to be applied

The amount of fertiliser to be applied per hectare on a given field is determined by:

1. the amount of nutrients needed by plant for optimum growth and productivity

2. the availability of nutrient in the soil (level of soil fertility)

3. the moisture status of the soil

4. the type of crops to be grown

5. the types and grades of fertilisers available.

Usually mineral fertilisers are delivered in 50-kg bags while the nutrient content (active ingredients) is given in percentages e.g. N 15 P15 K15. Meaning that each 50kg bag contained 15% N 15% P 15% K.

Steps to follow in calculating the rate of fertiliser to be applied

i. Determine the quantity of active ingredients contained in each bag, this could be done by dividing the percentage of each nutrient by two. Example, N15 P15 K15 would contain active ingredients N 15/2= 7.5kg P15/2= 7.5kg K 15/2=7.5kg.

If the recommendation is to apply N60-P60-K60 per hecter, the easiest option for the farmer is to buy a multi nutrient (compound) fertiliser grade N15-P15-K15.

One 50-kg bag contains N7.5kg -P7.5kg-K7.5kg of active ingredients.

To find the number of bags required to supply the recommended nutrients:

1 bag = 7.5kg
x = 60kg
find X
X = 60 divided by 7.5 = 8 bags of NPK.

ii. Example: how many bags of ammonium sulphate (AS) (with 21% N and 24% S) are needed to supply 60 kg/ha of N?

21 divided by 2 gives 10.5. Thus, approximately six bags of AS would supply 60.5 kg of active ingredients of N.

In addition, six bags of AS will supply 72 kg/ha of sulphur.

Thus eight bags of 50 kg of N15-P15-K15 are needed to apply the recommended rate of 60 kg/ha N, 60 kg/ha P_2O_5 and 60 kg/ha K_2O.

iii. When the recommendation per hectare isN60-P30-K30, with 50-kg bags of a N15-P15-K15 grade the farmer would divide 30 by 7.5 = 4. Since each 50kg bag contains 7.5 kg of active ingredients of NPK.

In this case he should apply only four 50-kg bags of NPK fertiliser per hectare, giving half of the recommended rate of nitrogen and the full rate of phosphate and potassium as basal dressing.
The remaining 30 kg/ha N should be applied in the form of a straight nitrogen fertiliser as one or two top-dressings in line with good agricultural practices

3.5 Time and Method of Fertiliser Application

To achieve maximum benefit from fertilisers, it is most essential to apply them at the right time and in the right place. The amount and timing of nutrient uptake depends on various factors, such as crop variety, planting date, crop rotation, soil and weather conditions. For good agricultural practices, the farmer chooses the timing and the quantity in such a way that as much as possible of the nutrients is used by the plants. For optimum crop use efficiency and minimum potential for environmental pollution, the farmer must apply the nutrients as near to the time the crop needs them. This is particularly important for mobile nutrients such as nitrogen, which can easily be leached out of the soil profile, if they are not taken up by the plant roots.

i. Time of applying nitrogen fertilisers

Since nitrogen is required throughout the growth period and nitrogenous fertiliser are lost through leaching, it is better not to apply too much nitrogen at one time. The split application of nitrogen throughout the growing period will ensure greater efficiency and plants would not suffer from nitrogen deficiency.

ii. Phosphorus

This element is required in greater quantities during the early growth period and as all phosphorus fertilisers become available to growing plant slowly, it is always recommended that the entire quantity of phosphorus fertilisers be applied in single doze before sowing or planting.

iii. Potassium

This element is absorbed right up to the harvest stage but it becomes available slowly. It is therefore always advisable to apply the entire quantity of potassium at sowing time.

Methods of Fertiliser Application

The method of application of fertilisers (organic manure or mineral fertilisers) is an essential component of good agricultural practices. A fast start and continued nutrition is essential for sustained maximum profit. It is important to place some of the fertiliser where it will intercept the roots of the young plant and to place the bulk of the nutrients deeper in the soil.

Nitrogenous fertilisers are easily soluble in water and have mobility, so they can be applied on the soil surface.

Phosphorus fertilisers moves slowly from the point of placement, it should be placed closer to the plant roots. To reduce phosphate fixation, phosphorus fertilisers should be so placed that they come into minimum contact with the soil particles and are close to the plant roots.

Potassium fertiliser moves slowly in the soil, they should also be placed near the root zone.

Based on these principles, the following methods are used to apply fertilisers.

i. Broadcasting

The fertiliser is spread over the entire soil surface to be fertilized with the objective of distributing the whole quantity of fertiliser evenly and uniformly and incorporating it in the plough layer. It is used mostly on dense crops not planted in rows or in dense rows and on grassland. It is also used when fertiliser should be incorporated into the soil after application to be effective (phosphate fertilisers), or to avoid evaporation losses of nitrogen (urea, diammonium phosphate). Incorporation through tilling or ploughing-in is also recommended to increase the fertility level of the entire plough layer. Whether the fertiliser is broadcast by hand or with fertiliser spreading equipment, the spreading should be as uniform as possible.

ii. Row or band placement

This refers to the application of fertilisers into the soil close to the seed or plant and is employed when relatively small quantities of fertilisers are to be applied. When fertilisers are placed along with, or close to the seed or plant in bands or pockets, the roots of the young plants are assured of an adequate supply of nutrients and this promotes rapid early growth. This method of placement also reduces the fixation of phosphorus and potassium.

When seeds or plants are sown close together in a row, the fertiliser is put in continuous band on one or both sides of the row. This method of application is referred to as **row placement,** and is used for potatoes, maize, tobacco, cotton, sugar cane, etc.

Where crops are cultivated by hand and planted in hills, the recommended grams of fertiliser are placed in the row or planting hole, under, or beside the seed, and covered with soil, this is known as **hill**

placement. Great care has to be taken such that no fertiliser is placed either too close to the seed or to the germinating plant to avoid toxicity.

iii. Top dressing

Top-dressing (broadcasting the fertiliser on standing crop) is mainly used for small and large grain crops and for crops such as forage, wheat and barley.

Top dressing of additional nitrogen is done when:

i. a single application of the total nitrogen needed at sowing might lead to losses through leaching and run-off.

ii. or where crops show a special need for nitrogen at certain stages of growth.

Top dressing of potassium, which does not move in the soil to the same extent as nitrogen, might be recommended on light soils, i.e. applying the total amount divided into a basal dressing and top-dressing.

Phosphate hardly moves in the soil at all. Hence, it is usually applied before or at sowing or planting time (basal application), preferably in combination with potassium and part of the nitrogen.

Side dressing: this is also another form of top dressing where fertiliser is spread between the rows or around the plants. Maize, cotton, sugar cane, trees and other perennial crops are normally side-dressed.

iv. Foliar application of fertiliser

Foliar application refers to the spraying of the leaves of growing plants with suitable fertiliser solutions. It is used mainly to correct micronutrient deficiencies. To minimise the risk of leaf scorch, the recommended concentration has to be respected and spraying should preferably be done on cloudy days and in the early morning or late afternoon.

v. Direct application into the soil

With the help of some special equipment, anhydrous ammonia (liquid fertiliser) and nitrogen solutions can be applied directly into the soil. There is very little plant injury or wastage of ammonium if the material is applied about 10cm below the seed, and the soil is moist.

vi. Application through irrigation water

Straight or mixed fertilisers which are easily soluble in water are allowed to dissolve in the irrigation stream. The nutrients are thus carried into the soil in solution. The fertilisers most commonly applied through irrigation water are nitrogenous fertilisers.

3.6 How to Determine Fertiliser Needs

To determine fertiliser needs for crops and soils in your locality you must know two things:

1. the status of nutrients in the soil

2. how much of each nutrient is needed to get the highest or most profitable (optimum) yield?

There are several approaches to finding the answers to these questions.

1. Fertiliser recommendation of crops.

2. Nutrient hunger signs on growing crops (deficiency symptoms).

3. Soil tests or analyses to determine the fertiliser nutrients and amount needed.

4. Plant or plant tissue test in the field.

5. Fertiliser field trials

Hunger signs in plants (nutrient deficiency symptoms)

If plants do not get enough of a particular nutrient they need, the symptoms show in the general appearance as well as in the colour of the plant. Very typical symptom are: the nutrient deficient plants are stunted , the leaves have a pale green colour or a very dark bluish green colour, yellowish or have reddish spotting or striping. At harvest, yield is reduced, sometimes severely.

Nitrogen deficiency symptoms

1. Stunted growth.

2. Loss of green colour, yellow discolouration of leaves from tip backward, older leaves brown.

3. Lower leaves may die premature while the top of the plant remains green.

Phosphorus deficiency symptoms

1. Stunted growth.

2. Leaves turn dark bluish green, purpling and browning from tip backward.

3. Plants slow to ripen, remaining green.

4. Fruits may be misshapen, grain is poorly filled.

Potassium deficiency symptoms

1. Stunted growth.

2. Leaves show discolouration along outer margin from tip to base.

3. Outer edges of leaves yellow or reddish, becoming brownish or scorched and dead; leaves wilted.

4. Lodging.

5. Tree leaves are yellowish, reddish, pinched, cupped or curved.

6. Fruit is small, may have lesions or injured sport, poor storage and keeping quality.

Magnesium deficiency symptoms

Yellowish discolouration between Greenleaf veins, followed by blotching and necrosis (death of tissue), starting at lower older leaves.

Sulphur deficiency symptoms

1. Whole plant is yellowish (often mistaken as N deficiency).

2. Yellowish of upper leaves, even on newest growth.

3. Delayed crop maturity.

Calcium deficiency symptoms

1. Young leaves turn yellowish to black and curved or cupped (brown spot).

2. Plants appear to wilt.

3. Fruits may appear rotten.

4. Roots are malformed.

Boron deficiency symptoms

1. Leaves frequently misshapen and crinkled, thick and brittle, white, irregular spots between veins.

2. Growing tips of buds die, with bushy growth near tips extension growth inhibited with shortened internodes.

3. Water-soaked, necrotic spots or cavities in beet and other root crops and in the pith of stems.

4. Fruit small and poorly formed, often with corky nodules and lesions.

5. Low seed production due to incomplete fertilisation.

Zinc deficiency symptoms

1. Stunted growth of leaves.

2. Fruit trees with typical shortened bushy shoots.

3. Chlorotic stripes (white bleached bands) between the leaf veins in lower part of leaf.

4. In some cases leaves have an olive green or grayish green colour (very similar to P deficiency).

Iron deficiency symptom

Young leaves with typical chlorosis between green veins, along the entire length of leaves (usually on calcareous soils).

3.7 Soil Amendments

Soil amendments are the substances used for correcting the acidity or alkalinity of the soil. In high rainfall areas, there is considerable leaching of bases leading to the formation of acidic soil, while in low land areas, saline and alkaline soils occur.

Soil reaction or soil pH

Soils vary considerably in degree of acidity or alkalinity or in reaction. The normal range is expressed in pH values as given in table 3.1 that follows

Table 3.1: Normal Soil Reaction Range with Corresponding pH Values

Range in soil reaction	pH value
Extremely acidic	Below 4.5
Very strongly acidic	4.5- 5.0
Strongly acidic	5.1-5.5
Medium acidic	5.6-6.0
Slightly acidic	6.1- 6.5
Neutral	6.6- 7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	9.1 and above

Liming of acidic soils

Liming as the term applies to agriculture is the addition of any calcium or calcium and magnesium-containing compound to the soil for reducing acidity. For this purpose, calcium oxide, calcium hydroxide, calcium carbonate, calcium magnesium carbonate and calcium silicate slags are used.

Methods of applying lime

Lime should be applied before ploughing or applied on ploughed land and then disked or mixed into the soil. When large quantities of lime are required, it is advisable to apply the required amount in two or three splits rather than in one heavy application. On strongly acidic soils, where 7-15 tonnes of lime are required per hectare, half the quantity should be applied before ploughing and the remaining half applied and disked after ploughing. When the lime required is below 4-5 tonnes per hectare, the entire amount should be applied and disked in at one time, 8-10 days before sowing.

4.0 CONCLUSION

Fertilisers are applied to crops to supply the nutrients that are not present in sufficient quantities in the soil. The purpose of an adequate fertilisation programme is to supply, year after year, the amount of nutrients that will result in sustained maximum net returns. This means that fertilisers are to be used in the most efficient way. To achieve maximum benefit from fertilisers, it is most essential to apply them at the right time and in the right place. Various types of fertilisers, the methods of their application, deficiency symptoms, and methods of calculating fertiliser needs have been discussed in this unit.

5.0 SUMMARY

The role of fertiliser in sustainable crop production cannot be overemphasised. This unit examines the types of organic fertiliser and chemical fertilisers, the role of each essential and non-essential elements in crop nutrition, method of determining fertiliser needs of crop, methods of fertiliser application, symptoms of deficiency of various types of fertilisers, method of calculating fertiliser needs of crops, principles of effective utilization of fertilisers were discussed. Also, soil reaction as it relates soil pH and its correction were treated in this unit.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. State the criteria that an element must meet before it is referred to as essential element.
   b. List essential elements in plant nutrition.
   c. Distinguish between macro and micro nutrients.
   d. State the sources of plant nutrients.
2. a. State the functions of Nitrogen.
   b. State the functions of Phosphorus.
   c. State the functions of Potassium.
   d. For each of the following Nitrogen, Phosphorus and Potassium, mention the form in which each is absorbed by the plants and deficiency symptoms.
3. Give the advantages of the following:
   a. Farm yard manure
   b. Green manure
   c. Composting.
4. For each of the following fertilisers, give two examples each of:
   a. Nitrate fertilisers
   b. Ammonium fertilisers

c. Phosphorus fertilisers
d. Potassium fertilisers
e. Compound fertilisers.
f. Liming materials.

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UNIT 4 TILLAGE PRACTICES

CONTENTS

1.0 INTRODUCTION

In this unit you will be studying tillage operations, its purposes, types, when and how deep it should be carried out, and the implements that would be needed to carry out the operations. The adverse effect of frequent tillage on the soil and environment is treated so that you would have a better appreciation of the need for sustainable crop production practices.

2.0 OBJECTIVES

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

- define tillage and state the purposes of tillage operations
- list the advantages and disadvantages of each type of tillage operation
- enumerate the adverse effects of frequent deep tillage on the soil and the environment.

3.0 MAIN CONTENT

3.1 Definition of Tillage

Tillage is defined as changing the soil condition with a tool for the benefit of man. After the land has been cleared and plant debris removed, it is often necessary to subject it to some form of tillage before the crop is planted. Various forms of tillage may be carried out while the crop is growing on the field.

3.2 Purposes of Tillage

Tillage is carried out for one or a combination of the following reasons:

1. seed bed preparation
2. control of weeds
3. incorporation of organic matter into the soil
4. soil and water conservation
5. improvement of the soil's physical condition.

i. Seed bed preparation

Tillage loosens the soil and results in a seed bed suitable for seed germination and development of the young seedlings. A good seed bed should be moist and should not contain large lumps of soil that may prevent close contact between the planted seed and soil particle. It should not contain large quantities of un-decomposed organic matter.

ii. Control of weeds

Often weeds growing on a fallow plot can be controlled by being ploughed under. Ploughing prior to cropping may also serve to kill the weeds present. Tillage between rows of growing crop can be an important method of weed control.

iii. Incorporation of organic matter into the soil

Organic matter and crop residues can be incorporated into the soil through tillage. Once in the soil, they decomposed rapidly thus releasing the nutrients they contain to the growing plants. The incorporation of plant residues in the soil through tillage also serve to improved soil structure.

iv. Soil and water conservation

Tillage often serves the purpose of breaking up the surface layers of the soil so that water is able to infiltrate more rapidly into the soil. This has the dual benefit of increasing the amount of water available in the soil for the crops and decreasing the amount of soil erosion caused by excessive run-off. For these reasons, land that is not to be cropped immediately may even be occasionally ploughed or tilled as a soil and water conservation measure.

v. Improvement of the soil's physical condition

The physical condition of the soil can be improved by tillage. For example, where the surface layers of the soil have formed a hardpan, it may be beneficial to break up the hardpan through tillage so that plants roots can penetrate more deeply and water could percolate into the lower layers of soil more easily.

vi. Increases soil aeration

Tillage opens up the soil, thus improving soil aeration which increases the oxidation of chemical compounds in the soil and make them more soluble and available for the plants roots to absorb. Improved aeration is also beneficial to soil inhabiting organism.

3.3 Historical development of tillage

Tillage began before the earliest written records of mankind. Primitive man uses hand tools made of wood, bone or stone as implements to chop or dig the soil. These simple hand tools were used to destroy the natural vegetation, and reduce competition from native plants and weeds growing among the crops. The next stage of tillage development was the application of power of domestic animals, which occurred in parts of the world before the dawn of history. This made possible development of implement with a steady forward movement. Among these were the crooked-stick plow to stir the soil and the brush drag to pulverise the surface soil. Little further progress was made for many centuries except that eventually some plows were fitted with iron shares. The development of steel in the 19th century resulted in a plow with sharp edges that can cut the soil layer and in a curved polished surface that permitted the plow to scour. The straight line movement of the plow has since been supplemented with rotary movement in such implements as disk plows, harrows, the rotary hoe and various pulverising and stirring tools.

3.4 Types of tillage

Ploughing

Harrowing

Mounding

Ridging

Bed making

Intertillage

Grading and terracing

Minimum tillage.

i. Ploughing

This is one of the most ancient and most universal forms of tillage. A shear, which is pulled along by some power device, slices its way under the soil as it goes along, thereby loosening the soil and turning it over. The soil is left in lumps of various sizes and may require other operations in order to make a suitable seed bed.

Implements used for Ploughing:

Moldboard plough

Disc plough.

ii. Harrowing

Planting may be done on the field after ploughing, but if the lumps of soil left after ploughing are too large, they must be broken up before planting. The conventional way of breaking up soil lumps is through harrowing. There are various kinds of animal-powered and tractor-powered harrows but they all function by breaking up the lumps of soil and leaving an even soil surface.

iii. Mounding

This involves the collection of the soil into more or less conical heaps or mounds. The mounds usually vary in height from 30-100cm, but are usually of approximately the same height on a particular farm. The distance from one mound to the next also varies but it is the distance that determines how much cropping can occur in the lower-lying spaces between the mounds.

Mounding is the most common form of soil collection tillage in tropical Africa and is often associated with intercropping since it simultaneously permits two or more kinds of seed bed on the field; the top of the mounds is used for crops such as tubers which requires a deep layer of loose soil, the low-lying furrows are used for crops that have high requirement for water such as rice while the slopes of the mounds are used for intermediate crops.

Advantages of mounding

1. Providing a deep, loose seed bed which is particularly suitable for the development of roots and tubers.

2. Providing a variety of seed bed types on the same field, which may be advantageous to intercropping.

3. Elevating the seed bed and plant roots above the water table in fields with a high water table.

4. Mounding improves aeration for roots and facilitates the growth and development of underground tuber and root crops and the pods of groundnuts.

5. Mounding makes harvesting of tuber crops and pods of groundnuts easier.

Disadvantages of mounding

1. The major disadvantage of mounding is that it has not been mechanised and would probably be extremely difficult to mechanised.

2. Mounds impede the free movement of men and machinery through the field. For these reasons, mounding is mostly confined to traditional agriculture (with intercropping) to which it is well suited.

iv. Ridging

This involves the collection of soil into elongated heaps called ridges. The distance between the ridges is variable, but is usually about one meter. Growing crops on ridges is quite common in tropical Africa. In the traditional settings, hoes and human labour are used to make ridges, but mechanical ridgers are also available and permit large areas to be ridged in a relatively short time.

Advantages

Ridging have the same advantages as mounding, but in addition ridging is an extremely useful measure for controlling erosion, particularly on sloping land. In such cases, ridging is done along the contour so that the flow of water down the slope is impeded. The water then flows along the furrows between the ridges. In order to further discourage the rapid flow of water within the furrows, cross ridges (also called cross bunds or tie ridges) are made across the furrows at intervals to connect one ridge to the next. Thus, ridging, when properly done, can decrease surface run-off, thereby reducing soil erosion and promoting water infiltration into the soil.

Since it has been completely mechanised, ridging finds a place in modern agriculture, where it is the most common form of soil collection tillage.

v. Bed making

This is a form of land preparation which is more often discovered in horticultural and nursery practices than in field crop production. A bed is like a ridge in that it is elongated raised portion of the field. It is, however, usually much broader than a ridge, its top is flat and its length is usually not more than 20 m. Bed making is most commonly done with hand tools.

vi. Inter-tillage

Inter-tillage is commonly practiced with respect to crops that are planted in rows. It involves tilling the areas between the crop rows. Its objectives are usually to control the weeds between the crop rows and to promote water percolation into the soil.

vii. Grading and terracing

These are two land preparation operations which aim at effecting changes in the gross topography of the field. **Grading** is most commonly done where it is desired to use furrow or some other form of surface irrigation. The land is graded in such a way that the point of water supply is the highest on the field and the field slopes downwards from the water source.

Grading of the crop field is also encouraged where the farmer intends to impound water for the flooding culture of rice or taro. If the land is sloping, it is graded to be relatively level. Elevated areas or dykes are constructed around the field so that the water does not flow away once impounded.

Terracing is one of the methods of managing extremely sloping land for crop production. It creates a series of relatively flat horizontal portions alternating with vertical portions very similar to a flight of stairs. The flat portions are used for cropping. Terracing provides erosion control measures and permit cropping on land that would have otherwise remain useless for cropping,

viii. Minimum tillage

There has been a realisation in recent years that frequent tillage operations tend to impair the soil structure thus exposes the soil to adverse effect of rainfall and strong wind. These observations have led many scientists to develop the concept of minimum tillage. This means that crop production could be carried out with as little tillage or soil disturbance as possible as tillage is seen as a necessary evil which should only be sparingly indulged in.

Advantages of minimum tillage

1. Preserve the soil structure.

2. It is economical, since the labour and cost normally incurred in tillage operations can be saved.

3.5 Tillage Implements

Ploughing implements

Plowing buries green or dried material, loosens the soil so that other implements can operate, removes or delays competition with weeds and roughens the soil surface so as to check runoff of rainfall.

The moldboard plow

Breaks loose or shears off furrows slice by forcing a triple wedge through the soil. This action inverts the soil and breaks it into lumps. Some soil pulverisation takes place.

The disk plows

These are important for use in loose soil but also in those soils too dry and hard for easy penetration of moldboard plows. The disks vary in size from 50 to 75 cm while the depth of plowing may be varied from 10 to 25 cm.

i. Implements for seed bed preparations

Tillage to prepare a seed bed after the land has been plowed is accomplished with harrows, field cultivators or other machines equipped with disks, shovels, teeth, spikes, sweeps, knives, etc.

Harrows

Harrows smoothen and pulverize plowed soil compact it and destroy weeds. The disk harrow cuts, moves, and pulverises the soil and destroys weeds.

The hand hoe

This is still the most common tillage implement among small scale farmers. The spike-tooth harrows breaks soil clods, levels the land, and kills small weeds.

Field cultivator

This implement makes the soil surface rough and cloddy, creating a condition necessary to check wind erosion.

ii. Implement for inter-tillage

Ordinary cultivator

Shovel or sweep cultivators are the types most frequently used for intertillage.

Rotary hoe

This consists of a series of 18-inch (45 cm) hoe wheels each of which is fitted with teeth shaped like fingers. As the wheels rotate these teeth penetrate and stir the soil. This hoe is useful for uprooting small weeds by blind cultivation before the crop grows up as well as early cultivation of young corn and other row crops.

The ordinary spike-tooth harrow

This is used with little injury to the corn, to kill small weeds in corn when the corn plants are still small.

The lister cultivator

This is sometimes equipped with disks or knives, or both and sometimes with disk and shovels. For the first cultivation, the disks are set to cut the weeds on the sides of the furrow, the soil being thrown away from the crop row. The shovels may be set to stir the soil near the plants.

4.0 CONCLUSION

This unit has identified the role of tillage practices in improving the physical properties of the soil, conservation of soil moisture, weed control and enhancing nutrient availability. The unit also considered its role in reducing surface run-off and erosion, pulverisation of the soil to provide fine seed bed and enhanced water percolation, which creates a favourable condition for the growth and development of plant as well as managing the environment.

5.0 SUMMARY

This unit highlights the importance of different types of tillage operations in crop production and the implements used in carrying out each operation. Detailed description of each type of tillage, its advantages and disadvantages were discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. Define the term tillage.
   b. What are the advantages and disadvantages of making a mound in crop production?
2. State five purposes of tillage operations.
   a. Briefly describe any three types of tillage.
   b. State one function of each of the following:
      - Hand hoe
      - Moldboard plough
      - Harrows
      - Cultivators
3. a. What is minimum tillage?
   b. State the advantages of minimum tillage.

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MODULE 2

UNIT 1 SOWING AND PLANTING PRACTICES

CONTENTS

1.0 INTRODUCTION

Seeds and other planting materials are the basic foundation upon which successful crop production is laid. Failure in the choice of correct seeds, seed storage, time of planting, depth of planting, rate of seeding and spacing could all lead to failure in the crop production enterprise.

In this unit all aspects of seeds and planting materials as they relate to quality, germinations, storage of seeds, seed treatments, time of planting, seed rate, depth of planting, seed placement, seed emergence and seedling vigour are treated.

2.0 OBJECTIVES

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

- explain the importance of quality seeds and planting materials in crop production
- identify conditions governing the germination of seeds
- describe seed dormancy and suggest measures to overcome it
- describe a quality seeds and state measures of enhancing seed quality
- explain the various methods of seed treatments.

3.0 MAIN CONTENT

3.1 Definition

The establishment of field crops could either be from seeds or vegetative parts. The terms sowing refers to seeds while planting is used when vegetative parts are involved. The following are examples of crops established by sowing seeds: maize, groundnuts, sorghum, millet, wheat, cowpeas and melon. Crops such as yams, sugarcane, ginger, sisal, cocoyam, sweet potatoes and cassava are normally established by planting vegetative parts.

A seed consist of a miniature plant (the embryo) enclosed in a wrapper (the testa). Sometimes a quantity of nutritive material (the endosperm) may also be enclosed in the wrapper. The embryo represents the new generation of the plant and it is the most essential part of the seed. It consists of a shoot axis (the plumule), a root axis (the radicle) and one or more seed leaves (the cotyledons). In seeds where the endosperm is absent, much of the food materials are stored in the cotyledons. The testa is the outer covering of the seed. It usually encloses the seed entirely except for a minute pore.

3.2 Germination of seeds

The process of germination involves the growth of the miniature plant (embryo) contained within the seed into a larger plant. The main function of the endosperm, where present, is to supply food materials to the growing embryo. The first event that occurs after a seed is sown in a moist soil is that the seed imbibes water. This process causes the seed to swell and also results in the activation of various enzymes systems in the seed. Following the intake of water, the food material present in the seed is hydrolyzed. The products of hydrolysis are then translocated to the growing points, where they are used as building blocks for new cells and as substrates for respiration to supply energy for various processes.

i. Conditions necessary for germination

For seeds to germinate certain environmental conditions must be fulfilled:

1. water must be available so that when it is imbibed by the seed, metabolic processes within the seeds are enhanced

2. oxygen should be present for aerobic respiration to occur so as to supply energy for germination process

3. thirdly, there should be an appropriate temperature.

ii. Types of germination

The morphological changes occurring during germination vary greatly from seed to seed. In some, the cotyledons are carried above ground level due to elongation of the region just below the cotyledons (hypocotyl). Seedlings whose germination occurs in this way are classified as **epigeal germination.** The seedlings of groundnuts, melon, cowpea, onion, okro, and castor are all epigeal. In contrast to epigeal seedlings are those in which the cotyledons remain at the level where the seed was planted and are not carried above ground. Such seedlings exhibit **hypogeal germination.** Rice, maize, guinea corn, rubber and broad bean seedlings are all examples of hypogeal germination.

3.3 Seed Dormancy

When a living seed fails to germinate even when provided with the normal conditions necessary for germination, such a seed is said to be dormant.

i. Causes of seed dormancy

1. Presence of an impermeable testa that may prevent intake of water and probably oxygen.

2. The presence of growth inhibitors in the seed.

3. Alternatively, it may be caused by the need for cold treatment or for exposure to certain photoperiods before the seed can germinate.

4. The embryo is still immature and has not yet reached its full development at the time of harvest.

5. Very high temperatures during seed maturity may induce dormancy in some species.

ii. Measures of overcoming seed dormancy

a. After ripening treatment

One type of primary dormancy is characterised by immature embryos. Although the seeds are shed by the plant, the embryo must continue to develop before germination will occur. Problems of immature embryos will be overcome if the seeds receive appropriate after ripening treatment. Often high temperatures are required for after-ripening of certain palm seed require 38°C to 40°C for three months.

b. Stratification

Seeds of many plants require moist chilling conditions for a period of time to render them capable of germination. This process is called **stratification**. Chilling is usually 0°C- 10°C for 7 to 180 days. For example, apple seeds require up to 60 days in moist medium at 3°C to 5°C to overcome dormancy.

c. Scarification

Seeds of some plant species have a very hard covering that may prevent them from germination unless treated. Hard seed covering can prevent absorption of water and gaseous exchange or may physically prevent the embryo from growing and emerging through the seed coat. It is therefore necessary to make these covering weaker or pervious to water and gases through the process of **scarification.**

d. Light

Is essential for seed germination of certain species of lettuce (positively photoblastic), if light is required seeds should be sown shallowly. Some species such as tomato and some lilies are negatively photoblastic (their germination is inhibited by light) and should be sown more deeply for good germination.

e. Vernalisation of seeds

Temperatures affect the time of flowering in many plants. Winter varieties of cereals crops head normally from spring sowing and behave like spring varieties when the seeds are germinated at temperatures slightly above freezing before they are sown. This process is called **vernalisation**.

iii. Methods of seeds scarifications

a. Seeds can be scarified by soaking them in concentrated sulpuric acid for a period ranging from few minutes to an hour or more.

b. A hot water soak is another method of scarifying seeds, first heating water to boiling point add seeds and remove them when the water is cool 12-24 hours later.

c. Dry heat can be used to rupture seed coats of some species.

d. Mechanical scarifier can be used to scratch the seed coats. When scarified seed deteriorate rapidly, they should be planted immediately.

e. Aging brings about slow natural deterioration of the seed coat in dry storage. In an experiment with alfalfa, one half of the impermeable seeds germinated after one and half years while all germinated after eleven years in storage.

f. Alternate freezing and thawing sometimes stimulates germination of hard seeds of alfalfa and sweet clover.

g. The germination of hard seeds of alfalfa or clover can also be achieved by exposure for 1 to 1.5 seconds or less to infrared rays of 1180 millimicrons wave length or by exposure to a few seconds to high frequency electric energy.

3.4 Seed Quality

The factors affecting seed quality

Factors affecting seed quality includes the following: maturity, wholesomeness, diseases and pests and foreign matter.

a. Maturity

Immature seeds tend to store poorly, and in many instances may fail to germinate. Both the stage of maturity when harvested and the conditions prevailing during maturity are important factors in seed quality.

b. Wholesomeness

Injury, cracking or breakage of the seed would result in reduced germination. The extent to which a seed's ability to germinate is impaired depends on the part of the seed that is injured. Relatively large amounts of injury occurring in the endosperm or at the edges of the cotyledons may impair germination only slightly, while minute injury to the plumule-radicle axis may cause failure of germination. Mechanical injury to seeds may also make them susceptible to diseases and pest and therefore reduces their storability. The market value of broken but otherwise good seed is lower than that of whole seeds. Thus, wholesomeness of seeds is important, whether or not they are to be sown.

c. Diseases and pest

The presence of diseases and pests reduce the quality of seeds both for consumption and for sowing. Diseases impart an unpleasant odour and taste to the seed, while pest may consume the seed and degrade it with excrement. Diseased seeds germinate poorly and pests such as cowpea weevil may damage the seeds and also cause poor germination. Seeds that are to be stored are commonly protected from diseases and pests by treating them with appropriate pesticides. This procedure is referred to as **seed dressing.**

d. Foreign matter

The presence of foreign matter in the seed lot reduces its quality. Inert foreign matter such as stones and dried plant material are objectionable, particularly in seeds destined for consumption. Even more objectionable are weed seeds which may pose grave problems when the seeds are sown. Moreover, weed seeds may promote spoilage of the seed lot during storage.

3.5 Seed Certification

In each country in Africa there is an agency responsible for overseeing and supervising the quality of seeds. In Nigeria that responsibility lies with the National Seed Service. It is the duty of National Seed Service to certify seed that is intended for sowing, using most of the quality criteria discussed earlier in this unit. The activities of the agency include the monitoring of the locations where seeds is produced, grading the seeds, carrying out viability and germination tests, certifying the seeds, and in some cases distributing certified seeds.

Classes of seeds

a. Breeder seeds

This provides the source for the initial and recurring increase of foundation seed. They are directly controlled by the originator or in some cases by the sponsoring plant breeder or institution.

b. Foundation seeds

Foundation seed is the source of all other certified seed classes, either directly or through registered seed. They are handled so as to maintain specific genetic identity and purity as prescribed by the agricultural experimental station.

c. Registered seeds

These are the progeny of foundation or registered seed. It is carefully handled so as to maintain satisfactory genetic identity and purity that has been approved and certified by the certifying agency. This class of seed should be of quality suitable for production of certified seed.

d. Certified seed

This shall be the progeny of foundation, registered or certified seed that is so handled as to maintain satisfactory genetic identity and purity. Such seeds have been approved and certified by the certifying agency.

3.6 Seed Storage

The optimum conditions for storing seeds that would endure long term storage are:

a. drying the seed to 5 -7 per cent moisture content

b. sealed storage in the absence of oxygen

c. a storage temperature of 7.5° to 15°C.

Most seeds stores well in cool dry condition. However, some seed may lose viability rapidly when dry. Within limits, for most species, for each 10 per cent decrease in seed moisture the life of the seed is doubled. Likewise the life of the seeds doubles for each 10°C drop in temperatures. Most seeds can be stored at – 18°C for considerable length of time.

Seeds of some plants including citrus and chestnut should be stored moist under refrigerated condition. Moist chilling condition is necessary to stratify seeds of many woody temperate species which help meet their dormancy requirement.

If stored in relatively small quantities, most seeds should be kept dry in a tightly sealed container.

3.7 Seed Treatments

Both insects and diseases may be seed borne. Disease and pest control by seed treatment is sometimes necessary.

Methods of seed treatment

a. Surface treatment

The organisms causing some seed-borne diseases are on the surface of the seed and may be controlled by chemical treatment e.g. damping off of seedlings. Seed treatment may also protect young seedlings from soil-borne diseases at the time of germination, when they are especially vulnerable. Copper sulphate, formaldehyde and oxide of copper are among the chemicals commonly used.

b. Hot water treatment

When the disease causing organism is found beneath the seed coat, surface application of chemicals may not be effective. Some of these seeds may be treated with hot water for a period of time sufficient to kill the disease without destroying the viability of the seeds.

c. Fumigation

Weevils in beans may be controlled by fumigation with formaldehyde. When seed is not treated, the weevils may develop within the seeds and render them incapable of germination.

d. Pelleted seeds

Even distribution of very small and irregular seeds is often a problem. A pelleting procedure has been developed whereby individual seeds are coated with a material which may contain a fungicide and chemicals to stimulate growth and enclose the seed in spheres of uniform size. Pelleted seeds are much more easily sown at regular intervals and may produce better result.

3.7 Sowing and Planting Practices

i. Time of Sowing or Planting

Several factors influence the time of sowing or planting. They are:

a. rainfall

b. temperature

c. day length

d. occurrence of diseases and pests

e. marketing

f. cropping system

g. availability of labour and equipment.

a. Rainfall

Rainfall or the availability of moisture is one of the principal factors which determine when a crop should be planted. On a seasonal basis, the crop should be planted at a time when there will be enough subsequent rainfall to see it to maturity or full establishment. For this reason, the planting of long season annual crop such as yams must occur at the beginning of the rainy season so that the crop has the entire rainy season available to it for development. For perennials crops such as cassava, cocoa and rubber, planting in the field early in the rainy season is also advisable so that the crop can become established before the dry season sets in.

For short-season annuals such as cowpeas, sweet potatoes and maize, planting may be delayed till later in the rainy season, as long as the crop can complete its growth and development before the onset of the dry season.

Sometimes the intention is to let the maturity period correspond with a rainless period. For example, the sowing of cowpeas or millet is often timed so that the crop matures during a dry period.

Planting should normally be done in moist soil to allow for rapid seed germination or sprouting of the vegetative propagule. For this reason, planting is normally done within a few days after rain.

b. Temperature

Temperature is another climatic factor that influences the time of planting. In the temperate regions, this aspect is crucial, but in the tropics it assumes appreciable importance only at high altitudes, where planting should be done when the soil is warm enough to permit rapid germination. In other parts of the tropics, especially in the drier regions, excessively high temperatures may adversely affect seedling emergence.

c. Day length

Day length or photoperiod is a third factor that may influence the time of planting. The crop should normally be planted at a time that would permit the appropriate photoperiod to exist at the flowering or tubering stage. For example, some okro varieties which require short days for flowering will remain vegetative for most of the rainy season while long day conditions persist. The planting of such varieties could conveniently be delayed so that short-day conditions for flowering exist shortly after the plants are fully established.

d. Occurrence of diseases and pests

The occurrence of diseases and pests may influence the time of planting. The strategy is usually to adjust the time of planting so that the crop is on the field during the time when its diseases and pests are least prevalent. Cowpea production in southern Nigeria, for example, has been strongly influenced by this factor. Cowpeas sown in the early part of the rainy season are bedeviled by numerous diseases and pests but if sowing is delayed until the latter half of the rainy season, the incidence of diseases and pests is less severe and a decent yield can be obtained.

e. Marketing

Marketing consideration may also influence the time of planting. Planting is timed so that harvesting occurs when the crop can command a good market price. This is particularly true of vegetables and other crops which cannot be stored for long.

f. Cropping system

The place of a crop in a rotation or in an intercropping system may determine at what time of the cropping cycle it is planted. For example, many intercroppers in West Africa usually plant their cassava in the latter part of the rainy season after some of the earlier intercrops such as maize; okra and melon have been harvested. The cassava could have been planted earlier, but it is made to wait until the harvesting of the earlier intercrops creates enough space between the yam plants.

g. Availability of labour and equipment

The availability of labour, equipment and processing facilities are other factors that may influence the time of planting.

ii. Methods of Seed Planting

Planting of field crops is generally carried out by any of the following methods of planting:

a. Broadcasting

b. Drilling

c. Precision planting

d. Transplanting.

a. Broadcasting

This is a deliberate random scattering of seeds on the field or prepared seed bed. There is no specific or definite inter or intra-row spacing of crops observed. Crops commonly planted by this method include rice, wheat, sesame and some vegetables.

b. Drilling method

In this method, seeds are placed in shallow furrows created with disc or hoe and then buried. The spacing between plants may not be regulated. Many field crops are planted using this method.

c. Precision planting

Cereal crops such as maize, sorghum and millet are planted with a definite inter and intra row spacing to achieve a precise plant density. This method ensures maximum productivity and high yield of crops.

d. Transplanting

Some crops are first raised in the nursery and later transplanted into the permanent field where they mature and complete their growth cycle. Seeds of tobacco, tomato, pepper, and many vegetables are first raised in the nursery before transferred to the field. Rice and sorghum are also transplanted in some instances. Transplanting has the advantage of reducing wastages of seeds and offers farmers the chance to transplant only healthy and vigorous seedling for best results.

iii. Factors determining the choice of planting methods include the following

a. Seed size

b. Growth habit of the plant

c. Seedbed preparation

d. Climatic condition

e. Labour availability

f. Seed placement in the field.

There are four general aspects to seed placement in the field:

a. the number of seeds sown at each spot stand

b. the spacing between stands

c. the depth to which seeds are placed

d. the position of the seed with respect to the previous tillage operations i.e. whether the seed is sown on the ridge or mound, in the furrow, on the slopes of the ridge, or on the flat.

v. Number of seeds per stand

The number of seeds sown per stand depends on the expected percentage germination of the seed and number of plants desired per stand. The expected percentage germination is ascertained by prior germination tests and if low, the number of seeds sown per stand is commensurately increased. Sometimes the number of seeds sown on each stand is kept deliberately high, so that the number of plants appearing on each stand is higher than the desired number. When the seedlings are well established, the extra plants are removed, leaving just the desired number per stand. This procedure of removing excess emerged seedlings is referred to as **thinning.**

The main advantages of deliberate over-seeding and subsequent thinning are that:

a. it provides the opportunity to select out weak seedlings

b. it ensures the retaining the vigorous ones

c. it ensures that every stand has the correct number of seedlings.

vi. Spacing between stands

The spacing between stands is largely determined by the extent of the root and shoots system of the crop plant in question. The spacing determines the size of the land area available to each plant or stand and the larger the plant the greater the area required for it to performed well. The spacing between the crop rows is usually adjusted to what mechanical planters can cope with.

Sometimes sowing is done by scattering the seeds at random on the field or plot. This method of sowing is referred to as **broadcasting.** Broadcasting is most commonly used to sow small seeds such as rice on the field or vegetable seeds in the nursery. A slightly different method of sowing seed is **drilling** in which the seeds are sown in a continuous band in rows. As such, the space between the rows is fixed and can be determined, but the spacing within the row is indeterminate.

The spacing between stands determines the number of stands per hectare. The number of stands per hectare and the number of plants per stand together determine the plants per hectare, or the plant density.

vii. Depth of sowing seeds

The depth at which the seed is placed in the soil is influenced by:

- seed size
- type of germination
- moisture status of the soil
- soil type.

a. Seed size

The larger the seed, the greater the depth from which it can emerge and the deeper it can be safely sown. This is because large seeds have ample quantities of stored food material for the germination process. As such, they produce vigorous seedlings which have enough stored food for the long time it may take to emerge from great depths. Small seeds, on the other hand, tend to deplete their stored food in a short time.

b. Type of germination

The type of germination exhibited by the seeds of a species influences their ability to emerge from great depths. Seeds with epigeal germination have to push their cotyledons to the surfaced and therefore have limited ability to emerge from great depths.

c. Moisture status of the soil

Under dry condition the seeds should be sown deeper in order to place them in contact with moist soil.

d. Soil type

All other factors being equal, seeds can emerge from greater depths in sandy soil than in clay soil. Sowing depth can therefore be adjusted according to soil texture.

viii. Position of seeds in respect to land preparation

The position at which the seed is sown with respect to land preparation depends on the nature of the crop and climatic factors. Under waterlogged conditions, the seed is normally planted on top of the mound or ridge so that it is removed from the high water table. At the other extreme is the situation in dry land areas where planting the crop in the furrow may ensure greater moisture availability.

ix. Placement of Vegetative Propagules

The principles of seed placement in the field are also generally applicable to the planting of vegetative propagules. Because of the large quantity of food that they usually contain, such propagules are capable of emerging from much greater depths than seeds. As a rule, however, they should not be planted more than 5-10 cm deep in the soil. An additional consideration with respect to vegetative propagules is their orientation. Stem cuttings fail to sprout or perform poorly if planted in an inverted position.

3.9 Seed Emergence and Seedling Vigour

Emergence is the appearance of the seedling above the ground. Even though germination occurs only a few days after planting, the emergence of the seedling above the ground is the first visible assurance to the farmer that germination has occurred and that the seedling is now on its way towards establishing itself.

From the farmers standpoint there are three important aspects of emergence:

a. time from planting to emergence

b. final percentage emergence

c. uniformity of emergence.

The time of emergence should ideally be as short as possible, so that the seedling can attain independent existence before the seed reserves have been depleted.

i. Factors influencing seed emergence

- Temperature
- The time to germination
- The sowing depth
- The nature of the soil, and the
- Vigour of the seedling.

Time to emergence is usually short if germination is rapid, the temperature is moderate, sowing depth is shallow, seedling is vigorous and the soil is light, loose and free of crust.

The final percentage emergence is the percentage of seeds sown that eventually emerge. It is this percentage that determines the nature of the stand obtained. If the percentage is low, the stand is poor and irregular and the farmer may consider replanting.

ii. Causes of poor emergence

- Poor germination
- Very low seedling vigour
- Sowing at too great a depth
- Attack of diseases and pests

- Extremes of temperature which may severely retard the growth of seedlings.

iii. The uniformity of emergence

This indicates whether all the seedlings that emerged did so simultaneously (i.e. on the same day) or whether there was a long period between the early emergers and the late emergers.

Importance of uniform emergence

- It ensures that all the plants on the field are at approximately the same age.

- Operations such as fertilising and harvesting which depend on timing can be programmed.

Factors affecting uniformity of emergence

- Uniformity of germination, non-uniform germination will usually result in non-uniform emergence.

- The use of dormant seed can also result in non-uniform germination and emergence.

iv. Seedling Vigour

The seedling vigour assessment is an indication of the health of the seedlings and of the likelihood that they will yield well.

Factors that may lower seedling vigour include the following:

- small seed size
- the presence of pathogens in the seed or in the soil
- protracted storage of the seed
- adverse environmental condition during germination.

4.0 CONCLUSION

The vital role of planting only quality seeds and planting materials in obtaining high yield cannot be over emphasised. Seeds germination, emergence, and vigour depends on using seeds and planting materials of superior quality as well as appropriate cultural practices such as seed dressing with appropriate chemicals, time of planting, depth of planting, rate of seeding, spacing and position of seeds and propagules in relation to land preparation practices.

5.0 SUMMARY

The quality of seeds and planting materials plays a significant role in successful crop production enterprises. The various methods of overcoming seed dormancy and of enhancing seed germination are treated. Depth of seeding, time of planting, spacing of plants and other parameters that could ensure seed emergence and seedling vigour are covered.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. State the conditions necessary for seed germination.
   b. Differentiate between epigeal and hypogeal types of germination.
2. a. State the causes of seed dormancy.
   b. Mention the measures of overcoming seed dormancy.
3. a. What are the factors influencing seed quality?
   b. Mention the seed treatments that enhance seed quality.
4. a. What are the factors influencing time of planting?
   b. State the conditions influencing depth of planting.

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UNIT 2 SOIL AND WATER CONSERVATION

CONTENTS

1.0 INTRODUCTION

Soil not only provides anchorage to plants but all nutrients and water are absorbed into the plants through the soil. Therefore, all cultural practices in crop production are directed toward improvement and maintenance of the physical condition of the soil so as to create a favourable condition for the growth and development of crop plants. Water is indispensable for growth and development of plants, too much or too little water, decide between success and failure of crop production enterprise. In this unit you would treat the different methods of soil and water conservation.

2.0 OBJECTIVES

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

- describe the principles of soil water conservation
- describe the various methods used in oil and water conservation
- discuss the role of tillage practices in soil conservation
- describe the methods of soil conservation and state merits and demerit of each method of soil conservation.

3.0 MAIN CONTENT

3.1 Principles of Soil Water Conservation

The principle of soil water conservation is basically that of reducing run-off, percolation and evaporation losses. Essentially, water management entails three basic practices:

1. conservation of natural precipitation (in sub humid and arid regions)

2. drainage of wet lands

3. supplementation of rainfall with irrigation.

3.2 Methods of Water Conservation

Water generally is a limiting factor for crop production where irrigation is not available. It can be limiting even in humid and sub-humid regions where there is a theoretical need to dispose of excess water. Dry periods with water deficit frequently occur in these regions and positive responses to moisture conservation techniques are commonly obtained. Over 80% of the agricultural land of the world is not irrigated. In Africa, where a little over 0.3% of the land is under irrigation (FAO 1987), rain fed agriculture prevails. In rain fed systems the constraint is not only the erratic rainfall distribution but the amount of rainfall that can be stored in the root zone.

i. Mulches and green manures

Mulch may be defined as a protective covering over the soil surface that is intended to minimise evaporation losses. Green manures may serve as mulches. Leaves, straw and saw dust are also commonly used. Paper and plastics may also be used.

Importance of mulch

- ⇨ Mulch intercepts solar radiation, reflects the light and so keeps the soil temperature low.
- ⇨ It reduces the effect of wind and air movement.
- ⇨ The presence of mulch on the surface of the soil improves infiltration because they reduce the impact of raindrops.
- ⇨ Reduces run-off losses.

ii. Run-off control

Run-off occurs when rainfall intensity exceeds the infiltration capacity of the soil which is a measure of the ability of the soil to absorb and transmit rain water. Run-off is limited on soils with a high infiltration capacity. This in turn depends on the water transmission characteristics and structural stability of the soil and its ability to maintain continuous pores. The transmission pores may exist in the soil as a result of coarse texture, good aggregation, or from the burrowing activities of the soil fauna, particularly certain species of earthworms. The rate and amount of run-off are also influenced by the intensity and amount of rainfall received, the previous soil moisture content, the degree of relief, slope steepness and aspect. These factors manifest themselves in a wide range of run-off management problems and conservation needs.

Ways of minimising run-off

- Careful and rational management of crop residues
- Fallowing
- Terraces and contouring
- Strip cropping and ridging.

iii. Fallowing

This is one of the most effective water conservation techniques particularly in areas of limited rainfall. It is the practice of leaving the land unplanted in alternate years or cropping the land for three years and then fallowing for the next few years. In general, the moisture saved in this way is small but it may be critical in dry-land farming.

iv. Terraces and contouring

These are methods of minimising the loss of surface water which may occur when water gushes down slopes after intense rainfall or excessive irrigation.

v. Contour farming

This is the practice of cultivating and planting on strips of land that are of the same elevation. The system of gently sloping terraces separated from each other by banks helps to hold water on the soil surface and so encourage infiltration. In preventing run-off, contour farming and terraces also reduces soil erosion which will remove valuable nutrients from the topsoil.

vi. Strip cropping

Spreading vegetation or crops are established in a strip which is at right angles to the flow of water or the prevailing wind. This gives protection to adjacent strip or rows of crops or fallow land.

i. Field strip cropping: Crops are grown in strips across the general slope of the land but not following the contour. Spreading crops or grass may be alternated with more upright crops.

ii. Contour strip cropping: Crops are grown in relatively narrow strips which are planted on the contour and at right angles to the natural direction of the slope. Crops are usually planted in strips of grass.

iii. Wind strip cropping: Crop strip are planted which are at right angle to the prevailing winds irrespective of the contour of land. The crops serve as series of miniature windbreaks to minimise wind damage.

vii. Ridging

Ridges help surface drainage during rains and prevent young plants from being washed away. Ridges are formed by pilling up top soil so the depth of soil for plant roots to grow is increased.

3.2 Agronomic Measures to Control Soil Erosion

Soil management practices are based on the following broad principles:

⇨ those practices which help maintain soil infiltration rates at sufficiently moderate levels to reduce run-off to a safe amount

⇨ those practices which help the safe disposal of run-off water from the field.

Cultural practices which help maintain a high soil infiltration rate are essentially based on agronomic measures which maintain a mulch or vegetation cover on the soil, such as no-tillage or minimum tillage, stubble mulching, or the use of cover crops.

i. Tillage practices

Beneficial Effects of Tillage

i. Increased infiltration of rainfall.

ii. Reduced surface run-off.

iii. The no-tillage system has the advantage of moisture conservation in the soil profile and decreasing run-off and soil loss to a minimum.

iv. In the no-tillage system the organic matter content of the surface horizon is also better maintained, as it is the water holding capacity of the soil.

Contour cultivation is to be generally recommended as one of the simplest and cheapest conservation measures.

Surface plant residues very effectively control erosion.

Tied-ridging is another effective practice in controlling erosion. This involves growing crops on ridges made approximately on the contour, adjacent ridges being joined at regular intervals, usually of 1.5 – 3.5 m by barriers or ties slightly slopes with permeable soil of adequate depth in areas not subjected to high-intensity rainstorms, the series of basins so formed can hold the rainfall where it falls, allowing it to infiltrate into the soil and preventing run-off.

Minimum tillage

Repeated ploughing and harrowing may break down the structure of some soils to such an extent that infiltration is drastically reduced. In most cases, this leads to an increase in soil erosion and decline in crop yields.

iii. Mulching

Beneficial effects of mulching

i. Mulching with cut grass or other vegetable refuse prevents surface sealing by avoiding direct raindrops impact on the soil, and by encouraging enhanced biological activity which leads to the development of macro pores in the soil.

ii. It is very effective in reducing run-off and erosion since it protect the ground from the impact of rains, slows down the movement of water over the surface, and improves the permeability of the soil.

Stubble mulching has similar effects to ordinary mulching. In this system, all or part of the crop residues and weeds is left on the surface of the soil as protective cover. This system involves shallow ploughing of the land after harvest, either leaving the stubble and weeds on the surface or partially burying them. The greater the quantity of stubble and weeds left on a unit of land, the greater the effectiveness of the practice in reducing run-off and soil erosion.

iv. Crop rotation

Growing wide-spaced row-tilled crops such as sorghum, maize, cotton, and sugarcane continuously for a few years makes the soil susceptible to erosion. On the other hand, growing grasses or legumes protect the soil from erosion because these provide a complete ground cover while they are growing and also improve the soil structure and permeability. To check or minimise the loss of soil it is therefore advisable to have close-spaced cereal crops such as wheat or finger millet and grasses or legumes, or grass-legumes mixtures in the rotation.

v. Strip cropping

The purpose of strip cropping is the same as that of crop rotation, i.e. to minimise the loss of soil. In strip cropping, strips of erosion permitting crops are separated by strips of close-growing protective crops, in such a way that there are successive strips of wide-spaced, row-tilled crop such as sorghum or maize; a dense untilled crop, such as grasses or legumes and close-spaced crop receiving little or no cultivation after planting, such as finger millet. In succeeding seasons, these strips are rotated.

vi. Cover crops

For effective erosion control, proper land use is imperative. The steepest slopes that are unsuitable for cultivation may be left under forest or permanent pastures; less steep land may be used for highly protective tree crops that provide a full canopy of foliage, such as cocoa, gentler slope may be planted with less protective tree crops such as coffee or citrus and grasses and arable crops may be planted on the gentlest slope.

These crops not only provide a protective cover, but also enhance rainfall infiltration by means of improving the organic matter content of the soil.

vii. Soil conditioning

in order to prevent the breakdown of soil aggregates due to raindrop impact, their aggregate stability musty be improved. Soil conditioning with bitumen emulsion, polyurethane, latex, asphalt, etc. minimises aggregate destruction and helping to preserve a high infiltration capacity. Soil conditioners may be applied by incorporation or surface treatment.

viii. Management

Crops and management practices which help produce an early ground cover are certainly more useful in controlling run-off and erosion than those which take longer for full canopy cover to develop. Practices such as mixed cropping also affect ground cover. Soil erosion and run-off losses are relatively less from mixed crops than from sole crops. Plant population, time of planting and fertility level are important cultural practices which could be used to control erosion.

3.4 Measures to Control Wind Erosion

The measures aim principally at:

- ⇨ maintaining more moisture in the soil
- ⇨ increasing surface roughness
- ⇨ reducing wind velocity.

To achieve these aims above, the following practices should be encouraged:

- ⇨ minimum tillage
- ⇨ ridging at the right angles to the direction of prevailing wind
- ⇨ early planting
- ⇨ cropping in alternate strips
- ⇨ mulching and stubble mulching
- ⇨ planting of windbreaks at intervals across the path of the wind to slow its velocity and to cause the deposition of soil particles already in movement.

4.0 CONCLUSION

Soil and water conservation is an integral part of sustainable crop production process. This unit emphasises the various cultural practices such as tillage, cover cropping, crop rotation, strip cropping, mulching, terracing and contouring, ridging, and fallowing which if judiciously implemented could reduce surface run-off and erosion, increase water percolations, reduce evaporations and ensures adequate drainage.

5.0 SUMMARY

In this unit, the basic principles of soil water conservation measures of reducing run-off, percolation and evaporation losses were treated. The various management practices of water conservation i.e. conservation of natural precipitation, drainage of wet lands and supplementation of rainfall with irrigation were discussed.

The role of cultural practices such as tillage practices, strip cropping, crop rotation, cover cropping and mulching in control of surface run-off and erosion were discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly describe measures of checking surface run-off.
2. Discuss the various cultural practices of soil conservation.
3. Describe the measures of controlling wind erosion.
4. Enumerate the role of mulch in soil and water conservation.
5. Explain the importance of the following in soil and water conservation:
    a. crop rotation
    b. cover crops.

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UNIT 3 IRRIGATION AND DRAINAGE

CONTENTS

1.0 INTRODUCTION

The pressure for survival and the need for additional food supplies to meet the demands of increasing populations are necessitating a rapid expansion of irrigation throughout the world. Irrigation is not only important for the arid regions but is becoming equally important in the humid regions. Although irrigation is very important and is becoming a basic part of well-developed agriculture throughout the world, it also has its negative sides. Irrigation can convert agriculturally productive land into waterlogged land and create problem of salinity. The successful cultivation of crops largely depends upon adequate drainage of the land in which they are grown.

This unit treats all aspects of irrigation and drainage i.e. methods of irrigation and drainage, the advantages and disadvantages of each method are discussed. The suitability of each method in terms of crops to be grown and topography of the land is also treated.

2.0 OBJECTIVES

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

- define irrigation and drainage
- state the objectives of irrigation and drainage
- describe the various methods of irrigation and drainage
- state the advantages and disadvantages of each method of irrigation and drainage.

3.0 MAIN CONTENT

3.1 Definitions

Irrigation

Irrigation is generally defined as the artificial application of water to the soil for the purpose of supplying the moisture essential for plant growth. Irrigation water is supplied to supplement the water available from rainfall.

Important terms and definitions

i. Water requirement

The water requirement (WR) of a crop may be defined as the quantity of water, regardless of its source, required by a crop in a given period for its normal growth and development under field conditions at a specific place. Water requirement includes the losses due to evapo-transpiration (ET) or consumptive use (CU) plus the losses during the application of irrigation water and the amount required for special operations such as land preparation, transplanting, leaching, etc. it may thus be formulated as follows: WR = ET or CU + application losses + special needs.

ii. Irrigation requirement

The field irrigation requirement (IR) of a crop, therefore, refers to the water requirement of the crop, excluding effective rainfall and the contribution from soil profile, and may be formulated as: IR =WR – (ER+S).

A farm irrigation requirement depends on the irrigation needs of the individual crops, their area and losses in the farm water distribution systems, mainly by seepage.

iii. Net irrigation requirement

This is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity. Thus it is the difference between field capacity and the soil moisture content in the root zone before starting irrigation.

iv. Gross irrigation requirement

This is the total amount of water applied through irrigation. In other words, it is the net irrigation requirement plus losses in water application and other losses. Gross irrigation requirement can be determined for a field, a farm, an outlet command area, or an irrigation project, depending on the need, by considering the appropriate losses at various stages of the crop growth.

Gross irrigation requirement in field = net irrigation requirement divided by irrigation efficiency. For example, if the net amount of irrigation is 10 cm and the irrigation efficiency is 70%, the gross amount of water to be applied to the field is 10 cm divided by 0.70 = 14.29 cm.

v. Irrigation efficiency

Irrigation efficiency is a measure of the amount of water delivered by irrigation that actually ends up as available water to the plant. To illustrate the point, let us assume a rooting depth of 1.5 m. ideally, the soil should be wetted evenly down to a depth of at least 4 m. In practice this is rarely attained. Irrigation efficiency is a measure of how close the water delivery system comes to achieving this ideal situation. It gives a measure of the amount of water effectively delivered to a farm and varies from soil to soil. The ratio between water requirement and irrigation requirement is a measure of irrigation efficiency. It indicates how efficiently the available water supply is being used.

Factors influencing irrigation efficiency

- The principal factors influencing irrigation efficiency are the design of the irrigation system

- The degree of land preparation

- And the skills and care of the irrigator.

Water is lost from the distribution system in several ways, by evaporation, unwanted wetting of banks of delivery ditches, deep percolation, seepage and run-off. In sprinkler system, for example, the tendency for high evaporation reduces irrigation efficiency. Any factor which causes loss of water will also reduce irrigation efficiency.

Ways of minimising the loss of irrigation water

- These losses can be minimised by adequate planning of the irrigation system
- Proper design of the irrigation method
- Proper land preparation
- Efficient operation of the system.

vi. Irrigation frequency

This refers to the number of days between any two subsequent irrigations during periods without rainfall. It depends on the consumptive use rate of a crop and the amount of available moisture in the crop root zone. It is a function of crop, soil and climate. Sandy soils are irrigated more often than fine-textured soils. Moisture use rate increases as the crop grows and the days become longer and hotter. In general, irrigation should start when about 50% of the available moisture has been used from the zone in which most of the roots are concentrated. A record of the growth stages of the crop with reference to the critical periods of growth is also kept with a view to determining the frequency of irrigation.

vii. Irrigation scheduling

The number and timing of irrigation vary widely for different crops. Earlier concept for scheduling were based on the soil water regime in which the water content at field capacity (the upper limit of the regime) was considered as 100% available for crop growth, and that at the permanent wilting point as 0% available. About 50% available water was accepted as the lower limit of the regime and it was taken as a criterion for scheduling irrigation. Later on it was realised that climatic parameters play a predominant role in governing the water needs of crops. This leads to the concept of evapo-transpiration, which has been used as the criterion for timing irrigations. The latest approach for scheduling irrigation is the plant water status itself. This may be considered as an ideal criterion as the plant is a good integrator of soil, water and climatic factors.

3.2 Crops Response to Moisture Level at Different Stages of Growth

It has been found that the water requirements of a crop vary with the different stages of its growth. When water is in abundance, irrigation can be given whenever needed, but when the water supply is limited, it is necessary to take into account the critical stages of crop growth with respect to moisture. The **term critical stage** is commonly used to define the stage of growth when plants are most sensitive to water shortage. Each crop has certain critical stages at which, if there is a shortage of moisture, yield is reduced drastically. Therefore, when there is a shortage of water, it is better to take care of the critical stages first to obtain increased water use efficiency.

Table 3.1: Critical Stages of Crop Growth in Relation to Moisture Availability

Crop	Critical periods
Wheat	Crown root initiation, heading, flowering, and grain formation
Rice	Tillering, heading and flowering
Maize	Early vegetative stage, Flowering, and milk ripe stage, i.e. tassel ling to hard- dough stages
Sorghum	Seedling, Booting to heading stage
Groundnuts	Flowering and pod development
Cotton	Start of flowering and during boll development

Source: (Onwueme, I.C. and Sinha, T. D. 1999)

3.3 Irrigation Methods

Irrigation methods vary in different parts of the world and on different farms in the same area because of differences in soil, topography, water supply, crops and customs. There are four methods of irrigation:

- surface irrigation (flooding, check basin method, border strip method, furrow method and corrugated method)
- overhead irrigation (sprinkler irrigation)
- sub-surface irrigation
- drip irrigation.

3.3.1 Surface irrigation

In the surface irrigation method, water is applied directly to the soil surface from a channel located at the upper reach of the field. Highly efficient irrigation can be achieved in surface methods by an appropriate combination of the size of the irrigation stream, the size, shape and slope of the irrigation bed, the infiltration rate of the soil and plant population.

Surface irrigation could be made more efficient by observing the following

- The water distribution system should be properly constructed to provide adequate control of water to the fields.

- The land should be well prepared to permit the uniform distribution of water over the fields.

- Fine textured soils with low infiltration rate require smaller streams to avoid excessive losses due to run-off at the downstream end and deep percolation at the lower reaches.

- Coarse-textured soils with high infiltration rates require larger streams to spread over the entire strip rapidly and avoid excessive losses due to percolation at the upper ridges.

Advantages of surface irrigation

1. **Adaptability**: Surface irrigation can be used on nearly all types of soil and crops. The system can be designed to accommodate a wide range of stream sizes and still maintain high water application efficiency.

2. **Flexibility**: Surface irrigation systems permit ample latitude to meet emergencies. The capacity of surface system is efficient to permit an entire farm to be irrigated in a small time period.

3. **Economy**: It is usually inexpensive to operate because of low power requirements. Water is usually applied directly to the farmland by gravity flow from the irrigation projects canals and laterals. Where water is pumped from wells, rivers, storage reservoirs or other sources of supply, only enough power to raise the water slightly above the land surface to be irrigated is needed.

3.3.2 Types of Surface Irrigation Systems

Surface irrigation systems may be grouped into two broad classifications:

i. **Complete flooding** of the soil surface which includes flooding from field ditches, flooding strips between border dikes, and flooding in basins or checks. In this method the entire land surface in the area being irrigated is covered with water.

ii. **Partial flooding or furrow method** where the entire irrigated area is only partially flooded. Closely spaced furrows (small ditches) contain and distribute the water which moves both laterally and downward from the furrow to moisten the plant root zone.

Flooding method of irrigation is most suitable for

- Land having such regular surfaces that the other surface irrigation methods are impractical.

- Areas where irrigation water is abundant and inexpensive.

- Crops such as rice which require standing water during most parts of their growing season.

3.3.3 Complete Flooding Systems of Irrigation

i Check basin method

This is the simplest and most common method of irrigation. It consists of applying irrigation water to the level areas enclosed by ridges. Fairly level fields are well graded and then divided by ridges into rectangular or square basins of 3 x 2 m to 30 x 30 m, so that each has a nearly level surface. The size of the basin depends on the soil type and head of stream available. The water is retained in the basins and then slowly percolates into the soil.

When irrigating orchards, square basins may be used as for other crops, but when the plants are widely spaced, the ring method of basin irrigation may be used. The rings are circular basins formed around each tree.

Advantage of Check basin method

- An advantage of the ring method is that the entire area is not flooded, thus obtaining high water use efficiency.

Suitability of Check basin method

- Check basin irrigation is suited to smooth, gentle and uniform land slopes and for soils with moderate to slow infiltration rates.

- The method is especially well suited to irrigating grain and fodder crops in heavy soils where water is absorbed very slowly and is required to stand for a relatively long time to ensure adequate irrigation.

ii. Border strip method

The well leveled and graded land is divided into a number of long parallel strips called borders that are separated by low ridges. Each border strip should be level and should have a uniform gentle slope in the direction of water flow. Each border is irrigated by allowing the water to flow from the upper end of the border in a thin sheet. The water moves towards the lower end with a non-corrosive velocity and covers the entire width of the border. When the advancing water reaches the lower end, the stream is turned to the second strip. The water temporarily stored in the border moves down the strip and infiltrates the soil, thus completing the irrigation.

Suitability of Border strip method

- This method of irrigation is more suitable for soils with moderately low to moderately high infiltration rates.

- This method is suitable for irrigating close-growing crops such as wheat, barley and fodder crops.

- It’s not suitable for rice which requires standing water during the greater part of the growing season.

3.3.4 Partial Flooding Methods

i. Furrow method

With furrow irrigation, small channels or furrows are used to convey the water over the soil surface in small individual parallel streams. Infiltration occurs through the sides and bottom of the furrow containing water. From the point of infiltration, the water moves both laterally and vertically downward to moisten the plant root zone. The degree of flooding of the land surface depends on the shape, size and spacing of the furrows, the land slope and hydraulic roughness of the furrow. Furrows are made between the crops rows and the crops are grown on the ridges. With furrow irrigation it is difficult to prevent some erosion. On steep slopes, the furrows should be laid out on the contour, i.e. across the slopes.

Suitability of Furrow method

- Nearly all row crops such as maize, sorghum, groundnuts, cotton, tobacco, potatoes and sugar cane are irrigated by the furrow method.

- Furrow method is suitable for most soils except sandy soils that have a very high infiltration rate and provide poor lateral distribution of water between the furrows.

ii. Corrugation method

This is a partial flooding method, as the water does not cover the entire field surface. The stream of water is guided to flow through small furrows called corrugations evenly spaced across the field. The water spread laterally, saturating the area between the corrugations. The main difference between this and regular furrow irrigation is that more but smaller furrows are used and the crop rows are not necessarily related to the irrigation furrows. The corrugations are made after sowing but before germination have taken place. The corrugations are U-shaped or V-shaped channels (furrows) of about 6-10 cm deep, spaced 50- 150 cm apart, running down the slope from field ditches, or preferably from portable gated pipes made of aluminium or hosepipes, in either case with outlet tubes. The length of the corrugations varies from 40 to 120 m and slope is usually 2- 6%.

The entire soil surface is wetted slowly by the capillary movement of the water which flows in the corrugation.

Advantages of Corrugation method

- This method of wetting the soil minimises the crusting effect on the surface soil, which may be a problem when the entire surface is flooded.

- The movable pipes make the method more efficient.

- The advantage of this method is that it makes it possible to irrigate on relatively steep slopes without causing erosion.

Suitability of Corrugation method

- This method is suited to close-growing crops and for pasture growing on steep slopes.

- It's most suitable for fine - to moderately coarse-textured soils.

- It is not recommended for saline soils or when the irrigation water has a high salt content.

Disadvantages

- The method is very conducive to increasing salinity.

- This method has a high requirement as each field must be corrugated at least once every year.

- Field operation is difficult due to rough surface.

3.3.5 Overhead Irrigation

Sprinkler irrigation

In this method, the irrigation water is applied to the crop above the ground surface in the form of spray. A sprinkler irrigation system consists of a pump to develop the desired operating pressure and main lines, laterals and risers to convey the water. Sprinkler head or nozzles discharge the water in the form of spray. For sprinkler irrigation, the water must be clean and free of sand, debris and large amounts of dissolved salts and a stable supply of water must always be available.

Factors to consider when selecting a sprinkler

- The sprinkler should have a capacity to meet the water requirements of the crop.

- Should apply water at a rate that does not exceed the minimum intake rate of the soil.

- The sprinkler should be able to apply water with some minimum economic uniformity.

- Should minimise the total annual cost of irrigation.

- Produce a crop that economically justifies the use of the system.

Types of sprinkler system

1. Rotating sprinkler heads are spaced equally along the lateral lines. The lateral lines remain in one place until required amount of water has been applied and are moved the same distance for each successive setting.

2. Perforated pipes: water is pumped through very small, closely spaced orifices in the pipe. These perforated pipes form the lateral lines and provide fairly uniform distribution along both sides of the pipe.

Suitability of sprinkler system

1. Sprinkler irrigation is both technically and economically very suitable for terrain that is too uneven for surface irrigation, as well as for sandy soils.

2. This method can be used for nearly all crops except rice and jute.

3. It is not suitable for heavy clay soils where the infiltration rate is very low.

Advantages of sprinkler system

i. Soluble fertilisers, herbicides and fungicides can be applied to the irrigation water economically.

ii. It is used to protect crops against frost or high temperatures that reduce the quality and quantity of the produce.

iii. Water application can be more uniform and carried out with greater precision with sprinkler system than with surface irrigation, except during times of high wind.

iv. Water use efficiency is also greater with sprinkler irrigation.

v. Sprinkler during the hot hours of the day may improve the micro-climate, prevent transient wilting, and increase stomatal opening and thereby improving the photosynthetic effectiveness.

vi. The elimination of the field ditches required for surface irrigation increases the net area available for crop production and reduces water losses to seepage and percolation.

vii. This method does not interfere with the movement of farm machinery

Disadvantage of sprinkler system

i. The capital investment for equipment is relatively high.

ii. Water loss due to evaporation and the interception of water by the foliage is greater with sprinklers than with surface irrigation method.

iii. It is not well suited to very windy areas.

3.3.6 Subsurface Irrigation

In subsurface irrigation, water is applied below the ground surface by maintaining an artificial water table at a predetermined depth, depending upon the soil texture and rooting depth of the plant roots. Water reaches the plant roots through capillary action. Water may be introduced either through correctly spaced open ditches in field or underground pipelines such as tile drains or mole drains. The depth of open ditches or trenches varies from 30- 100 cm and they are spaced about 15- 30 m apart. The water application system consists of field supply channels, ditches or trenches suitably spaced to cover the field adequately and drainage ditches for the disposal of excess water.

Types of subsurface irrigation

1. **Open ditches system**. It is most widely used sub-surface system. Feeder ditches are excavated on the contour and spaced close enough to ensure control of water table. They are connected to a supply ditch that runs down the predominant field slope and has control structure as needed to maintain the desired water level in the feeder ditches. The lower ends are connected by an outlet tile which is used to carry excess irrigation water and storm water to a satisfactory outlet.

2. **Perforated tubes. (Drip irrigation).** The perforated tube is buried 4” – 8” under the ground depending on the type of crop to be grown. It is generally used for row crops especially cotton. Water is pumped through these tubes under a low pressure and it oozes out through the numerous tiny holes to supply the roots. At this slow rate of application, water percolates immediately downwards and sideways into the soil.

Advantages of drip irrigation

i. There is considerable saving in water by adopting this method since the water can be applied almost precisely to the root zone and there is no need to wet the entire area between the crops.

ii. It permits the application of fertiliser through the system.

iii. It minimises such conventional losses as deep percolation, run-off and soil water evaporation.

iv. The system has a greater advantage over other sub-surface irrigation systems because it is easily laid down and can be removed at any time after the crop has been harvested.

Suitability of subsurface irrigation method

- This method can be used for most soils with a low water-holding capacity and a high infiltration rate.

- Subsurface irrigation is suited to soils having reasonably uniform texture and permeable enough for water to move rapidly both horizontally and vertically within and for some distance below the crop's root zone.

- This method is suited to irrigating vegetables, most field crops, small grains, pasture grass, most forage crops and flowers.

Advantages of subsurface irrigation

i. Effective on soils having low water holding capacity and high intake rates where other methods are impracticable due to labour, equipment and water costs.

ii. Dispersion of weed seeds is reduced, thus reducing weed control costs.

iii. Evaporative loss of water from land surface is minimal.

iv. Special tillage and frequent land preparation for conveying surface water is eliminated, thus less damage to soil structure.

v. The amount of water for irrigation can be controlled and even distribution is possible.

vi. Normal farm operations can be carried out without interference or major alteration of the lay-out.

Disadvantages of subsurface irrigation

i. Subsurface irrigation tends to cause salt accumulation in the root zone.

ii. Requires a more complex combination of physical conditions not readily found in nature.

iii. Drainage and leaching practices must be more intensive to assure adequate salinity control.

iv. It is expensive and should be used only for high-value crops.

3.4 Water Management in Irrigation Scheme

The important aspects of a comprehensive irrigation development programme are:

- integrated development of water resources
- efficient method of conveyance and distribution of water
- judicious methods of water application
- proper soil management practices
- cropping pattern for high water-use efficiency
- proper timing of irrigation based on the development stages of the plant
- removal of excess water.

i. Integrated development of water resources

Watershed management and harvesting are important aspects of water resources development programme. Loss of water by seepage and evaporation from farm tanks can be minimised by lining and covering reservoirs with plastic, artificial rubber or chemical.

ii. Efficient methods of conveyance and distribution of water

For efficient water use, irrigation channels should be stable, have negligible scour and negligible deposition of sediments. To achieve this, irrigation channels and canals are lined with suitable materials which include concrete, rock masonry, brick, bentonite-earth mixtures, natural clays of low permeability, and various rubber, plastic and asphalt compound. If canals and channels are not lined, or not properly lined, weeds and willows will grow on the canal banks, and moss and other aquatic plants will grow in the canals. These greatly retard water velocity and so decrease canal capacity. Silt and clay sedimentation in canal also restrict water flow.

iii. Judicious methods of water application

Whatever the method of irrigation, the essential requirement in water use is the application of right amount of water and its uniform distribution in the field so as to wet the root zone to its storage capacity. Excessive depth of application would result in low efficiency.

iv. Proper soil management practices

Soil management practices which relates to irrigation are land grading, land preparation and cultivation practices. These aim at obtaining a uniform distribution of irrigation water on the farm, storing large amounts of rainwater within the root zone, and improving the soil structure for increased water availability.

v. Cropping pattern for high water-use efficiency

An efficient cropping pattern must ensure the most efficient use of land, fertiliser, irrigation water and other inputs. In the cropping pattern, the selection of crops and varieties is most important. A crop or variety should be short-duration, photo-insensitive, have a low water requirement, be fertiliser-responsive and high yielding, all of which may enable the farmer to increase the intensity of cropping and thus raise the production per unit input.

Proper timing of irrigation based on the development stages of the plant.

To raise a good crop of rice about 2000mm of water is required. Of this 1500mm is lost by percolation during land preparation. This huge loss can be prevented and the water used during the growing period of rice. The loss of water through percolation can be minimised by the incorporation of a small quantity of bentonite in the top 25 cm of soil.

vi. Removal of excess water

A large mass of land is water-logged due to seepage from canals. There should be a proper drainage programme to drain out excess water either into the canal or to a distant place to be used as irrigation water, but with proper salinity-checking devices.

3.5 Drainage

Drainage may be defined as the means by which soil and subsoil -water is controlled in, and removed from, the root zone in relation to the health and vigour of the crop. A soil may need artificial drainage because the water table is high or because of excess surface water. In both cases, all the pore spaces are filled with water and aeration is poor. The result is reduced root development and possibly an accumulation or concentration of ions such as manganese.

The major sources of excess water that make drainage necessary are:

- seepage losses from reservoirs or canals
- deep percolation loss from irrigated lands
- flooding of low lands
- flow of groundwater towards waterlogged lands in the arid region.

Aims of drainage

The basic aim of field drainage is to assist land to get rid of water from the upper layers of the soil in a manner that will maintain the conditions which provide aeration, warmth and adequate moisture within the root zone of the crop. The adequate drainage of crop-producing lands requires a general lowering of shallow water tables.

Ways of lowering the water table include:

- eliminating or controlling sources of excess water
- improving natural drainage facilities
- providing man-made artificial drainage systems such as open channel drains, covered clay or concrete pipes pumping ground water.

Benefits of drainage

- Draining cultivatable land promotes a number of environmental conditions in the soil that are favourable to higher plants and the micro flora and fauna.

- It improves soil aggregation or granulation and thus encourages aeration, better plant root development, biological activity and nutrient uptake.

- Providing more available soil moisture and plant food by increasing the depth of the root zone soil.

- It decreases losses of soil nitrogen due to denitrification.

- Decreasing soil erosion by increasing water infiltration into soils.

- Leaching excess salts from the soil.

- Assuring higher soil temperatures.

3.5.1 Drainage Systems

There are two main types of drainage systems:

- surface

- subsurface drainage.

1. Surface drainage

Surface drainage involves smoothing the soil surface and creating enough slope to ensure water run-off.

Lowland areas often receive water from the surrounding uplands. Impermeable soils may be unable to get rid of excess water by downward movement through the soil profile. Sometimes excess water is applied to a field during irrigation. In all of these cases, surface drainage is used to dispose of the excess water. Ditches are built of concrete to ensure durability, especially where rapid water movement occurs. Ditches must be cleaned and weeded periodically.

Disadvantages of surface drainage

- Silt and clay sedimentation and the growth of weeds and willows restrict the flow of water.

- Surface drains are troublesome to maintain and water distribution interferes with them.

- Another major disadvantage of surface ditches is that they may interfere with the use of machinery.

2. Sub-surface drainage

i. **Mole drains** are cut in the soil at a pre-arranged depth, below the main root zone. Mole drains are usually 10-15 cm in diameter, circular or nearly so in cross section, 50- 60 cm deep, and 3-4 m apart. Some cuts are made in the drains. These cuts assist the passage of water from the surface and through the soil to the drains. Mole drains require not only suitable land but proper grading of the drains and free outlets at the lower ends, leading into surface cuts of sufficient depth which discharge to main drainage canals or a natural water course.

ii. **Tile drains** are formed by hollow cylindrical tiles of 10- 25 cm internal diameter. The tiles are made of concrete and are laid in deep trenches cut at predetermined intervals to a depth of 75 cm or more. When the soil surrounding the tile is saturated with water, the water seeps into the tile and eventually reaches an outlet where it is discharged.

Advantages of underground drainage

i. Low maintenance costs.

ii. Unobstructed passage of farm implement over them.

iii. Arable land is not sacrificed as is often the case with surface drainage.

iv. They also indirectly help in providing water for irrigation.

v. Assists in protecting the soil from erosion.

vi. The firmer particles of surface soil carried away in large quantities and deposited in the trenches and main drains are cleaned and reformed after some years.

Maintenance of drains

- The maintenance of drainage systems requires the regular removal of soil and vegetation from the drains.

- To keep closed drains clean, it is essential to destroy the penetrating roots periodically by adding some chemicals to the drain water. To achieve this, all undesirable vegetation in the field should be killed with chemicals.

4.0 CONCLUSION

The importance of irrigation and drainage in sustainable crop production cannot be over emphasised. Too much or too little moisture is a determinant factor in the growth, development and crop yield. Various agronomic practices carried out in the process of crop production are aimed at creating the most suitable moisture regimes that could guaranty optimum growth and productivity of crop plants. Irrigation supplies the needed moisture at the right quantity and time while drainage removes excess moisture from the field thereby creating suitable moisture regime that encourages microbial activities in the soil as well as nutrient availability and absorption by the plants. Various method of irrigation and drainage, their advantages and disadvantages and suitability to given crops and locality were highlighted.

5.0 SUMMARY

In this unit you have studied the various methods of irrigation i.e. surface and sub-surface irrigation methods, the suitability, the advantages and disadvantages of each method were treated. Also the various methods of draining excess water from the land, the advantages and the disadvantages of each method were discussed. Irrigation and drainage are integral part of any sustainable crop production programme.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term irrigation and state why it is important.
2. For each of the following, state two advantages and two disadvantages:
   a. Surface irrigation
   b. Sprinkler irrigation
   c. Drip irrigation.
3. Define the term Drainage and state why it is important.
4. a. State the advantages of sub-surface drainage.
   b. What are the disadvantages of surface drainage?

7.0 REFERENCES/FURTHER READING

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UNIT 4 WEEDS

CONTENTS

1.0 INTRODUCTION

Crop yield losses ranging from 37 to 93 per cent have been recorded due to weed infestation in unweeded dry land crops in Northern Nigeria (Rowland, R. J. 1993). Therefore, attempt at understanding nature of weeds and its characteristics is a necessary condition if we are to reduce the harmful effects of weeds on crops and crop production.

This unit attempts to describe weeds, characterise, and categorise them. Questions as to why weeds are able to persist, survive in competition with crop plant, their competitive ability, how weeds are able to develop an efficient mechanism of dispersing their seeds are tackled. The desirable and undesirable effects of weeds are also treated in this unit.

2.0 OBJECTIVES

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

- define a weed and enumerate the harmful effects of weeds
- classify weeds based on life span and controllability
- list the beneficial and harmful effects of weeds
- name the common weeds found in the locality and in Nigeria
- explain the mechanisms of seeds dispersal in weeds

- recognise the most critical periods in the life of plants when weeds infestation has the highest effect and when control measures would produce the most desired result.

3.0 MAIN CONTENT

3.1 Weeds: Definitions

A weed is a plant growing where man does not want it. Almost any kind of plant can therefore be a weed, as long as it exists in a location or situation where it is considered undesirable. It also follows that a kind of plant may be a weed in one situation and not a weed in another situation. Because the concept of a weed came from humans the definition of a weed has varied, depending on the effect that weeds are perceived to have on food production, recreative activities and aesthetic values of humans. Generally, it is the undesirability or unwanted aspects of those plants which also have nuisance values that make them weeds.

3.2 Classification of Weeds

Weeds are classified in several ways that include life cycle, habitat, growth habit, degree of undesirability or noxiousness, morphology and by taxonomy or scientific classification.

Based on Life cycle

i. Annual weeds

These are those weeds that complete their life cycle (from seed germination to seed production) in one year. Such weeds die off during the dry season after completing their life cycle. Examples of annual weeds are *Ageratum conyzoides, Amaranthus spinosus, Brachiaria deflexa*, etc. Some of the characteristics of annual weeds include an ability to produce large quantity of seeds, tendency to occur in high density, efficient methods of seeds dispersal, and seed dormancy that prevent all seeds produced by the weed in one year from germinating at once.

ii. Biennial weeds

These weeds require two seasons to complete their growth. They grow from seeds and devote the first season to food storage, usually in short fleshy roots. During the next spring they draw on the stored food to produce a vigorous vegetative growth and to mature seeds. Among biennials weeds are wild carrots, wild parsnip, burdock, etc.

iii. Perennial weeds

These weeds live for more than two years. The majority of simple perennials posses root crown that produce new plants year after year. Plants of this type depend upon production of seeds for their spread or by means of underground part. Quack grass, Johnson grass, and Kirikiri grass are spread by underground stems.

Other classifications include:

i. Common weeds

Common weeds are annuals, biennials, or simple perennials that are readily controlled by ordinary good farming practices.

ii. Noxious weeds

These are those weeds which are difficult to control because of an extensive perennials root system or because of other characteristics that make them persistent.

3.3 Characteristics of weeds

Characteristics of weeds which enable them compete effectively with crop plants and therefore to survive over the generations in association with crop production are as follows:

i. Weeds have the ability to flower and produce seeds in short period of time. With this characteristic it means weeds are able to complete its life cycle even if the favourable season for growth is relatively short.

ii. High reproductive capacity: many annual weeds have ability to produce large quantities of seeds for example *Striga asiatica* produce 90000 seeds per plant, *Striga hermonthica* 42000, *Digitaria horizontalis* 12000, *Amaranthus spinosus* 235000, etc.

iii. Seeds of many weeds species exhibit varying forms of dormancy. Seed dormancy characteristics are survival mechanism in weeds. They ensure that weed seeds, particularly of annual weeds, do not all germinate during the first period in which environmental conditions are favourable. Rather, certain percentages of viable seeds remain dormant and are able to germinate at later dates, often in several succeeding seasons.

iv. Weed seeds posses specialised dormancy mechanism such as impervious seed coats the presence of growth inhibitors and requirements for exposure to certain temperature or light treatments. The net effect of these dormancy mechanisms is that seed germination occurs only under conditions that will enable the plant to complete its life cycle. Weed seeds are able to survive in the dormant state in the soil for several years, only to germinate and grow when they are brought to the surface or when environmental conditions are appropriate.

v. Weed seeds posses an efficient mechanism for dispersal. The main agents of weed dispersal are wind, animals and water. Most weed seeds are adapted to be dispersed by one or more of these agents.

vi. Presence of allelochemicals that inhibit the growth of crops or other weeds, such as in Siam weed (*Chromolena odorata*)

vii. Weeds have a very wide adaptation therefore, has the ability to grow and produce seeds under a wide range of environment.

viii. Weeds posses the ability to grow very rapidly, branched or tiller profusely, and cover extensive areas example of such weed is *Andropogon spp*.

ix. The presence of perennating organs such as rhizomes, corms, tubers, and bulbs. These organs not only enable the weed to survive from season to season but they also enable the weed plant to re-grow each time it is cut off at soil level by the farmer.

x. Many weed species are able to propagate themselves from pieces of stems and roots. Thus when the plant is cut into pieces during weeding or tillage operations, each piece is able to give rise to a new plant. For example, the ability of morning glory plant to propagate itself in this way makes it a difficult weed to control.

xi. Weeds are persistent and resistant to control measures. Weeds that are able to develop such resistance are additionally favoured by the fact that the chemical usually eliminates other weeds that would normally have competed with the resistant weed.

3.4 Losses caused by weeds

Weeds may cause losses in several ways either direct or indirect losses:

Direct losses caused by weeds

i. Decrease in crop yield

Weeds decrease yield by competing with the crop for water, nutrients and light. Crops yield are most depressed when either water, nutrient is in short supply making the competition for these factors very severe. The competition for light depends on the canopy structure of the crop and the weed and upon their relative times of establishment. A tall-growing weed in a prostrate crop, such as goat weed in melon, is likely to compete more severely for light than a prostrate weed in tall crop, such as portulaca in maize.

ii. Impairment of crop quality

- The presence of weed seeds in small grains lower the quality of the grain.

- The cost of separating seeds of weeds from crop seeds is one of the added (indirect) costs of growing the crop.

- Green weed pieces in threshed grain raise the moisture content so that the grain may not keep in storage.

- Weed debris sticking to harvested cotton lint tend to reduce its quality

- Presence of weeds can also lower the quality of forages or make them unpalatable or even poisonous to livestock for example, weeds such as wild garlic, mustard, fan weed, etc. consumed in hay or pastures impart undesirable flavors to dairy products.

- Seeds of many weeds (e.g. *Achyranthes aspera, Boerhavia diffusa, B. erecta*) will also reduce the quality of animal wool.

- Spiny weeds such as wild yam and those which produce certain kinds of pollen may also pose considerable health hazards to humans working on the farm.

iii. Harboring of plant pest and diseases

Many weeds act as host to organisms that carry plant diseases example, the wheat rust disease, in which the barberry weed plant is a necessary alternate host and Curly top, a serious virus disease of the sugar beet, is carried from such weeds as the common mallow, chickweed, and lambs quarters to the sugar beet by the beet leafhopper, which breeds upon these weeds. Weeds of the family *Solanaceae* contribute to the spread of such pests as the Colorado potato beetle.

iv. Weeds interfere with harvest operation

Picking maize by hand is hampered if the field is infested with *Rottboellia cochinchinensis.* Heavy weed infestation interferes with speedy drying of crops and generally slows down harvest operations, thus increasing cost of harvesting. Additional time may be required to clean crop seeds of weeds.

The presence of weeds can impede water flow in irrigation canals as well as damage to farm machinery through clogging by weeds, these presence of weeds can also increase the cost of irrigation through direct costs in keeping the canals weed-free.

The cost of weed control adds considerably to the cost of crop production; the farmer has to spend an appreciable percentage of his annual budget on various weed control measures.

Indirect losses caused by weeds

Weeds cause many other types of losses in agriculture that cannot be directly related to weeds. These losses are indirect in nature and include the following:

i. Weeds serve as alternative host for many plant diseases and pest that attack crops.

ii. The presence of weeds imposes a limit on farm size. Farmers generally cultivate only the area that they know from experience they will be able to keep weed-free.

iii. The presence of weeds can reduce the economic value of lakes by preventing or limiting fishing activities.

iv. Weeds such as *Imperata cylindrical*, *Andropogan spp*, *Pennisetum spp* and *Hyparrhenia spp* become fire hazards in the dry season. Fires expose the soil to erosion hazards, destroy wildlife and help to impoverish the soil.

3.5 Beneficial Effects of Weeds

Although weeds appear to have many undesirable features, there are some that are useful.

i. Weeds provide a vegetative cover that protects the soil surface against soil erosion by rain or wind.

ii. Weeds play an important role in nutrient recycling. Roots of weeds absorbed nutrients from the lower soil depth and return these to the top soil surface as litter when the weeds shed their leaves or when the entire plant dies and decays.

iii. Weeds add organic matter to the soil.

iv. Many weeds are used directly as food for humans e.g. *Talinum triangulare*, and *Pannisetum purpureum*, are commonly used as vegetable in Nigeria.

v. Weeds play an important role as a source of drugs used in public health.

vi. Weeds provide food and cover for animals.

vii. Weeds serve as important source of genetic materials for crop improvement.

viii. Weeds serve as host to beneficial insects and at the same time a source of nectar for bees.

ix. Many weed species help to beautify the landscape.

3.6 Factors effecting crop competitive ability against weed

a. Stage of crop development

Usually, the competitive ability of crop is low during the seedling and early vegetative stages of development and are particular sensitive to weed competition. Once the stages have been identified, the farmer ensures maximum weed control at those times, while permitting less stringent weed control during the other less critical stages. In yam, for example, the crop is particularly sensitive to weed competition during the first two or three months after emergence and failure to control weeds during that period result in lower yields than failure to control weeds during the latter part of the season (Kasasian and Seeyave, (1969).

b. The density of the crop plant

This can also influence its competitive ability against weeds. A high crop density, by providing a dense canopy, may control weeds by depriving them of light. For example, closely spaced cassava experience little weeds problem after the first three months, whereas widely spaced cassava plantings suffer from weeds problems throughout their field life.

Persistence of weeds

Weeds usually are able to survive in competition with crop plants because of the following:

- a wide range of adaptability to adverse environmental condition
- effective means of propagation, such as possessing of underground parts
- many weeds produce large amount of seeds per plant
- many weed seeds remain viable in the soil for many years
- many weed seeds exhibit dormancy.

3.7 Dissemination of Weeds

The main agents of seed dispersal for weeds are wind, animals and water.

Dispersal by wind: The possessions of feathery structures as in milkweed, or of wings, tend to facilitate dispersal of weed seeds by wind.

i. Dispersal by water

Adaptations for water dispersal include a low density of the seed as well as the possession of membranous structure or cork on the testa. These adaptations enable the seeds to float on water and be carried for long distances.

ii. Dispersal by animal

To aid dispersal by animal, many weed seeds have hooks or barbs with which they can stick to the skin of animal and the clothing of humans. For example seeds of Bermuda grass are spread in this way. Weed seeds eaten by animal may pass through the digestive tract uninjured. Cactus is spread principally by jack rabbit that eat the fruit that contain indigestible seeds.

iii. Man made agencies of weed seeds dispersal

a. Weeds are widely spread in impure seeds. Some of the most serious weed pests have been introduced from foreign countries in crop seeds.

b. Spreading of fresh farm yard manure on cultivated fields may disseminate weed seed.

c. Farm machinery may spread weed seeds. Plows, harrows and cultivators may drag roots or seed-bearing portion of perennial plants to other parts of a field.

d. Irrigation water may carry along with it seeds of weeds that grow on the bank of reservoir, canals and ditches to cultivated field.

3.8 Some Common Weeds of West Africa

Table 4.1: Some Common Weeds of West Africa

Common name	**Botanical name**	**Remarks**
Bahama grass	*Cynodon dactylon*	Perennial, vegetative propagation and by seeds.
Elephant grass	*Pennisetum purpureum*	Perennial propagated vegetative propagation and by seeds.
Goat weed	*Ageratum conyzoides*	Broad leaf weed.
Guinea grass	*Panicum maximum*	Perennial, vegetative propagation and by seeds.
Lalang	*Imperata cylindrica*	Perennial, vegetative propagation and by seeds.
Bamboo grass	*Paspalum conjugatum*	Perennial, vegetative propagation and by seeds.
Milk weed	*Euphorbia aegyptica*	Broad leaf weed.
Pig weed	*Amaranthus spinosus*	Broad leaf weed.
Tridax	*Tridax procumbens*	Produce numerous seeds

		and is adapted to wind and animal dispersal.
Goose grass	*Eleusina indica*	Annual.
Crab grass	*Digitaria sanguinalis*	Annual.
Foxtail	*Setaria spp*	Annual.
Purtulaca	*Portulaca oleraceae*	Very effective in vegetative propagation.
Sedges	*Cyperus spp.*	Propagated by seeds and by rhizomes.
Green amaranth	*Amaranthus palmeri*	Annual.
Morning glory	*Ipomoea purpurea* or *ipomoea involucrate*	Vegetative propagation.

Source: Onwueme, I. C. and Sinha, T. D. (1999)

4.0 CONCLUSION

Weeds are plants growing out of place. Weeds bring about a lot of harmful and beneficial effect to the farmer. They could be classified as annuals, biennials, perennial, common or noxious weeds. They possess some special features that aid their adaptability, competitiveness and dispersal. Clear understandings of weeds characteristic, classification, harmful and beneficial effects as well as some special adaptive features of weeds and dispersal methods of weed seeds are necessary if we are to effectively tackle them and minimise their harmful effects.

5.0 SUMMARY

In this unit, weed has been defined; its classification, characteristics and adaptability are clearly stated. The harmful and beneficial effects of weeds are highlighted. Weed seeds dispersal mechanism, a glossary of commonly found weeds of West Africa and some of their basic features are presented. Understanding this unit is fundamental to having effective weed control programme.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. Define the term weeds.
   b. State the characteristic of weeds which make them excellent competitors with the crop plants.
2. a. Briefly describe five ways in which weed causes direct losses to the farmer.
   b. State how weeds are able to cause indirect losses to the farmer.
3. a. Mention the beneficial effects of weeds if any.

b. State the reasons that aid the persistence of weeds.

4. Write short notes on any 4 of the following:
   a. Common weed.
   b. Annual weed.
   c. Noxious weed.
   d. Man made agencies for weed dispersal.
   e. State the factors affecting the competitive ability of weeds against crop.

7.0 REFERENCES/FURTHER READING

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UNIT 5 WEEDS CONTROL

CONTENTS

1.0 INTRODUCTION

Martin, H. J. *et al.* (1963) reported that, weeds cost the American farmers $5 billion annually in crop losses and in the expense of keeping them under control. Therefore, understanding the principles of weeds control and various methods of controlling weeds are preconditions for successful execution of weed control programme.

In this unit the basic principles of weed control and the various methods of weeds control are discussed. The cultural weed management system and its various elements are explained. Chemical, biological and integrated methods of weed control are also treated in such a way that the strength, suitability and limitations of each method of weed controlled were stressed.

2.0 OBJECTIVES

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

- state the basic principles of weed control
- suggest the most suitable method of weed control in a particular crop and locality
- draw a crop rotation system that could tackle effectively a given sets of weeds in a given locality
- identify suitable biological methods of controlling certain weeds.

3.0 MAIN CONTENT

3.1 Definitions

i. Weed control

Refers to those actions that seek to restrict the spread of weeds and destroy or reduce their population in a given location.

ii. Weed eradication

This refers to the complete removal of all weeds and their Propagules from a habitat. Weed eradication is difficult to achieve and is uneconomical in most situations. There are situations when problems posed by a noxious weed becomes so overwhelming that eradication is a desirable long term goal. For example, *Striga asiatica* and *Striga hermonthica* are parasitic weeds of several cereal crops throughout the tropics. These weeds do not respond to weed control technologies available at present to farmers in the region. An eradication program is seen as a desirable long term goal for these weed species.

Factors necessitating weed eradication program

- Other weed control measures are ineffective.
- Weeds have many buried seeds that cannot be controlled by conventional practices.
- The infested field is small.
- Benefits from eradication outweigh those of the alternative methods for coping with the weed.

iii. Weed management

This is the ability to manipulate weeds so that they do not seriously interfere with the growth, development and economic yield of crops and animals. The major components of weed management are preventive weed control, cultural control, and biological and chemical weed control.

3.2 Principles of Weed Control

1. The weed should be killed before it has a chance to produce seeds. For this reason, land that is left fallow should be ploughed at intervals in order to kill weeds before they produce seeds.

2. Weeding should occur before the crop begins to suffer from the competition of the weeds.

3. Perennial weeds should be attacked at the beginning of the rainy season when the amount of reserved food present in them is minimal.

4. The cost of controlling weeds on a crop should be weighed against the expected loss in yield and quality if the weeds are not controlled.

5. Crops should be properly spaced so that when the crops are fully grown the ground is completely covered, thus depriving the weeds of sun light, therefore can only grow slowly.

Factors affecting the effectiveness of weed control

1. The type of crop grown.

2. Timing of the weeding operation.

3. Nature of the weed problem.

4. Method of weed control.

5. Types of weeds to be controlled.

6. Cost of the operation and availability of cash resources.

7. Environmental condition before, during, and after the time of operation.

3.3 Cultural Weed Management System

Cultural weed management system includes all aspects of good crop husbandry used to minimise weed interference with crop. These consist of the following:

a. Hand weeding
b. Mechanical weeding
c. Tillage
d. Mulching
e. Burning
f. Flooding
g. Crop rotation.

i. Hand weeding

Hand weeding is one of the oldest methods of weed control and consists of hand pulling, hand slashing and hoeing and mowing of weeds. Most of the drudgery associated with subsistence farming in the tropics centres around the peasant farmer and his manual weeding effort.

Problems associated with hand weeding

- A lot of drudgery and time consuming.
- Limited agricultural productivity because there is a limit to the amount of land area that can be weeded manually.
- Organisational and other logistics and supervisory problems associated with human labour make its use cumbersome.

Hand pulling

Hand pulling is a major weed control method used in crop production in many parts of the tropics. It is particularly used in controlling weeds in cereal crops such as rice that are traditionally broadcast seeded.

Advantages of hand pulling

- It requires no additional tool.
- It is best for controlling weeds in broadcast-seeded crop where chemical weeding is not practiced.
- It is useful in removing weeds that have escaped other weed control measures.

Disadvantages

- It is laborious and full of drudgery.
- It is expensive when cheap labour is in short supply.
- Not suitable for controlling perennial weeds.
- Weeds cannot always be completely pulled out of the soil.

ii. Hand hoeing

This is by far the most widely used method of weed control in the tropics. It is a faster method of weed control than hand pulling and can be used in range of cropping systems. This method of weed control is used after the weeds have emerged but before they get too tall to interfere with hoeing operations. Hoe weeding is applicable to both annual and perennial weeds. Weeding hoes can be broadly grouped into light and heavy hoes. Generally, the short handled hoes are used in the humid part of the tropics while the long-handled heavy hoes are used mainly in the tropical savanna for seed bed preparations.

Advantages of hand hoeing

- Both annuals and perennial weeds are controlled.
- It is an effective weed control measure for crops in rows.
- It provides a clean seed bed and loosens the soil.
- It is suitable for small farm size.

Disadvantages

- Weeds are usually well established in crops before farmers start weeding.
- Is labour intensive and could be expensive where cheap labour is in short supply.
- It is unsuitable for larger farms.
- Predisposes the soil to erosion as a result of clean weeding and loosening up of the soil.
- The propagule of perennial weeds may be buried at depth beyond the reach of hand hoes, thus making the control of such weeds difficult.
- Hand hoeing has a high risk of crop damage in many root and tuber crops.

iii. Hand-slashing

This is another manual method of weed control used mainly in right of way, non crop areas, bush clearing and in plantation crops. Hand-slashing is used in food crops for control of over grown annual weeds. The most widely used tool for manual slashing is the cutlass or machete and a sickle.

Advantages of slashing

- It minimises erosion.
- It is more labour efficient than hand hoeing.

Disadvantages of slashing

- Rapid regeneration of weeds is a major setback of slashing.
- Crop reduction as a result of accidental damage during slashing.
- High labour requirement.
- Drudgery.
- Is not suitable method of weed control in field crops that are under water stress because the basal portions of the weeds continue to deprive the crop of the limited water?

iv. Mechanical weeding

In mechanical weeding, a farmer channels energy produced by machines or animals into weeding operations. He gets more work done with the use of this type of energy than in hand weeding, when he not only produces the energy but also directs its use. The plough and harrows are most often used to control weeds before the crop is planted and between the rows of growing crop. During ploughing, weed seeds that have remained buried in the soil are brought to the surface. They then begin to germinate and if shallow tillage is done shortly afterwards the weed seedlings are destroyed. This is a particularly good method for controlling annual weeds. For perennials, repeated tillage at relatively short intervals may be necessary. Each tillage operation destroys the top growth, and forces the weed plant to produce new growth at the expense of underground reserves. Eventually these reserves are exhausted and the plant dies.

Tillage should be aim at destroying the weed plant before they reach the stage of setting seeds. For this reason, even fallow or uncropped fields should be subjected to occasional tillage as a method of controlling weeds. The point here is that if the weeds are permitted to produce seeds on fallow fields such seeds can easily be dispersed to the cropped fields.

Those that are not dispersed may remain viable for several years and pose a problem when that particular field is eventually cropped.

Advantages of mechanical weeding

- Increase productivity.
- Increase economic returns, consequently improving the farmers' welfare.
- Reduces drudgery.
- Increases timeliness and precision in operations.
- More areas of land could be cultivated.
- Managing animals or machines is less problematic than managing human labour.

Disadvantages of mechanical weeding

- The initial cost of machines is high beyond the reach of most farmers in tropical Africa.
- It requires highly trained experts to maintain the machines.
- Availability and cost of fuel may affect the cost of running the machines.

v. Animal drawn weeders

The use of animal-drawn weeders in the tropics is limited due to presence of tsetse fly which transmits the parasite *trypanosome spp.* to cattle in many humid and sub humid tropics. They are widely used throughout the arid and semi-arid savanna tropics.

Advantages of using animal drawn weeders

- Low capital investment on source of power.
- Low cost of maintenance as draft animals are fed on forages available to other animals.
- Droppings from the animal serve as rich source of soil organic matter.

- No specialised training is required to operate the tool and guide the animal.

- Weeding implements is within the technological competence of most tropical farmers.

- Animal-drawn cultivators and weeders fit into the cropping patterns and farming systems of most farmers in many grassland region of the tropics.

- These implements can be used in both small and large farms.

Disadvantages of animal-drawn weeders

- Productivity of the system and work output of the animals depends on the state of their health and expertise of the handler.

- Precise cultivation and planting cannot always be obtained because of difficulty in controlling the animals.

- The presence of tsetse fly and animal diseases makes it impossible to use animals in some parts of the tropics.

- Religious beliefs and local customs of some parts of the tropics may make farming with animal difficult to practice.

vi. Machine-powered weeders

Machine-powered weeding refers to all weeding operations where the power used for removing weeds is derived from machines which in turn are using fossil fuel as source of energy.

Advantages of machine-powered weeders

- Weeding can be done more timely, reliably and cheaply than in manual or animal-drawn implements.

- Weeding can be done in less time and large farm land can be weeded.

- The same engine power can be used for other farm related activities such as tillage, planting, harvesting and transportation of farm produce.

- The use of machines eliminates drudgery and reduces risk of labour uncertainties.

Disadvantages of machine-powered weeders

- It is unsuitable where crops are not grown in rows.

- Heavy capital investment is required to buy and maintain the machines and equipment.

- Service maintenance and availability of spare parts are chronic problems facing machine-powered agricultural operations throughout the tropics.

vii. Tillage

Cropland has for centuries been cultivated primarily to provide a good seed bed for seed germination and seedling growth. Other reasons for tillage include weed control. In addition to routine tillage, farmers usually carry out two distinct types of tillage for weed control purposes.

Types of tillage for weed control

These are delayed tillage and blind tillage:

- **Delayed tillage** involves preparing the seed bed and waiting until the weeds emerge before lightly cultivating the soil again and planting the seeds. The purpose of delayed tillage is therefore to destroy the first flush of weeds so that the subsequently planted crop can grow at a reduced weed pressure.

- **Blind tillage** is when crop seeds are planted after the usual land preparation and lightly cultivated after weeds have emerged but before crop emergence. This type of tillage works well if weeds germinate ahead of the crop.

Pre-planting land cultivation

This has the objectives of burying weed seeds and incorporation of organic matter in to the soil and cut off weeds as close to soil surface as possible. Use of tillage as a weed control method involving animal-drawn implements is often handicapped by the inability of animal-drawn cultivators to accomplish deep tillage satisfactorily even on light soil. Mounds are more desirable in controlling weeds because in giant mounds the weed seeds are buried deep in the mounds, thereby reducing weed pressure.

viii. Burning

Fire is used as a weed control device in practically all parts of the world, it is used mostly to remove plant growth and plant material prior to cropping and also destroy weed seeds lying close to the surface. Most of burning is done before crops are planted. There are three types of pre-plant field burning that are carried out in agricultural land worldwide:

- the uncontrolled
- controlled burning
- the direct burner-assisted burning.

Uncontrolled burning refers to both the accidental forest (bush) fires and the type of burning deliberately started in the dry season of the savanna for hunting purposes. Uncontrolled burning damages the landscape, destroys wild life, destroys homes and property, destroys vegetation, exposes soil to erosion and may destroy economic trees.

a. Controlled burning

This refers to agricultural fires set by farmers for the purpose of creating a favourable environment for crop production and getting rid of unwanted vegetation. Controlled burning is used extensively in forestry to reduce the accumulation of litter and reduce the risk of wild fires that could destroy forests and property. This type of burning is done when environmental conditions are favourable and winds optimum.

Hard-to kill weeds such as *Imperata cylindrical*, *Andropogon spp*. and *Hyparrhenia spp*. are often burned by peasant farmers during the dry season to stimulate new growth, which can then be fed to livestock before the cropping season begins or hoe weeded after the crop is established.

Advantages of controlled burning

- It is a cheap way of getting rid of excess vegetation.
- It adds nutrients such as P and K to the soil.
- It reduces soil acidity.
- It destroys animal pests and pathogens that use the fallow vegetation as alternative hosts.

- Destroys weed seeds and soil borne pathogens.

- It stimulates re-growth in perennial grasses and may be used to rejuvenate grass pastures.

- It is a cheap and effective way to kill woody perennials.

Disadvantage of controlled burning

- It results in rapid loss of soil organic matter.

- Loss of non-metal elements, e.g. sulphur and nitrogen as gases.

- Soil temperature, generated during burning is often not high enough and of long enough duration to ensure complete destruction of partially buried weed seeds and nematodes.

b. Direct burning

This is a type of controlled burning where special burners (mobile field incinerators, propane flamers) equipped with propane gas are used for burning plant residues.

Advantages of direct burning

- A good chance for complete and environmentally friendlier burning because there is practically no smoke.

- The speed of the operation can be controlled.

Disadvantages of direct burning

- It is expensive to buy special burners.

- Is slower than controlled burning.

- Reduces farmer net profit due to additional cost on fuel and machinery.

ix. Flooding

This is also an effective method of weed control, although its use is mostly limited to paddy rice and taro. Flooding kills the weeds by depriving them of oxygen. Since many weeds can survive flooding if they are not completely submerged, it is important the water level is maintained high enough so that no parts of the weeds are exposed.

Generally, several weeks of water logging are necessary to destroy the unwanted vegetation.

Advantages of flooding

- Helps to kill some soil-borne fungi and nematodes.
- Anaerobic condition in flooded fields suffocates roots of dry-land plants and kills weed seeds.

Disadvantages of flooding as method of weed control

- It is not effective on well established aquatic weeds that cannot be submerged.
- It requires a terrain that is level or can be leveled.
- Could only be used in areas where water is available and can be impounded.

x. Mulching

Mulch is a layer of non-living material placed over the surface of the soil to smother the weeds and cut them off from direct sunlight. Mulching, in addition to this favourable effect on soil organic matter, is useful in managing the fragile tropical soil and:

- mulching can help to conserve soil moisture
- protect the soil from erosion
- reduce soil surface temperature
- increase water infiltration
- maintain soil structure
- provide favourable environment for biological activities in the soil.

Limitation of mulching

- It is a labour-intensive activity particularly if the mulch has to be transported.
- Most crops do not generate enough crop residues to provide effective ground cover.

- To be effective, the mulching materials must cover the soil surface and smother weeds.

- Covering the soil completely by the mulching material may interfere with other farming operations.

- Mulching materials placed before seedling emergence may interfere with seed germination or the growth of seedlings.

- Mulching material may serve as a trap for animal pest of crop, including promoting termite activity.

xi. Crop rotation

Crop rotation is a valuable tool in weed control because many weeds are associated with certain crops:

- rotation play a long term role in weed control by preventing particular weed species from adapting to the growth cycle of specific crops

- rotating cereals with legumes and other trap crops is recommended for reducing *Striga* infestations in small holder farms

- crop rotation also helps the farmer to rotate his herbicides, thus ensuring that weeds resistant to a particular herbicide do not take over in a field.

3.4 Biological Methods of Weed Control

Biological method of weed control refers to the control or suppression of weeds by the action of one or more organisms, through natural means or by manipulation of the weed, organism, or the environment. The most dramatic instances are those in which natural enemies of the weed species have been identified and are either introduced or encouraged. With this approach, the Klamath weed is being controlled in the U.S.A with parasitic beetles; the prickly pear cactus has been controlled in Australia by the Argentine moth borer. This approach is, however, most efficacious where single troublesome weed species is predominant.

Major developments in this area include biological control of weeds with vertebrate animals (microbial control), use of microorganism such as plant pathogens for weed control (microbial control) and live mulch. Other areas with potential for biocontrol of weeds are exploitation of crop canopy, density and the allelopathic effects of both weeds and crops on weeds.

i. Live mulch

Live mulch is defined as a crop production system in which a food crop is planted directly in the living cover of an established cover crop without destruction of the fallow (cover crop) vegetation. Perennial legume cover crops have been evaluated and found to be suitable for use as live mulch.

Live mulch crop production aims at the following

- Suppresses weeds
- Reduces weed seeds population in the soil
- Reduces loss of soil organic matter
- Provide favourable condition for earth worm activity
- Protect the soil from erosion
- Reduces soil compaction
- As additional fodder for livestock.

Advantages of using live mulch

- Reduces the need to control weeds after harvest.
- It prevents the establishment of those weeds that colonise fallow land.

ii. Biological control with invertebrate animals

This involves the use of insects to control weeds. Example, the Klamath weed is being controlled in the U.S.A with parasitic beetles; the prickly pear cactus has been controlled in Australia by the Argentine moth borer. This approach is, however, most efficacious where single troublesome weed species is predominant.

Advantages of biological control of weeds by insects

- The effect is permanent.
- It can be used in places that are not easily accessible to man.
- It is cheaper in the long run.
- It does not pose any risk of polluting the environment.

Disadvantages of biological control of weeds by insects

- It is not suitable for food crop.
- Unfavourable weather condition or presence of predators may prevent the insects from adapting to the new environment.
- Inability of the appropriate growth stage of the insect to synchronise with the susceptible stage of growth of the target weed.

iii. Biological control of weeds with vertebrate animals

Animals have been used for suppressing vegetation for centuries. Pasturing land with sheep sometimes is an effective method for controlling certain weeds. Sheep are able to suppress field bindweed on land seeded to Sudan grass for pasture. They eat the bindweed in preference to the Sudan grass, but they make good gain on the latter after eating down the weeds. Fish consumed algae in flooded fields.

iv. Microbial weed control

Microbial weed control involves the use of microorganism such as fungi, bacteria, nematodes and virus. Microbial control of weeds involved the multiplication of pathogens in a controlled environment and spraying them on the target weed as mycoherbicides.

v. Allelopathy

Allelopathy is a term used to describe the detrimental effects of chemicals or exudates produced by one living plant species on the germination, growth or development of another plant species or microorganisms sharing the same habitat.

vi. Plant canopy

The main effect of plant canopy is to shade the weeds and limit their ability to carry out photosynthesis. Example, melon (*Colocynthis citrullis*) and sweet potato can provide early ground cover and shade out weeds when intercropped with other crops.

3.5 Chemical Methods of Weed Control

Chemicals that are used for killing or adversely affecting plant growth are known as **herbicides.** The practice by which weeds are killed with herbicides is called **chemical weed control**

Criteria used to classify herbicides

- The time when they are normally applied.
- Whether they are selective or not.
- Whether they normally act through the shoot or the root.

1. Classification of herbicides based on time of application

There are generally three distinct times when herbicide may be applied.

i. Pre-planting application

This application that is done before the crop is planted. A preplant herbicide may be applied broadcast on the foliage to kill fallow vegetation such as paraquat or it may be the type, such as trifluralin, that is incorporated into the soil during tillage operations.

ii. A pre-emergence herbicide application

Is the application that is done after planting but before the crop emerged. The weeds may or may not have emerged by the time of pre-emergence application. If the weeds have not emerged, then a herbicide such as diuron or ametryne that acts on un-emerged seedlings can be used. If the weeds have emerged already, a herbicide that can kill the established weeds could be used.

iii. A post emergence herbicide application

Is the application of herbicide that is done after the crop has emerged. Again weeds may or may not have emerged at the time of herbicide application. Example of post emergence herbicides are 2,4-D propanil, paraquat, etc. A post emergence herbicide must find a way to avoid herbicide damage to the emerged crop.

2 Classification of herbicide based on type of plants killed

All herbicides kill plants either selectively or non-selectively:

i. **Nonselective herbicides** are those herbicides that exert toxic effects on all plants that may come in contact with them. Examples include diquat, glyphosate, paraquat and sodium chlorate.

ii. **Selective herbicides** are those that will preferentially kill certain plants species at recommended rates but will not harm other plants that they come in contact with. Example, 2,4-D, diclofop-methyl, fluometuron and metolachor.

3. Classification of herbicides based on movement in plants

i. Contact herbicides

These are herbicides that kill the tissues they touch. Contact herbicides commonly in used in the tropics include the following: paraquat, propanil, oryzalin and diquat.

ii. Systemic herbicides

These are those herbicides that are transported in the xylem or phloem vessels of the treated plants. Examples of systemic herbicides are atrazine, dalapon and glyphosate. Systemic herbicides are particularly useful in controlling perennial weeds because underground perennating organs and roots are killed in addition to the shoot.

iii. Soil-acting herbicides

Are those which act primarily in the soil. They are usually applied to the soil where they retard or inhibit the germination of weed seeds. Such herbicides usually have long residual action so that they can prevent the growth of weeds for a substantial part of the cropping season.

3.6 Preventive Methods of Weed Control

Preventive weed control refers to those measures necessary to prevent the introduction of new weed species into a given geographical area as well as multiplication and spread of existing weed species. Preventive weed control includes all sanitation measures that should be routinely used in the farm, including the vigilance that keeps a farmer alert to the presence of a strange plant on his farm land. Its generally accepted wisdom that it is easier to prevent the spread of a weed to a new site than to get rid of it after it is well established.

i. Fallowing

This is an effective method of suppressing annual grasses and troublesome perennial weeds such as speargrass. Although fallowing has been used for controlling weeds, proper management of fallows can be used to prevent weeds from going to seed and reduce weed population in a given ecology. An example of preventive weed management by bush fallowing is the live mulch cropping system. In this system the living cover of legumes such as *Centrosema pubescens* and *Mucuna pruriens* provide complete cover, smother weeds, prevent erosion and return organic matter to the soil.

ii. Preventing weeds from setting seeds

Annual weeds and simple perennials produce large quantities of seeds that end up in the seed bank already in the soil. Late germinating weeds in the field crops are the main sources of weed seeds in newly harvested field because these weeds usually complete their life cycle after crop harvest.

Methods of preventing weeds from going to seed

a. Post- harvest weed control will be necessary to prevent these weeds from going to seed (producing seeds).

b. Enlightening the farmers on the adverse effects that seeds produced by these volunteer weeds will have on their subsequent use of the land.

c. Repeated mowing and hand-slashing can be used to deplete the food reserve in the storage organs of perennial weeds there by reducing their competitiveness.

Preventing the spread of weeds and their propagules by

a. Use of clean seeds for planting.

b. Weed spread through the use of contaminated crop seeds can be prevented by keeping crop plants in the field weed-free.

c. By thoroughly cleaning the seeds intended for planting in the following cropping season.

d. Planting weed-free crop seeds is one way of avoiding the introduction of new weed seeds to the newly cleared crop land.

e. Cultivating tools play a role in spreading weed seeds and vegetative perennating organs. Routine sanitary measure involving careful cleaning of farm machinery immediately after use is an important preventive measure for weed control.

f. Seeds of many weeds are spread by animals. Care should be taken by the farmer to organise carefully the transfer of farm animals between fields.

g. Preventive weed control can also be achieved by screening irrigation canals to prevent weed seeds from being transported from infested fields to clean areas.

h. Well-decomposed manure is unlikely to contain viable weed seeds but poorly prepared manure which is a potential source of weed seeds, therefore, should be avoided.

i. Strict enforcement of quarantine laws is necessary to prevent the accidental introduction of noxious weeds through seeds and propagules.

3.7 Integrated Weed Management System

Integrated weed management (IWM) is neither a method nor a system of weed control, but a philosophy whose goals is to use all available knowledge in weed science to manage weeds so that they do not cause economic loss to humans and subsequently minimising hazards to the environment.

Reasons that made IWM desirable

i. Inability of any one method of weed control to completely solve the weed problem of a given crop at all times and without adverse effect.

ii. The ability of weeds to develop resistance to a herbicides that is frequently used.

4.0 CONCLUSION

By now you must have learnt the different methods of weed control including cultural, biological, chemical or integrated weed control programme. The emphasis has been on "Prevention is better than cure" so your knowledge of weed science should help you to manage weeds so that they do not cause economic loss to the farmer and subsequently minimise hazards to the environment. Understanding the different types of herbicides, their mode of action, time of application and types of plants they commonly kill is essential for an effective weed control programme. The integration of cultural, biological and chemical methods of weed control in other words integrated weed control is the most sustainable and effective method of weed control programme.

5.0 SUMMARY

At the end of this unit you should have learnt the basic principles of weed control, the cultural methods of weed control, and the biological and chemical methods of weed control. In this unit, the advantages and disadvantages of each method of weed control were highlighted. Emphasis was particularly made on the prevention not the total eradication of weeds. Herbicides are classified based on time of application, movements in plants and types of plants killed for easy identification and utilisation. Effective weed control programme should be hinged on utilising all available knowledge of weed science to manage weeds so that they do not cause economic loss to the farmer and thereby minimise hazards to the environment.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. State the principles of weed control.
   b. What is weed eradication? And what are conditions necessitating it?
2. a. What are the advantages and disadvantages of mechanical weeding?
   b. State the advantages and disadvantages of manual weeding.
3. a. Enumerate five methods of preventing the spread of weeds by their seeds and propagules.
   b. Briefly describe measures to prevent weed from going to seed.
4. a. Give the classification of herbicides based on movements in plants and time of application.
   b. Write short notes on the following:
      - Live mulch
      - Allelopathy

- Crop rotation as a measure of weed control
- Burning.

7.0 REFERENCES/FURTHER READING

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MODULE 3

UNIT 1 PESTS AND DISEASES

CONTENTS

1.0 INTRODUCTION

It is estimated that world crop losses due to pests are of the order of about 35 per cent of potential yield, but in most tropical countries of Africa and Asia, the field and store losses are of a higher magnitude and may be as high as 50 per cent in some cases. FAO estimates showed, for example, that nearly 100 million metric tons of cereals grains are destroyed by pests each year. Diseases are estimated to cause about 10 per cent loss of the annual agricultural production in the USA and about 20-30 per cent in the developing countries. Therefore, it is now widely recognised that the reduction of losses due to pests and diseases is an important element in increasing the efficiency of crop production.

This unit starts with explanation of what a pest is and the different categorisation of pests based on economic threshold of their effects on crops, on feeding patterns, on crops and the basic principles of pest control. The various methods of pest control are discussed with emphasis on prevention rather than the control of pest. Definition of diseases, description of disease causing organisms, symptoms of plant diseases and control and preventive measures are extensively discussed.

2.0 OBJECTIVES

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

- define and classified pests according to feeding pattern and economic threshold of destruction
- state the effects of pest on crop production
- analyse and prescribe the best practices of pest control
- analyse the symptoms of plant diseases and identify the kind of diseases that may be affecting a particular crop based on the symptoms
- prescribe the methods of controlling plant diseases.

3.0 MAIN CONTENT

3.1 Definition and Classification of Pests

Pest is any animal or plant which harm or causes damage to man, his animals, crops, or possession. On agricultural basis, a pest is that which causes a loss in yield or quality of the crops resulting in loss of profits by the farmer. When a loss in yield reaches certain proportions, then, the pest can be defined as an **economic pest**. When a loss in yield in a particular crop reaches 5 to 10 per cent a **pest status** is established. Economic damage is the amount of injury done to a crop which will justify the cost of artificial control measures. The **economic injury level** is the lowest pest population density that will cause economic damage to a crop and this varies from crop to crop, season to season, and area to area. **Economic threshold** is defined as the population density at which control measures should be started to prevent an increasing pest population from reaching the economic injury level.

Classification of pests on the basis of economic threshold

i. The regular pests

These are pests which perennially damage crops and whose population levels rarely fall below the economic threshold. Examples of these are *Maruca testulalis* on cowpea, *Dysdercus spp*. and red boll-worm on cotton, sorghum midge and Quelea birds in most parts of the grain producing Guinea and Sudan savanna of tropical Africa.

ii. The occasional pests

These are pests whose populations levels are normally below the economic threshold but occasionally rise above it. Examples of these include locusts that periodically ravage cereal crops and grasses in Sub-Saharan Africa, the stem borers and armyworms of cereals in western and eastern Africa, the variegated grasshopper, *Zonocerus variegates*, in West Africa, and many species of snails and lepidopterous larvae attacking deciduous forest trees, and arable and plantation crops.

iii. The potential pests

Those pest whose population levels are usually considered to be far below the economic threshold but which can become highly injurious under changed cultural conditions or as introduced pest. Examples of these include many species of grasshoppers and caterpillars in western and central Africa.

3.2 Brief Description of the Important Pests of Crops

The arthropods which comprise the insects, mites, millipedes and woodlice constitute the most dominant group, other of organisms include: nematodes, rodents, birds and mollusks.

1. Insects

Insects belong to a group of organism known as arthropods. Their small size, remarkable range of adaptation, rapid rate of reproduction, great mobility and efficient water conservation enables them to colonise nearly every habitat, including all the types in which crop production takes place. These features of insects contribute towards making their control of paramount importance to the farmer. Some insects are beneficial as pollinators of flowers and as predators which feed on destructive insects. Other types of insects are directly harmful as pest of crops, as carriers of diseases and as destroyers of stored food. Insects' pests exhibit three basic feeding patterns, namely:

- biting and chewing
- sucking
- boring insects.

i. Biting and chewing insects

These are insects which have biting mouth parts consisting of a pair of toothed horny jaws (mandibles) and a pair of accessory jaws. They tear and bite plant parts in their larval or adult stages. As a result, most of the leaves on the plant are eaten up. The grasshopper or locus, chewing beetle, the larvae of many butterflies and moths, the caterpillars are all examples of chewing insects.

ii. Sucking insects

These differ from biting insects in that they have mouthparts which extract the sap from plants. This consists mainly of a long, powerful, piercing proboscis with which these insects suck the liquid cell contents from leaves, stems or fruits. Sucking has weakening effect on plants but the ability to transmit plant diseases such as viruses is the most serious effect which sucking insects have on crops.

The commonest types of sucking insects are those which have probosces both at the immature and mature stages of growth. These insects feed on the stems and young fruits of many crops and may also introduce poisonous toxins into the crop tissues. Capsids are typical example of this group of insects that attacked both young and old shoots and pods of cocoa. The cotton stainer is a troublesome sucking insect pest of cotton. It feeds on the young pods, and reduces the commercial value of cotton by staining the lint.

Other types of sucking insects include; scale insects, mealy bugs and aphid. Scale insects have shell that protects them during adverse weather condition and from predators. Scale insects are found mostly on tree crops such as oil palm, cocoa, citrus, etc. they feed on the leaves and stems of tree crops, weakening them and reducing their productivity and life span. Mealy bugs feed on the leaves and stems of young cocoa and citrus trees. Aphids are serious agricultural pests, carrying virus diseases from plant to plant through their piecing mouthparts. They feed mainly on young stems. Aphids transmit swollen shoot disease of cocoa in Africa.

Fruit piecing moths are sucking insects which feed mainly on citrus fruits. Their probosces are very powerful and easily pierce the skin of the fruits and in some cases, the holes made by the insects allow the entry of organisms responsible for causing decay.

iii. Boring insects

These have mouth parts which are adapted to digging holes through plant and material. The cowpea weevil which infests cowpea is a good example of boring insect.

2. Nematodes

These are small organisms which are normally referred to as eelworms. Nematodes can cause a considerable damage to crops such as yams, cowpea and many vegetable. A disease known as root-knot disease of cowpea, for example, causes the formation of irregular nodules on the roots and dwarfing of the mature plant.

3. Rodents

These are mammals with teeth which are well adapted to gnaw or grind hard substances. They include mice, squirrels, porcupines, rats and grass cutters. These animals may damage fruits and vegetables and are particularly very injurious to young seedlings of oil palm, rice, sugar cane, and the tubers of root crops such as cassava. The larger rodents such as squirrels and grass cutters can be trapped, and wire netting fences may be erected to protect crops from damage. Small rodents can be prevented from destroying young seedling of palm trees by placing collars of small-mesh wire netting around the base of the trunk.

4. Birds

Birds of various types may do considerable damage to grain crop farms by eating both developing and dry grains. *Quelea* birds are by far the most populous and destructive birds in Africa. They invade crops like locust and cause heavy damage. Attacking the birds at their nesting and resting sites provides the most effective method of control. Toxic chemicals sprayed at dusk, has been found to be cheap and effective.

5. Mollusks

Garden snails and slugs may damage leaves of many kinds of vegetable.

3.3 Effects of Pests on Crop Plants

a. Direct effect of insect feeding

i. Leaves eaten, with subsequent reduction in assimilative tissue and hindrance of growth; examples are grasshoppers, caterpillars, sawfly larvae, leaf-cutting ants, leaf beetle and some weevil.

ii. Leaves rolled and webbed, and eaten; examples are larvae of skippers, and all Lepidoptera.

iii. Leaves mined with either tunnel or blotch mines.

iv. Buds eaten, destroying either the growing point of young flowers and fruit.

v. Flowers and young fruit eaten, as by pollen beetle, blister beetles.

vi. fruits and seeds eaten or bored and destroyed, as by sorghum midge larvae, pea pod borers, maize weevil, coffee berry borer and various fruit flies.

vii. Fruits bored and caused to fall prematurely for example mango fruit fly, and coffee fruit fly.

viii. Stems of both woody and herbaceous plants bored, with subsequent death of the distal part of the stem, for example *Earias spp* in cotton stem.

ix. Stems of seedlings bored, producing a dead-heart; for example *Athergona spp*. larvae in cereal seedlings, and *Chilo spp*. larvae in cereals.

x. Stem of woody plants ring-barked, as done by *Anthores spp*. on coffee.

xi. Roots eaten, causing a loss of water and nutrient absorbing tissue, as by chafer grubs and some weevil larvae.

xii. Tubers and corms bored, leading to a reduction of stored food material, and impairing both storage properties and next season’s growth; examples are *Cylas spp*. weevils in sweet potato tubers, yam beetles and potato tuber moth larvae.

b. Damage by insects with piercing and chewing mouthparts and mites

i. Loss of plant vigour due to removal of excessive amounts of sap, resulting in extreme cases in wilting, followed by stunting of growth; for example most aphid species, and whiteflies on a range of crop plants.

ii. Cause leaf-curling and deformation, as shown by aphids, thrips, mealybugs, white/black flies and jassids.

iii. Cause premature leaf-fall, as do many diaspidid scales.

iv. Cause leaf and fruit scarification by rupturing epidermal cells and removing sap; as by spider mites and many thrips.

v. Toxic saliva injected by feeding bugs causes premature fruit-fall in coconut and abortion of young cotton bolls, etc.

vi. Provides physical entry points for pathogenic fungi and bacteria.

c. Indirect Effect of Insects on Crops

i. Insects can make the crop more difficult to cultivate/harvest.

ii. They may distort the plant as do *Earias spp*. larvae on cotton.

iii. They may delay crop maturity, as do the bollworms in cotton, which makes the plant to develop a spreading habit thus, making weeding and spraying difficult.

iv. Grain in cereal crops may become dwarfed or distorted.

v. Insect infestation results in contamination and loss of quality in the crop. The loss of quality may be in nutritional value or in marketability.

d. Transmission of disease organisms

i. Cassava mosaic, tobacco mosaic and banana bunchy top are typical examples of crop diseases that are transmitted by insect vector.

ii. Mechanical or passive transmission takes place through lesions in the cuticle caused by feeding. The pathogen, usually a fungus or bacterium, may be carried on the proboscis of the bug or on the body of a tunneling insect.

3.4 Insect Pest Control

The control of the various insect pests affecting crop plants is a major problem for crop production. Insect pests may be controlled by means of various cultural practices, the use of chemicals known as insecticide and, biological methods of insect control.

1. Cultural methods of insect control

i. Hand picking: For example, fully grown adult grasshoppers and caterpillars of some insects may be partially controlled by hand picking.

ii. Crop rotation: Since insects are generally selective in the choice of crops they attack; a rotation of crops can result in a reduction of insect numbers when new crops are planted.

iii. Tillage practices: Ploughing by harrowing normally reduces the population of soil pest by exposing them to sunlight and desiccation, and to predators and parasites.

iv. Weed control: Some weeds act as host to insect pest, timely control of weeds would deprive them of their host.

v. Adjusting time of planting to avoid period when insect's population is at its peak. For example sorghum midges can be effectively controlled by planting early so that flowering is complete before the adult midge population reaches damaging levels.

vi. Resistant varieties: Pest may also be controlled by planting pests resistant varieties. New varieties, resistant to an increasing number of insect pests have been produced in recent years by the research institute.

vii. Timely harvesting: Prompt harvesting is known to help protect maize and beans from damage by maize weevil and bean bruchid.

viii. Observance of a closed season: Some pest cannot survive in the absence of a specific host plant. Observing a closed season for the cultivation of this plant provides effective control. A good example is the pink bollworm (*pectinophora gossypiella*) provided no cotton is grown during the closed season, this pest is deprived of a carry-over site for the next season, with the result that its population is kept below the level at which it causes serious economic loss.

ix. Trap cropping: A trap crop is used to divert the pest from the main crop. The pest usually prefers it to the main crop for feeding or egg laying. The trap crops are grown in strips at appropriate intervals within the field. The pest population concentrates on the trap crop, while the main crop suffers little damage.

x. Optimum plant density: The biology of both pest and their natural enemies can be affected by plant density. For example, bean fly infestation in kidney bean is less severe in densely planted crops than in thinly planted ones (Abate, 1990). Similarly, populations of aphid *Aphid craccivora* are lower and the spread of rosette virus, of which this insect is a vector, is less rapid on more densely sown fields of groundnut (Farrell, 1976a).

xi. Crop sanitation: Cleaning crop fields after harvest and burning crop residues to destroy over wintering pest populations are important cultural practices.

xii. Cropping patterns: For example intercropping check the spread of pest and is less frequent than in monoculture.

2. Chemical method of insect pest control

The most effective method of controlling insect pest is by spraying or dusting crops with insecticides. The choice of insecticide will depend on the feeding habits of any particular insects.

i. Biting and chewing insects are usually controlled by the use of **stomach poisons**. These are chemicals which, although they do not harm the crop, will poison the insects. They are sprayed or dusted on to the crop usually before the rains, to avoid them being washed off the leaves, or may be applied directly on the insect. Example of stomach poisons are lead arsenate and Paris green.

ii. **Contact poisons**: This would kill insects as a result of direct application and are most effective when they are sprayed onto the body in a form of a fine mist which completely covers the insect. Contact insecticide may also be sprayed on the leaves or stem of the crop as a preventive measure before the arrival of the insects. This type of insecticide is particularly useful in controlling sucking insects. Examples of contact poison include DDT, Gammexane, Lindane, nicotine sulphate, Gammalin 20, Didimac 25, etc.

iii. **Systemic poisons:** These chemicals are absorbed either by the leaves, stems or roots of crops without harming them but the chemical will poison any insect which feeds on the treated crop. Systemic insecticides are particularly useful in controlling sucking insects such as mealy bugs and aphids.

iv. **Suffocation:** Some insects have a protective covering which make their control difficult. One method of controlling insects such as scale insects and mealy bug is by suffocating them, which is cutting off the air supply to their spiracles with chemicals such as kerosene emulsion which is sprayed directly onto the insects.

v. **Fumigation:** Insect pest of stored products are generally controlled by fumigants - that is insecticides which kill by poisonous vapours or fumes. Fumigants may either be gaseous, liquid, or powder forms. Examples are carbon disulphide, hydrogen cyanide (gas) sulphur and methyl bromide.

3. Host Plant Resistance

Host plant resistance works in three major ways:

- Antixenosis
- Antibiosis
- Tolerant plants.

i. Antixenosis: Or non-preference refers to the innate qualities of the plant that render it unsuitable to the insect for oviposition, feeding and shelter. Examples of antixenonsis are resistance of pubescent varieties to the potato aphid (*Aulacorthum solani*) and to leafhoppers and of nectar less cotton to plant bugs.

ii. Antibiosis: Plants possessing antibiosis have deleterious effects on the pest feeding on them. Seeds of some pulses contain substances that inhibit the growth or reproduction of storage pest.

iii. Tolerant plants: Are those plants that suffer little damage in spite of supporting a pest population capable of inflicting heavy yield losses. Example is the introduction of resistant variety of cotton to cotton leafhopper (*Empoasca lybica*) in some parts of Africa, which relegated it to minor pest status.

4. Biological method of pest control

Biological control refers to the use of living organisms for the control of pests; it involves the use of predators, which feed on harmful insects and reduce their numbers to a minimum. Broadly speaking, biological control also includes the use of pathogens (bacteria, fungi, viruses, protozoan, and nematodes).

Biological control using parasites and predators has been effectively utilised in the control of Kenya mealbug (*Planococus kenyae*) by *Anagyrus spp.*

5. Regulatory method of pest control

Regulatory methods depend on legislation to enforce the quarantine of plant material. The legislation requires that propagating material (seeds cuttings, whole plant) imported from abroad be accompanied by a phytosanitary certificate stating that they are free from pests and diseases. Materials are inspected by a trained quarantine officer at the port of entry and if dangerous organisms are found the whole consignment may be destroyed.

6. Insect growth regulators

Insect growth regulators (IGR) are substances that interfere with the growth and development of insects. These compounds do not kill the insects immediately and thus do not prevent pest damage on a current crop.

7. Sterile insect technique

In the sterile insect technique (SIT), insects (male or female) are mass reared in the laboratory, sterilised (by radiation or chemosterilants) and released in the field. They mate with the wild population and produce sterile progeny. Because of its technicality and high cost this method has no application in sub-Saharan Africa.

8. Integrated pest management

Integrated Pest Management (IPM) can be defined as the judicious selection and use of compatible control options to keep pest population below damaging levels. IPM is based on knowledge of the ecology and population dynamics of the pest and its natural enemies. The emphasis here is on controlling pests rather than attempting to eradicate them altogether.

3.5 Plant Diseases

Plant diseases can be defined in the widest sense as conditions of the plant involving abnormalities of growth or structure. It is this departure from the normal healthy condition, resulting in the appearance of disease symptoms, which enables diseases to be recognised.

There are many factors which cause plants to appear unhealthy. Diseases may be caused by **pathogens**. These are parasitic organisms which live in or on the host plant and cause the appearance of disease symptoms; this process is called **pathogenesis.**

Plants may also be damaged by pest and mechanical forces, such as wind, hail and farm implements. There are non-parasitic diseases or disorders which are caused either by adverse environmental conditions or by internal physiological disturbances, usually of genetic origin. These include climatic damage due to frost, sun or lightning; mineral deficiencies or imbalances and genetic mutations. Parasitic diseases are important because they are infectious - they can spread between plants, often rapidly and extensively, and frequently produce epidemics.

The most important effect of plant diseases for the farmer is the reduction in crop yield or quality which results.

3.5.1 Symptoms of Plant Diseases

Many diseases can be recognised immediately by the characteristic symptoms which they produced. Symptoms are usually described according to their appearance. Thus, changes of foliage color may involve chlorosis (yellowing), mottled patterns as in mosaics or leaf stripe diseases, or the complete death of areas of tissues (necrosis). Symptoms of plant disease can be divided into two groups.

- Localised symptom, involve small parts of individual plant organ, such as leaf spots or whole plant organs, such as root rots and blights.

- Systemic symptoms are those which affect the whole plant, such as wilts and general stunting.

Symptoms of Plant Diseases

i. Death of the tissues or necrosis: various terms are used to describe the extent and shape of necrotic lesions, particularly on leaves, stripe for narrow, elongated lesions, scorch, scald, fire and blotch for indefinite areas which often becomes blanched and then brittle, and leaf spot for well defined lesions of limited extent.

ii. An abnormal increase in the tissues: this can result from both an increase in size (hypertrophy) and an increase in number (hyperplasia) of cells. The more common symptoms of this type are witches brooms, galls, canker and scab.

iii. A failure to attain normal size or development (hypoplasia): An overall dwarfing or stunting of the plant is common in many diseases.

iv. Change in color: yellowing or chlorosis is a common symptom of disease and one is often associated with tissue surrounding a necrotic area.

v. Wilting, caused by an interference with the normal movement of water within the plant.

vi. Unusual development or transformation of organs: for example maize infected with *Ustilago maydis* the staminate inflorescences may bear pistillate flowers.

vii. Disintegration of tissues: this is termed rot. It may be accompanied by a release of cell fluids (wet rot), so much so that there is an exudates from partially disintegrated tissue. Alternatively, the cells may crumble to a powdery mass (dry rot).

viii. Excessive gum formation: this is particularly associated with diseases of trees and is known as gummosis or gumming.

3.5.2 Causes of Plant Diseases

Disease can be caused by various agents either acting singly or in combination with another, and the study of these agents is term **etiology** of the disease. The agents themselves fall into the following categories:

- there are the bacteria, fungi and viruses which together probably account for the greatest number of diseases

- nematodes

- some insects (excluding those that only serve as vectors for disease agents).

- a few flowering plants such as broomrape (*Orobanche*), dodder *(Cuscuta*) and witch weed (*Striga)*

- heterogeneous group which includes mineral deficiencies and excesses

- unfavourable environmental conditions.

Disease-inciting agents that are themselves living organisms are called **pathogens.** The term **parasite and host** describe a nutritional relationship between two organisms, but the growth of a parasite in its host usually results in changes which are detrimental to the plant and considered on its ability to induce disease, a parasite can also be a pathogen.

Parasites causing plant disease can be classified according to their dependence upon the host plant as:

- Obligate

- Facultative.

i. Obligate parasite

These organisms can only grow directly upon the host plant and cannot generally grow saprophytically on non living organic matter. Their survival in the absence of a suitable host depends upon dormant resting stages in the life cycle, such as spores. An obligate parasite depends critically upon the existence of the host. They cause only fairly mild symptoms such as growth malformation, stunting and discoloration; they would not kill the host.

ii. Facultative parasites

These are usually well adapted to a saprophytic existence and can survive long periods in an active stage in the absence of a suitable host. The destruction of the host is of less consequence to the facultative parasites which therefore cause more immediate and drastic damage, such as necrosis and wilting.

Mode of action

Parasites produce pathogenic symptoms in their host plants in a variety of ways. Obligate parasites live directly on host cells and even this physical penetration of the plant tissues and utilisation of plant food may produce little immediate effect. Facultative parasites may produce a variety of toxins and enzymes which kill the plant tissues as they are penetrated. Many disease symptoms are the result of the defence reactions of the host, and include the production of gums and resins, the suberisation of cell walls, the blocking of xylem vessels by tyloses, and the shedding of infected plant parts.

1. Causal Agents of Crop Diseases

i. Fungi

The majority of plant diseases are caused by various parasitic fungi. Most parasitic fungi are facultative although some are specialised obligate parasites, such as powdery mildews (*Erysiphaceae)* and rusts (*Uredinales*). Fungal pathogens, although diverse in form are characterised by the production of spores which enable them to spread between plants.

Many parasitic fungi disperse their spores through water, in rain splashes or are carried in air currents. Some fungi attack crops at or below the soil level while others are dispersed by insects or through seeds. The dispersal of spores is aided by the fact that most fungal spores are very small and are also produced in large numbers. When the spores of these fungi fall on a suitable host plant they grow into its tissue, absorb food and develop reproductive sporangia.

Some common diseases caused by this genus *phytophora* include*:*

- *Phytophthora palmivora* which causes black pod disease of cocoa
- *Phytophthora infestans* which causes potato and tomato blights
- *Phytophthora parasitica* which causes stem rot of tomato.

Some common diseases caused by the genus *Pythium* include a number of soil inhibiting fungi which usually enter the host plant through wounds and subsequently cause rotting. Seedlings infected by *Pythium* *spp*. turn black and rapidly die; this is often referred to as **damping off diseases**.

- Many crops are attacked at the seedling stage by *Pythium debaryanum* which rapidly causes death of the seedlings.

- Watery wounds rot of potato tubers is often caused by *Pythium ultimum.*

The genus *Peronospora* includes species which are widely referred to as downy mildew diseases. Examples are:

- *Peronospora destructor*; which infests crops such as onion.

- *Sclerospora graminicola* which attack guinea corn.

The genus *Puccinia*, include many different types of rust and smut diseases. They form rust colored spore patches which develop on the epidermis of the infected host plants. These fungi infect graminaceous crops such as maize, guinea corn and rice, making the grains worthless for both food and planting materials.

ii. Bacteria

These microscopic organisms are generally capable of survival where other living organism cannot exist, such as water, the tissue of plants, dust particles and damp soils. Bacteria usually enter into the tissue of crops through wounds, stomata, flowers or fruits. The symptoms of bacterial infection are varied, but the most common ones are decay, accompanied by an unpleasant odour. Examples of bacterial diseases are: blight diseases of guinea corn and bacterial wilt of tomatoes, tobacco, garden eggs and peppers. Affected plants rapidly wilt, collapse and die. Citrus and mango fruits are liable to infection due to bacteria entering the wounds made by sucking insects or birds.

iii. Viruses

Viruses are a group of extremely minute particles which are visible only through a powerful electron. They are very highly specialised obligate parasites and can only exist within living plant cells. Frequently they cause obscure symptoms easily confused with mineral deficiencies of other environmental effects. Plants infected with diseases due to viruses show varying symptoms such as change in leaf color, malformation such as swollen shoots, mosaic leaf patterns and distortion, reduced leaf formation, leaf spot, rings and streak on leaves and stunting.

Most viruses spread between plants by means of living vector, usually insects or nematodes, which themselves become infected with the virus, after feeding on a diseases plant. Many viruses can be carried by insects, particularly sucking insects such as aphids, mealy bugs and leaf-hopper. The knives used in budding and grafting may also transmit viruses if used on infected plants. Viruses are rarely disseminated through seeds.

Examples of common viruses which affect crops are:

- tobacco mosaic virus (TMV)
- cassava mosaic virus (CMV)
- capsicum leaf curl virus (CLCV)
- cocoa swollen shoot virus
- tristeza virus which affects citrus.

Control measures against virus diseases are usually aimed at the vector, but resistant crop varieties and use of clean planting material are also important.

3.5.3 Measures of Controlling Plant Diseases

Plant disease control is concerned with preventing or at least restricting the development of plant disease epidemics. Most control measures for plant disease are designed to prevent rather than cure. They aim to operate on the pathogen before it has established a parasitic relationship with the host.

Principles of plant disease control

Two of these methods are mainly concerned with the pathogen:

- if the pathogen is not already present in an area then methods are devised to exclude it (exclusion);
- if it does get in then attempts are made to eradicate it (eradication).

The other two concern the host:

- by applying a chemical to the plant surface or by modifying the condition under which the plant is growing it is often possible to protect it from attack (protection)

- by breeding, it is sometimes possible to obtain varieties of the particular plant which resist attack (breeding for disease resistance).

Control measures can be classified into various categories. These include cultural practices, the destruction of insects by chemicals and the development of diseases resistant varieties.

a. Cultural practices

i. Crop rotation

Important pest and diseases such as cyst nematode and club root, attack specific crops. By the simple method of planting a given crop in a different plot each season, such pests or diseases are excluded from their preferred host for several seasons.

ii. Destruction of infected material

An important cultural practiced is the eradication of suspected sources of plant diseases. This includes the uprooting of weed hosts and alternate hosts and the removal, burning or burying of diseased plants, particularly those infected by bacterial or virus diseases. Diseased tree crops should be treated by pruning away diseased portions of individual plants, after which all cut surfaces, should be treated with white lead paint.

iii. Ploughing

This brings about physical improvement of the soil structure as a preparation for growing of crops. The improved drainage and tilt may reduce damping-off diseases, expose soil pest to the birds.

iv. Soil fertility

While the correct and balance of major nutrients in the soil are recognised as vitally important for maximum yield and quality, excessive nitrogen levels may encourage the increase of insects such as peach potato aphid, fungi e.g. grey mould. Adequate levels of potassium help control fungal diseases e.g. *Fusarium* wilt on carnation, and tomato mosaic virus. Club root disease of brassicas is less damaging in soil pH greater than six, and lime may be incorporated before planting these crops to achieve this aim. Dressing with suitable fertiliser may stimulate growth of the host plant so that it will recover from damage caused by disease.

v. General farm sanitation

Reasonable sanitary precaution on the farm may help to prevent the introduction of diseases from other fields. Some virus diseases are spread by contact. Clothing, machinery, and equipment that have been in use on such infested fields should be disinfected before being used on other fields.

vi. Seed treatment

To avoid seed borne diseases being carried over from one season to the next, seed to be planted is often treated with a fungicide, e.g. Arasan.

vii. Avoidance

Sometimes, a pest or disease is most prevalent at a certain time of the year. The planting may be so timed that the crop grows during the time when the diseases or pest incidence is least. Example the deliberate planting of early potato cultivars enables harvesting before the maturation of potato cyst nematode, so that damage to crop and the release of the nematode eggs is avoided.

b. Chemical method (destruction of insects' vectors)

i. Use Chemicals (insecticides)

The control of insect vectors which carry disease has been effective in reducing the spread of some diseases such as swollen shoot disease of cocoa and mosaic disease of cassava. Aphids and leaf-hoppers which transmit these diseases can be controlled by the use of **insecticides.**

ii. **Fungal diseases** are controlled by chemicals referred to as **fungicides.** These chemicals may be sprayed or dusted on to the seeds, young leaves, shoots or flower buds before the arrival of the fungal spores.

iii. **Seed treatments** are normally effective when the disease is transmitted via seed. Diseases such as smuts or rust may be controlled by soaking the seeds in fungicides before sowing. Certain chemicals (soil fumigants) are effective in controlling nematodes, soil-borne insects and soil borne diseases.

iv. **Repellents**; Repellents are chemicals which do not actually kill the pests, but they repel them from coming near the plants.

c. Biological control

A more recent approach to the control of plant pests and diseases is biological control, which emphasises the control of diseases and pest through manipulation of natural and ecological factors.

i. **Planting disease-resistant varieties**; the use of disease resistant varieties of some crops has proved to be very successful in the control of plant diseases.

ii. Biological control also refers to control of diseases by the use of other organisms to reduce inoculum density or the disease producing activities of the causative agents of diseases.

d. Physical Method

i. Treating seeds of cereals in hot water to kill the loose smut pathogen (*Ustilago nuda*), and floating of cereal seeds to separate healthy grains from those infected by ergot (*Claviceps purpurea*) are two examples of physical method of disease control.

ii. Grain smut of sorghum may be controlled by soaking seed in water for 4 hours to initiate germination of the fungal spores. The seed is then spread out to dry, first in the shade and later in the sun, causing the germination of spores to be killed without harming the seed. Physical methods of this kind may be widely applicable in Africa for certain diseases, and represent one of the more feasible control options available to smallholders.

4.0 CONCLUSION

This unit concentrated on pest and diseases affecting crops. It explained the nature and characteristics of pest, effects of pests and the control and preventive measures. Diseases, symptoms of plant diseases, causative organisms, control and preventive measures were also treated. It stressed that the effective control of pests and diseases should be based on a sound knowledge and understanding of pests and diseases of a particular crop in a given locality.

5.0 SUMMARY

This unit discussed pest and diseases of crop plants. The characteristics of pests and how they destroy crop produce and how to tackle them were also treated. Diseases, definitions, symptoms and causes of plant diseases were highlighted; and the different methods of disease prevention and control were enumerated and explained.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. Define the term pests.
   b. Categorise pests based on pattern of feeding.
   c. Enumerate the direct effects of pests.
2. a. State the principles of pest control.
   b. Describe the cultural methods of pest control.
   c. What is integrated pest management?
3. a. Distinguish between localised and systemic symptoms of plant diseases.
   b. Give the generalised symptoms of plant disease.
4. a. Explain the chemical method of disease control.
   b. Briefly describe the physical method of disease control.
   c. List the cultural practices of diseases control.

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UNIT 2 CROP IMPROVEMENT

CONTENTS

1.0 INTRODUCTION

Crop improvement will always be an important aspect of agricultural industry because crop products are essential to the existence of man. In the past, new land was always cleared and plowed out by the peasant farmer for increased food production. This means of expansion of arable land is seldom possible today. The increased world grain yields were achieved by growing more productive varieties and hybrids, greater fertiliser use and other improvement practices. The breeding of more productive types is the only stable method of increasing crop yields. Improved cultivars of many crops are rapidly replacing inferior local varieties in most countries of the world. The maintenance, production and appropriate distribution of seed stock of improved types have resulted in striking increases in crop yields in many countries. Some of the outstanding accomplishment of crop breeding is the development of disease-resistant varieties of wheat, rice, maize, sugarcane, potatoes sorghum and alfalfa. This unit treats those aspects of crop improvement such as methods of crop breeding and production of hybrid seeds as well as examined the Mendelian laws of inheritance.

2.0 OBJECTIVES

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

- state Mendel's first law of inheritance
- state the objectives of crop breeding
- describe selection method of crop breeding
- describe the techniques of hybridisation.

3.0 MAIN CONTENT

3.1 Mendel's Work in Genetics

Gregor Mendel (1822-1884) carried out the first quantitative studies on inheritance. He published the results of his work in1867. These laid down the basic laws of genetics.

Mendel's conclusions about inheritance were based on his hybridisation experiments in which he considered either one pair of contrasting characters or two pairs of contrasting characters involving cross between plants with these characters. The cross involving only one pair of contrasting character is called **monohybridisation** and the related experiment is called **monohybrid experiment** or monohybrid cross. Likewise, the cross involving two pairs of contrasting characters is called **dihybridisation** and the related experiment is referred to as **dihybrid** experiment or cross experiment.

3.2 Mendelian Laws

From the results of his experiments, Mendel came to certain conclusions which are referred to as the principles of Mendelian Inheritance or Mendel's Laws of Heredity. Mendel's two important laws are:

- The Law of Segregation (of genes), and
- The Law of Independent Assortment (genes).

Law of Segregation

This is Mendel's first law of heredity. It states that:

- the hereditary characters of an organism are determined by genes (called ' factors' by Mendel) which are discrete unchanging units (do not blend) of inheritance;
- a gene for a character may have alternative forms (alleles) which express the character in different ways;
- in a diploid organism , each character is controlled by two copies of each gene which may be identical alleles (homozygous) or different alleles (heterozygous);
- if a diploid organism has two different alleles (heterozygous) for a character, one allele may be dominant, dictating the expression

of the character to the complete exclusion of other (the recessive allele);

- in a diploid organism that is heterozygous for a character, the two alternative alleles separate (segregate) from each other during meiosis (called 'factor' reducing process by Mendel), each going randomly to a different gamete.

Law of Independent Assortment

This is Mendel's second law. It states that during gamete formation, the way one pair of alleles for a given character distributes itself in the gametes does not affect the way other allelic pairs (for other characters) distribute themselves. This, however, only applies to allelic pairs on different homologous chromosomes. As a result, this law may now be restated in the following way: alleles on different chromosomes assort independently during meiosis (gamete formation). Or this law states that each pair of contrasting characteristics (genes) behaves or segregates independently of those of any other pair. One gene apparently has no influence on another for a different characteristic.

Law of paired units

There are unit carriers of heredity which occur in pairs. One each pairs came from the mother while the other came from the father. The unit carriers were called by Mendel determiners or **factors** but they are now known as **genes.**

Law of dominance

When two hereditary units of a pair are unlike, the one which functions and produces its character or effect is called **dominant** while the other which remains undeveloped or unexpressed is called **recessive.**

3.3 Crop Improvement

Crop improvement has been in progress since primitive man first exercised a choice in selecting seed from wild plants for growing under cultivation. The greatest advances were made before the dawn of civilisation. Material progress was also made thereafter. However, not until the last century, when some knowledge of genetics was acquired, did crop breeding become a science with the outcome of breeding methods reasonably predictable. Remarkable increases in yield followed the breeding and distribution of semi dwarf, photoperiod- insensitive cultivars of rice and wheat that are resistant to lodging under heavy nitrogen fertilisation.

Crop breeding is concerned mainly with more abundant, stable and economical crop production, but is also deeply motivated by social and humane wants. Farmers now have smooth-awned cereals that do not irritate the eyes, mouth, or skin of the farm workers or livestock. Consumers now have some food products that are higher in protein or certain essential amino acids. They also have sweeter and tenderer sweet corn as well as lighter bread made from stronger wheat. Crops that are easier for man to harvest and feed crops that are more palatable or less toxic to livestock have been developed. Improved cultivars have helped to alleviate crop failures and their accompanying human and livestock starvation.

Objectives of crop improvement

Crop breeders are yet to create a perfect crop variety. Each variety has several weaknesses or defects that curtail maximum yield and quality. The objectives or crop breeding is therefore, to correct these deficiencies while developing new cultivars with higher yield capabilities. First generation hybrids with increased vigour, growth, and reproduction have markedly increased the yields of several crops. Improvements of the following characteristics are considered the objectives of crop breeding:

i. to produced crops that are resistant to common diseases and pest

ii. to produce crops that are resistant to adverse weather condition such as drought, cold, heat and salt

iii. to produce crops that have adaptation to variable photoperiods

iv. to produce crops with adaptation to heavy grazing or frequent cuttings

v. crops with enhanced market quality e.g. higher content of fiber, of protein, sugar, starch, or other extractives; better processing quality for textiles, foods, beverages, and drugs, and better colour

vi. seed quality e.g. higher or lower seed-setting tendency, greater longevity, high viability, larger size and non-shattering

vii. growth habit e.g. more erect or prostrate stems, more or less tillering or branching, more uniform flowering and maturity, more uniform height, longer life, and better ratio of tops to roots

viii. harvesting quality e.g. stronger, shorter, or taller stalks, erect stalks and heads, non-shattering qualities, easier processing and freedom from irritating awns and fuzz

ix. productive capacity e.g. greater vigour, higher fertility and faster recovery after cutting

x. feeding quality of fodder e.g. palatability, leafiness, hull percentage, nutritive value and texture.

3.3.1 Methods of Crop Improvement

There are three general methods of crop improvements namely:

i. Introduction

ii. Selection

iii. Hybridisation.

1. Introduction

This is the act of importing crop variety from other countries to be used as foundation stock in breeding programme. Crop introduction from other countries may be of superior productivity and they often provide better foundation stock for breeding. Foreign varieties may possess resistance to some diseases or insects pests or may have some useful characteristics that can be transferred to adapted varies by hybridisation. Collection of exotic and domestic wild and cultivated species and strains of various crop plants are being screened for disease and insect resistance, and other characteristics that might be useful in breeding.

When some variety, strain or inbred line is found to be outstanding for some desired character such as disease resistance, heterosis capacity or cytoplasmic sterility, it is likely to be used by most plant breeders. This results in narrow genetic base, which could be disastrous when a new or minor race of parasite multiplies and almost destroys previously resistant varieties or hybrids that are widely grown.

2. Selection

Mass selection is a quick method of purifying or improving mixed or un-adapted crop varieties. It is done by selecting a large number of plants of the desired characteristics and then increasing the progeny. It serves to eliminate undesirable types.

i. Pure-line or pedigree selection

Pure-line pedigree selection or individual plant selection consists of growing individual progenies of each selected plant so that their performances can be observed, compared and recorded. Only a few superior strains among the numerous original selections are saved for advanced testing.

In crops that are partly or largely crossed-fertilised selection must be repeated until the strains appear to be uniform. Also cross-fertilised crops selected for propagation must be self pollinated under controlled conditions. This may be done by covering the floral parts to exclude foreign pollen or by hand pollinating, or both.

Pure-line selection offers a quick means of segregating desired types from mixed varieties. In cross-pollinated crops or when the original variety and the selections differ by several genetic factors, several (five or more) generations of selection may be required to purify the strains so that each would continue to breed true thereafter while being tested for yield. The major limitations of this method are the partial inbreeding that reduces yield as well as the lack of complete control of the pollen parentage of the seed ears.

ii. Pure-line concept

The modern methods of handling, testing, and increasing individual selections of self-fertilized crops had as their basis the pure-line concept proposed in 1903 by W. L. Johansson who worked with beans. According to this concept variations in the progeny of a single plant of a self-fertilized species are not heritable but are due to environmental effects. Failure to recognise this principle before resulted in some futile works in continuously selecting self-fertilized crops such as wheat and barley.

When homozygous self-fertilized plants are selected, the progeny is pure for all its characters until outcrossing or mutations occur. Pure-line comprises the descendants of one or more individuals of like germinal constitution that have undergone no germinal change.

3. Hybridisation

Hybridisation is the only effective means of combining the desirable characters of two crop varieties. The first step in breeding by hybridisation is to choose parents that can supply the important character or characters that a good standard variety lacks. It is important to have in mind definite characteristics.
The seeds that develops from the cross-pollinated flowers, when planted, produce plants of the first filial of F_1 generation. These plants should be all alike, only the dominant and mutual recessive characters being expressed. In the second F_2 generation, the plants break up or segregate

into all possible combinations of the dominant and recessive characters of the two parents. Plants of the types desired are selected, these and several subsequent generations are handled as previously described under selection methods. Reselection continues thereafter until the desired strains are uniform usually for three to six generations. However, additional true breeding plants of the desired recombination would be obtained in later generations from segregating F_2 lines.

i. Inbreeding of Cross-fertilised crops

Before making hybrids in cross-fertilized crops, it may be desirable to select and inbreed the varieties for several generations or until they are reasonably pure for the characters desired. Without such inbreeding, the hybrids that are obtained from cross-fertilized crops cannot be reproduced. Artificial self-pollination in a normally cross-fertilized crop leads to segregation into pure uniform (homozygous) lines. There is often rapid reduction in vigor when self-pollination is practiced. When appropriate lines of self-pollinated plants are intercrossed there is usually a restoration of vigor, a fact that is used in hybrid corn production. In addition, certain abnormalities such as sterility, poor chlorophyll development, dwarf habit, lethal seedlings, and susceptibility to diseases may appear as result of inbreeding.

ii. Back crossing

Backcrossing is a useful method of breeding when it is desired to add only one or two new characters to an otherwise desirable variety. In this method the good variety is crossed with one having the other character desired. First generation plants are backcrossed with the good variety. Thereafter in each segregating generation a number of plants approaching the desired new recombination are selected and backcrossed with the good commercial parent. Usually, with repeated rigid selection, the improved type is recovered in approximately five backcrosses.

iii. Bulk Propagation of Hybrid Material

In the bulk method of handling hybrid material the entire population from a cross is grown and harvested in mass each year. Successive crops of seed are sown for five to ten years to allow natural selection for characters, such as cold resistance or insect resistance, to take place. By this time the poorly adapted strains are largely eliminated, while the remaining strains are mostly true breeding (or homozygous). Plants are then selected, and the progenies tested as previously described.

3.4 Production of Hybrid Seed

Commercial hybrid seed of corn can be produced by detasseling the seed-parent rows in a cross-pollination field, or by use of cytoplasmic male-sterile. Pearl millet hybrids have been produced by planting a mixture of four selected lines. They can also be produced by clipping (topping) the upper part of the heads on the seed-parent plants before they shed pollen, but after the stigmas are exerted or by pollinating cytoplasmic male sterile lines. Hybrid seeds of crops that naturally are wholly or largely self-pollinated can be produced economically only by the use of male-sterile lines. Plants with cytoplasmic male-sterility have been discovered or developed in many crops. A related strain that carries the recessive sterile-producer gene is used as a pollinator to maintain or to increase the male-sterile lines. An unrelated variety or strain that carries the dominant fertility-restorer gene is used as a pollen parent to produce commercial hybrid seed.

4.0 CONCLUSION

In this unit we have examined the Mendel's laws of inheritance and how these laws now form the basis for all studies of heredity or genetics. Crop improvement has recorded tremendous progress in the last century due to advances in genetic engineering, genetic mapping and cloning. The traditional methods of crop improvement e.g. selection, introduction and hybridisation as well as production of hybrid seeds were described in this unit. The breeding of more productive types is the only stable means of increasing crop yield; therefore improved varieties are fast replacing inferior local varieties.

5.0 SUMMARY

This unit treats Mendelian laws of inheritance as the foundation for all studies in heredity and genetics. In this unit the objectives of crop improvement in solving complex deficiencies in crop varieties and satisfying the needs of man in terms of food, feed and fiber production were highlighted and discussed. The various methods of crop improvement i.e. selection, introduction and hybridisation were described, so also the method of sustainable hybrid seed production.

6.0 TUTOR-MARKED ASSIGNMENT

1. State the Mendelian laws of inheritance.
2. a. What is crop improvement?
   b. Give the objectives of crop improvement.
3. List the methods of crop improvement and briefly describe any two of them.

4. a. What is hybridisation?
   b. Briefly describe back crossing and the method of hybrid seed production.

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UNIT 3 HARVESTING AND PROCESSING OF FIELD CROPS

CONTENTS

1.0 INTRODUCTION

Harvesting constitutes a major operation among agricultural activities. Considered for a long time as the last step in production, it can also be approached as the first activity in the postproduction system. Harvesting has a great influence on subsequent processing and preservation of the products. This unit will take you through the different processes of harvesting, threshing, cleaning, drying, grading and grain quality parameters of major field crops.

2.0 OBJECTIVES

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

- identify different stages of crop maturity and subsequently, recommend the most appropriate stage to harvest field crops
- describe the different harvesting and threshing methods of rice, maize, millet and sorghum

- describe the methods of cleaning, drying and grading of grains and be able to make appropriate recommendation as to the best method of carrying out the above mentioned processes
- describe quality characteristics of grains intrinsic and induced qualities.

3.0 MAIN CONTENT

3.1 Harvesting of Field Crops

1. Stage of harvest for small grains

Grains cease growing and gaining in dry weight when they reach approximately the hard-dough stage, or when the moisture content of the grain drops below about 40 per cent. Further ripening consists of desiccation unaccompanied by transport of nutrients into the kernel. Ripening is not entirely uniform among different heads or different grains within a head. Consequently, growth may continue until the average moisture content is appreciably below 40 per cent. Small grains at the hard-dough stage have a moisture content of 25 to 35 per cent, the heads are usually light yellow, and the kernels are too firm to be cut easily with the thumbnail.

Effect of premature harvest

1. Premature harvest reduces both yield and quality.

2. Under hot, moist conditions, grain quality deteriorates rapidly, mould problems can develop within days and insect problems in a month or two.

3. Underdeveloped grains are low in test weight, starch content and market value.

Strategies for handling over-moisture grain

1. Blending with dry grain to meet moisture specifications.

2. Aeration cooling to prevent mould development until the grain is used or dried.

3. Aeration drying.

4. Hot air drying.

5. Drying grain in the paddock.

Effects of delayed harvest

1. Lead to loss of grains due to shattering, crinkling, lodging and leaching.

2. Cereals stems are likely to crinkle down or break soon after maturity, leading to insects attack, sprouting dirtying of the grain, which consequently lowered the grain quality.

3. Weathered or sun-bleach grain is unattractive and often brings a lower grade and the market value.

4. Ripe grains exposed to wet and dry condition for long periods in the field are lower in weight because the grains swell when damp and do not shrink to their original volume after drying.

3.1.1 Methods of Harvesting Field Crops

Harvesting methods differ according to the part of the plant to be used. As regards forage crops, the whole plant is cut, but for underground crops (e.g. groundnuts, roots and tubers), the crop is lifted while the soil sticking to it is removed. With cereals, the crop is first cut either as a whole or partially (ears), and then threshed and cleaned to separate the grain from the ears and straw.

In the latter case, two main alternatives exist, separate harvesting and threshing, or combined harvesting and threshing.

i. Manual harvesting

In developing countries the first alternative is generally the most widely applied. Although harvesting and threshing are still frequently done by hand, their mechanisation has begun to develop during recent years, especially where the crop is produced not for self-consumption but rather for commercial purpose. Nevertheless, such mechanisation has not developed everywhere to the same extent but according to the type of crop concerned, because labour requirements remain high for handling the produce before threshing.

ii. Mechanised harvesting

In industrialised countries, attempts have been made since the beginning of the 20th century to devise machines which would both harvest and thresh grain, so as to reduce the labour requirements involved. Combine harvesters ('combines') which can cut, convey, separate and thresh the grain were the product of this development work. They are in widespread use, and have been used already on large grain production schemes in a number of developing countries.

3.1.2 Factors Affecting Mechanised Harvesting of Field Crops in Nigeria

1. Cropping and Farming Systems

i. Previous analyses of the cropping and farming systems are required to determine the actual needs regarding mechanisation. Location of the land under cultivation, intensification level, prices of products, etc. are some important factors to be considered.

ii. The mechanisation of the harvesting operation for crops - mainly food crops - with yields ranging between 0.5 and 2 tonnes per hectare rarely justifies itself economically.

iii. On the other hand, mechanising the harvesting operation will be more easily justified on an intensified irrigated area of several hectares with paddy rice as main crop, where small farmers can group together, and the sale price for paddy is sufficiently attractive.

2. Cropping Conditions

The constraints affecting harvesting and threshing operations which influence the quality of the product are:

- the moisture content of the grain at harvest time
- the maturity of the crop
- the type of plant involved
- the way it stands in the field.

i. The moisture content of the grain at harvest time

The moisture content of the grain must be between 18 and 23% at harvest time, or between 12 and 20% at the threshing stage. These guidelines determine the start of operations. Below such values, losses (in the case of rice) from shattering during harvest and breakage during threshing are excessively high and bad for the subsequent processing. Above such values, problems arise at storage level: risks of moulds developing and germination of the grain in stores, drying cribs or granaries.

ii. The crop maturity

Crop maturity and type directly affect mechanisation and vice versa. The introduction of mechanised technology has reduced the tendency to plant mixed varieties of grain: single variety crops ripen uniformly thus making it easier to harvest or thresh them mechanically. With crops which do not mature at one time, the choice of the date for performing the harvesting operation will determine the results: for paddy an earlier harvest will generally result in low yields and high percentage of unripe grain; on the other hand, delayed harvesting will lead to shattering losses, higher percentage of broken grain at the processing level, etc. In addition, the weed infestation level will affect the use of machines and also the cleanliness of the harvested and threshed materials.

iii. The type of crop involved

The type of plant influences both the choice of machines and their performance:

1. the grain-straw ratio must be as high as possible to limit the volume of straw entering the machine;

2. the attachment of the grains to the panicles or spikes must allow relatively easy stripping at maturity;

3. erect and short stemmed varieties are preferred (paddy varieties with very curved grain ears make it necessary to cut high proportions of straw, and tall varieties of maize, millet and sorghum prove difficult to mechanise);

4. the abrasive property of certain seeds (e.g., paddy) makes it necessary to use high quality materials in the manufacture of machines.

To meet these objectives, it is necessary to observe a very strict work schedule, especially for wetland paddy. Accordingly, machines must be able to work under particularly difficult conditions: in the mud with special attachments (tracks, cage-wheels, etc.) before the complete drainage of rice fields, at low working speeds, on a produce difficult to cut being still partially green, and handling of a product often soiled with mud.

3. Social and Labour Constraints

Harvesting is a labour-intensive operation but is less arduous than threshing. Because most of the rural population consider threshing as a particularly tedious operation (especially in the case of millet), grain producers accept the relatively high cost of mechanical threshing.

The skills and experience of farmers, and the interests of traditional systems, must necessarily be taken into account when mechanising certain operations. It will be easier to extend the use of harvesting machines where farmers are already employing other powered equipment such as tractors, motor pumps or processing units. The availability of workers skilled in the operation, maintenance and repair of engine-powered equipment favours the adoption of new machines.

Lastly, in developing countries harvesting and threshing operations are traditionally carried out by women. However, in most situations, as these operations become mechanised, they are taken over by men and the role of women is reduced to winnowing and the gleaning of grain scattered during harvesting and threshing. The mechanisation of post-harvest operations frequently means the transfer of activities from women to men.

4. Economic Constraints

Economic constraints are a drawback to the purchase of farm machinery. The high costs involved, above individual farmers' resources, allow the acquisition of such equipment only if credit and the possibility of farmers grouping together exist. Alternatively, if private individuals are interested in equipping themselves, they can hire out their services to the rest of the community.

To justify and encourage the purchase of machines, technical versatility can be an incentive (e.g. a rice thresher which can also be used for threshing millet and maize), even if the equipment proves less efficient with certain crops than a specific single-purpose one. In such a case, the choice of the equipment should be made according to the crop which is mechanised first. In practice, the costs of machines and services vary from one country to another.

3.1.3 Rice Harvesting and Threshing Methods

1. Rice Harvesting

i. Manual harvesting

In many countries rice ears are cut by hand. A special knife is frequently used in South East Asia ("ani-ani"), Latin America ("cuchillo") and Africa. For instance, in the Casamance region of Senegal, rice is cut stem by stem with a knife, 10 cm below the panicle so as to leave straw in the field in amounts large enough to produce grazing for cattle. Nevertheless such practice is labour intensive.

To harvest denser varieties (500 stems/sq metre instead of 100) a sickle is used mainly on a generally wetter produce. But work times remain high: 100 to 200 man-hours per ha for cutting and stocking.

ii. Mechanised harvesting

During past decades the mechanisation of rice harvesting has rapidly evolved. It was first developed in Japan, then in Europe and has now reached many tropical countries.

The first machines used were simple animal-drawn (horses in Europe, oxen in the tropics) or tractor-driven mowing machines fitted with a cutter bar. The improvements made on this equipment have first resulted in the development of swathers. These drop the crop in a continuous windrow to the side of the machine making it easy to pick up the panicles and manually tie them into bundles. The next step forward has been the reaper that forms unbound sheaves; and finally the reaper/binder which has a tying device to produce sheaves bound with a twine. However the supply, cost and quality of the twine are the main problems associated with the use of such equipment.

The output of these machines varies between 4 and 10 hours per hectare, which is slow. However, they may be usefully introduced into tropical rice growing areas, where hand harvesting results in great labour problems. In temperate countries they have been gradually replaced by combine harvesters.

2. Rice threshing methods

After being harvested, paddy bunches may be stacked on the plot. This in-field storage method results in a pre-drying of the rice ears before threshing, the purpose of which is to separate seeds from panicles.

i. Traditional threshing

The traditional threshing of rice is generally made by hand: bunches of panicles are beaten against a hard element (eg, a wooden bar, bamboo table or stone) or with a flail. The outputs are 10g to 30kg of grain per man-hour according to the variety of rice and the method applied. Grain losses amount to 1-2%, or up to 4% when threshing is performed excessively late; some unthreshed grains can also be lost around the threshing area.

In many countries in Asia and Africa, and in Madagascar, the crop is threshed by being trodden underfoot (by humans or animals); the output is 30kg to 50kg of grain per man hour. The same method, but using a vehicle (tractor or lorry) is also commonly applied. The vehicle is driven in circles over the paddy bunches as these are thrown on to the threshing area (15m to 20m in diameter around the stack). The output is a few hundred kg per hour. This method results in some losses due to the grain being broken or buried in the earth.

In south-east Asia, total losses induced by traditional harvesting and threshing methods are estimated between 5 and 15%.

ii. Mechanised threshing

From a historical viewpoint, threshing operations were mechanised earlier than harvesting methods, and were studied throughout the 18th century.

Two main types of stationary threshing machines have been developed.

The machines of Western design are known as 'through-flow' threshers because stalks and ears pass through the machine. They consist of a threshing device with pegs, teeth or loops, and (in more complex models) a cleaning-winnowing mechanism based upon shakers, sieves and centrifugal fan. The capacities of the models from European manufacturers (e.g., Alvan Blanch, Vicon, Borga) or tropical countries (Brazil, India, etc.) range from 500 to 2000kg per hour.

In the 70s, IRRI developed an axial flow thresher which has been widely manufactured at local level. Such is the case in Thailand where several thousands of these units have been put into use. They are generally mounted on lorries and belong to contractors working about 500 hours per year.

More recently, a Dutch company (Votex) has developed a small mobile thresher provided with either one or two threshers. The machine has been widely adopted in many rice growing areas. The simple design and work rates of these machines (about 500kg per hour) seem to meet the requirements of rural communities.

The 'hold-on' thresher of Japanese design, is so-called because the bundles are held by a chain conveyor which carries them and presents only the panicles to the threshing cylinder, keeping the straw out. According to the condition of the crop, work rates can range between 300kg and 700kg per hour (Iseki model). The main disadvantage of these machines is their fragility.

3. Combined harvesting and threshing methods

Combine-harvesters, as the name implies, combine the actions of reaping and threshing. Either the 'through-flow' or the 'hold-on' principle of threshing may be employed, but the reaping action is basically the same. The main difference is that combine-harvesters of the Western ('through-flow') type are equipped with a wide cutting bar (4-5m) while the working width of the Japanese ('hold-on') units is small (1m). According to the type of machine used, and especially to their working width, capacities range from 2 to 15 hours per hectare.

Such machines are being increasingly used in some tropical countries. In the Senegal River Delta region, private contractors or farmers' organisations have recently acquired combine harvesters, mainly of the Western type (Massey Ferguson, Laverda, etc.). So, almost 40% of the Delta surface area is harvested with a pool of about 50 units. Between 200 and 300 hectares of winter rice are mechanically harvested. In this region the popularity of combine harvesters is high despite their poor suitability for some small-sized fields.

3.1.4 Maize Harvesting and Threshing Methods

1. Maize Harvesting

i. Manual harvesting

In village farming systems the crop is often harvested by hand, and cobs are stored in traditional structures. Quite often, the crop is left standing in the field long after the cobs have matured, so that the cobs may lose moisture and store more safely after harvest.

During this period the crop can suffer infestation by moulds and insects and be attacked by birds and rodents. To reduce such risks, an old practice (called "el doblado") is sometimes applied in South and Central America. This involves hand-bending the ears in the standing crop without removing them from the stalks. It helps mainly to prevent rainwater from entering the cobs, and also limits bird attacks; but, because of the high labour requirements involved, the practice is gradually falling into disuse.

Manual harvesting of maize does not require any specific tool; it simply involves removing the cob from the standing stalk. The work time averages 25 to 30 days per hectare. Traditionally, maize cobs are commonly stored in their unhusked form. To improve their drying, it is often recommended to remove the husks from the cobs. Maize husking is usually a manual task carried out by groups of women. Some machine manufacturers (e.g. Bourgoin in France) have developed stationary maize huskers, such as the "Tonga" unit.

ii. Mechanised harvesting

The first mechanised harvester to detach ears of maize from the standing stalks, the 'corn snapper', was built in North America in the middle of the 19th century. This was followed by the development of 'corn pickers', which incorporated a mechanism for removing the husks from the harvested ears. The first animal-drawn maize pickers were replaced by tractor-drawn units (l or 2 rows) and then tractor-mounted units (1 row). Finally came the development of self-propelled units capable of harvesting from up to 4 rows. A specific feature in maize harvesters is the header which leaves the stalks standing as it removes the ears.

The rates of work can vary from 2 hours per hectare with a 3-row self-propelled harvester to 5 hours per hectare with a tractor-drawn or -mounted single row unit. Generally speaking, harvest losses range from 3% to 5%, but they may be up to 10%-15% under adverse conditions. Depending on the situation, a single-row harvester can be employed effectively on up to 20 hectares or more; but the use of a multi-row machine demands several tens of hectares to be economically effective.

Specially designed for harvesting maize as grain, the corn-sheller was initially a cornhusker in which the husking mechanism was replaced by a threshing one (usually of the axial type). Corn-shellers are self-propelled machines of the 3 to 6-row type with capacities of 1 to 2 hours per hectare. The surface areas harvested during a 180-hour campaign range between 100ha (with a 3-row unit) and 200ha (with a 6-row one).

Another alternative consists of equipping a conventional combine with a number of headers corresponding to the machine horsepower. However, although widely used, such a method requires many adjustments to the threshing and cleaning mechanisms.

2. Maize Threshing Methods

i. Shelling and threshing

Traditional maize shelling is carried out as a manual operation: maize kernels are separated from the cob by pressing on the grains with the thumbs. According to the operator's ability the work rate is about 10kg per hour. Outputs up to 20kg per hour can be achieved with hand-held tools (wooden or slotted metal cylinders). To increase output, small disk shellers such as those marketed by many manufacturers can be recommended. These are hand-driven or powered machines which commonly require 2 operators to obtain 150kg to 300kg per hour. Another threshing method, sometimes applied in tropical countries, involves putting cobs in bags and beating them with sticks; outputs achieved prove attractive but bags deteriorate rapidly.

ii. Motorised threshing

Nowadays, many small maize shellers, equipped with a rotating cylinder of the peg or bar type, are available on the market. Their output ranges between 500 and 2000kg per hour, and they may be driven from a tractor power take off or have their own engine; power requirements vary between 5 and 15hp according to the equipment involved. For instance the French Bourgoin "Bamba" model seems well-suited to rural areas in developing countries because of its simple design, easy handling and versatility (maize, millet sorghum, etc.).

3.1.5 Millet and Sorghum Harvesting and Threshing

1. Harvesting of Millet and Sorghum

i. Manual harvesting

In Africa, and especially in the Sudano-Sahelian area, these cereals constitute the staple food in the human diet. They are harvested almost exclusively by hand, with a knife after uprooting or bending the taller stems to reach the spikes. Harvesting and removal from the field takes 10 to 20 days per hectare, according to yields. Harvested ears are stored in traditional granaries while the straw is used as feed for cattle or for other purposes (e.g. thatching).

ii. Gradual mechanisation of threshing

Women separate the grain from the ears with a mortar and pestle, as it is needed for consumption or for marketing purpose. The threshed grain is cleaned by tossing it in the air using gourds or shallow baskets.
This traditional method is arduous and slow at (10kg per woman-day). Consequently, research has been conducted for some years on how to mechanise it.

The mechanical threshing of sorghum ears does not raise any special problems: conventional grain threshers can be used with some modifications; such as adjustment of the cylinder speed, size of the slots in the cleaning screens, etc. On the other hand, the dense arrangement of spikelets on the rachis and the shape of millet ears (especially pearl millet), make their mechanical threshing excessively difficult.

The first millet and sorghum threshers were developed in Senegal in the 1960-70s: the Siscoma BS 1000 and the Marot DAK II. Giving relatively high outputs (about 1000kg per hour) they have been intended for village farmers' groups, cooperatives or private contractors going from village to village to work on big threshing layouts. The multipurpose "Bamba" thresher, better suited to rural communities, has a capacity of about 300kg per hour. The Senegalese pool of millet and sorghum threshers currently amounts to 120-150 units.

As regards mechanised harvesting at family level, some hand-operated threshers (Champenois) were developed and tested experimentally but they did not prove very successful. CIRAD is currently working on the design of powered millet threshers of low capacities (50 to 100kg per hour).

3.2 Grain Cleaning

Threshing operations leave all kinds of trash mixed with the grain; they comprise both vegetable (e.g. foreign seeds or kernels, chaff, stalk, empty grains, etc.) and mineral materials (e.g. earth, stones, sand, metal particles, etc.), and can adversely affect subsequent storage and processing conditions. The cleaning operation aims at removing as much trash as possible from the threshed grain.

i. Manual cleaning of grains

The simplest traditional cleaning method is winnowing, which uses the wind to remove light elements from the grain.

ii. Mechanised cleaning

The most rustic equipment is the winnower a fan-originated current of air passes through several superposed reciprocating sieves or screens. This type of machine was widely used in the past for on-farm cleaning of seed in Europe. It can be either manually powered or motorized; capacities range from a few hundred kilogram's to several tones per hour.

In Europe, with the use of combine harvesters and the development of centralised gathering, cereal winnowers have been progressively replaced by seed cleaners in the big storage centers. These machines, also equipped with a system of vibrating sieves, are generally capable of very high outputs (several tens of tones per hour).

In developing countries, mechanising the cleaning operation at village level has seldom been felt as a necessity, because of the lack of quality standards in grain trading. However, because of the current trend towards privatisation of marketing networks, the demand for cleaning machines will probably increase. The local manufacture and popularisation of simple and easily portable equipment, such as winnowers or screen graders suited to cereal crops, need to be encouraged. CIRAD/SAR has recently developed cleaning machines of the rotary type with outputs of a few hundred kilograms per hour.

3.3 Drying of Grains

i. Drying Mechanisms

In the process of drying, heat is necessary to evaporate moisture from the grain and a flow of air is needed to carry away the evaporated moisture. There are two basic mechanisms involved in the drying process; the migration of moisture from the interior of an individual grain to the surface, and the evaporation of moisture from the surface to the surrounding air. The rate of drying is determined by the moisture content and the temperature of the grain and the temperature, (relative) humidity and velocity of the air in contact with the grain.

In general, the drying rate decreases with moisture content, increases with increase in air temperature or decreases with increase in air humidity. At very low air flows, increasing the velocity causes faster drying but at greater velocities the effect is minimal indicating that moisture diffusion within the grain is the controlling mechanism.

Grains are hydroscopic and will lose or gain moisture until equilibrium is reached with the surrounding air. The equilibrium moisture content

(EMC) is dependent on the relative humidity and the temperature of the air.

It is very important to appreciate the practical significance of the EMC. Under no circumstances is it possible to dry to moisture content lower than the EMC associated with the temperature and humidity of the drying air.

ii. Sun Drying

The traditional practice of grain drying is to spread crop on the ground, thus exposing it to the effects of sun, wind and rain. The logic of this is inescapable; the sun supplies an appreciable and inexhaustible source of heat to evaporate moisture from the grain, and the velocity of the wind to remove the evaporated moisture is, in many locations, at least the equivalent of the airflow produced in a mechanical dryer.

Even today, sun drying of grain remains the most common drying method in tropical developing countries. It is first employed when the crop is standing in the field prior to harvest; maize cobs may be left on the standing plant for several weeks after attaining maturity. Although not requiring labour or other inputs field drying may render the grain subject to insect infestation and mould growth, prevent the land being prepared for the next crop and is vulnerable to theft and damage from animals. Drying in the field may also be carried out after harvest with the harvested plants laid in stacks with the grain, maize cobs or panicles raised above the ground and exposed directly to the sun.

Drying on flat exposed surfaces is the most common way of drying grain after harvesting and threshing. For drying, small amounts on the farm grain may be spread on any convenient area of land. Contamination with dirt cannot be easily avoided with this method and cleaner dried grain can be obtained by drying the grain on plastic sheets, preferably black.

Purpose-constructed drying floors are commonly used where there is a need to dry large quantities of grain during the season, e.g. at most rice mills. The floors are usually made of concrete or brick, these materials presenting a relatively smooth and hardwearing surface. Floors should be constructed to withstand the movement of vehicles and sloped or channeled to hasten the runoff of rainwater. The paddy is spread in a thin layer on the floors and raked at intervals, preferably 7-8 times daily, to facilitate even drying. At night the paddy is heaped into rows and covered with sheeting.

The grain can reach temperatures as high as 60°C under clear skies and the rate of drying can be extremely high. Under these circumstances kernel cracking and loss of head rice can be appreciable, particularly if paddy is dried to below 14% moisture. Covering the paddy around midday may be beneficial under particularly hot and sunny conditions. Experiments at IRRI have shown that cracking can be reduced by 25% if paddy is dried in the shade but the benefit from the improved quality is generally more than offset by the longer drying times and hence reduced throughput and increased costs.

In rainy weather, even though drying will be slow, every effort should be made to prevent wet freshly-harvested paddy from over-heating with deterioration in quality by spreading on floors rather than let it remain in heaps and sacks. Under these conditions or when there is great demand for drying space paddy can be dried to 17-18% moisture and then temporarily stored for 15-30 days before final drying.

iii. Crib Drying

Compared with paddy, cob maize can remain at relatively high moisture contents, in excess of 20% with natural ventilation for considerably longer periods, from one to three months. The maize crib in its many forms acts as both a dryer and a storage structure. The rate and uniformity of drying are controlled by the relative humidity of the air and the ease with which air can pass through the bed of cobs. The degree of movement of air through the loaded crib is largely attributable to the width of the crib.

iv. Solar Dryers

An improved technology in utilising solar energy for drying grain is the use of solar dryers where the air is heated in a solar collector and then passed through beds of grain. There are two basic types of solar dryer appropriate for use with grain: natural convection dryers where the air flow is induced by thermal gradients; and forced convection dryers wherein air is forced through a solar collector and the grain bed by a fan.

Natural convection dryers are generally of a size appropriate for on-farm use. The dryer consists of three components, a solar collector, the drying bin and a solar chimney. For a 1 tonne capacity dryer the collector is 4.5 m long and 7.0 m wide with the solar absorber base of burnt rice husks or black plastic sheet covered with clear plastic sheet. The drying bin is 1.0 m long and 7.0 m wide with a base of perforated steel or bamboo matting.

The solar chimney provides a column of warm air that increases the thermal draught of air through the dryer.

The forced convection solar dryer can be considered as a conventional mechanical drying system in which air is forced through a bed of grain but the air is heated by a flat plate solar collector rather than by more conventional means.
Considerable work has been undertaken in developing low-cost and efficient solar collectors for crop drying applications. The simplest type of collector is the bare plate which consists simply of an air ducts the uppermost surface of which acts as the absorber plate. The covered plate collector in its many forms utilises a translucent cover above the absorber plate.

The optimum design suitable for use at farms and mills in developing countries is probably the bare plate collector which is capable of operating at a collection efficiency of 40-50% with airflow of 0.10 $kg/s.m^2$.

A major advantage of the bare plate collector is that it can be easily incorporated into the roof of a dryer or storage building. Corrugated iron is a popular and inexpensive roofing material in many areas and when painted black forms an excellent solar absorber. A false ceiling can be fixed to the roof joists so forming a shallow duct running the length of the building and easily connected to a fan via ducting at one end of the building. The heat available from the collector is weather dependent and consideration should therefore be given as to whether solar energy should be the sole source for heating the air or a supplement to more conventional heating systems.

5. Effect of Drying on Grain Quality

The drying operation must not be considered as merely the removal of moisture since there are many quality factors that can be adversely affected by incorrect selection of drying conditions and equipment. **The desirable properties of high-quality grains include**:

- low and uniform moisture content
- minimal proportion of broken and damaged grains
- low susceptibility to subsequent breakage
- high viability
- low mould counts

- high nutritive value
- consumer acceptability of appearance and organoleptic properties.

1. Moisture content

It is essential that the grain after drying is at moisture content suitable for storage. As discussed, the desired moisture content will depend on the type of grain, duration of storage and the storage conditions available. It is also important that the drying operation is carried out to minimise the range of moisture levels in a batch of dried grain. Portions of under-dried grain can lead to heating and deterioration.

2. Stress cracking and broken grains

Drying with heated air or excessive exposure to sun can raise the internal kernel temperature to such a level that the endosperm cracks. The extent of stress cracking is related to the rate of drying. Rapid cooling of grain can also contribute to stress crack development.

3. Nutritive value

Grain constituents such as proteins, sugars and gluten may be adversely affected when the grain attains excessive temperatures. The feeding value of grains can be lowered if inadequately dried.

4. Grain viability

Seed grain requires a high proportion of individual grains with germination properties. The viability of grain is directly linked to the temperature attained by grains during drying.

5. Mould growth

Many changes in grain quality are linked to the growth of moulds and other microorganisms. The rate of development of microorganism is dependent on the grain moisture content, grain temperature, and the degree of physical damage to individual grains. Mould growth causes damage to individual grains resulting in a reduction in value. Under certain circumstances mycotoxin development can be a particular hazard.

6. Appearance and organoleptic properties

The colour and appearance is as perceived by the customer and/or consumer. For example, the colour of milled rice can be adversely affected if the paddy is dried with direct heated dryers with poorly maintained or operated burners or furnaces.

3.4 Standardisation and Grading of Grains

Most countries have developed national standards for their main grain crops. These have evolved to facilitate the movement of grain, providing both sellers and purchasers with guidelines to support financial transactions, and ensuring that quality will meet up with end-use requirements.

Where trading involves direct choice and price negotiation in front of the commodity, grading standards are rarely employed, quality is assessed visually and is influenced by end user, and the price is determined more by local rather than national factors. For transactions that involve the movement of large volumes of grain over long distances, the buyer may never meet the seller or be able to examine the whole consignment. The standard will provide an unambiguous description of the quality of the consignment and assist in the formation of a legally-binding contract. Standards can also be seen to protect consumers' rights through setting limits to the amount of unsuitable or noxious material.

The use of grading standards can send a clear indication of quality requirements to both producer and end-user. Although some countries have sought to support small farmers through purchase of all grain at the same price without regard to quality: under these circumstances grading standards cease to be operative by default. This may stimulate productivity but creates problems for end-users such as millers who require uniformity and consistency in quality to ensure efficient and cost-effective processing.

Whilst establishment of standards can set the guide-lines and rules for sale and purchase of grains, there has to be an institutional framework for their implementation. This is much easier to establish at centers of aggregation of grain, e.g. ports, parastatals grain depots, than in the more diffuse rural areas and markets, where control and supervision of regulations are difficult.

Notwithstanding these problems, the establishment of quality and grading standards for producers and users can be beneficial in the following ways:

Advantages of quality and grading standards

1. Graded grains are likely to be more equably priced than non-standardised grains. This will bring stability not only to market prices but also to the quality offered.

2. Prices quoted against a recognised grade assist producers and traders to market their products. This will also benefit net consumers of grains in more stable prices with assured quality.

3. Greater conformity in quality through standardisation will provide the millers, bakers and other processors with the consistency necessary for optimum performance.

4. Standards reveal clear variations in quality and indicate the opportunities for improvement and the potential rewards to be obtained.

5. The sanitary hazards associated with the inter-country movement of grain can be reduced if clearly-defined standards are enforced, particularly in relation to the prevention of spread of serious storage pests like the Larger Grain Borer.

Disadvantages of standardisation and grading

1. National standards may reflect local end-uses and hinder export to areas that have differing requirements. Whilst restricting opportunities for commercial trade, this can also be detrimental for regional food security. The stimulation of regional trade would require inter-country conformity in export standards. These may have to be more stringent in relation to physical conditions such as moisture content, defective grains and insect infestation, than that for national use.

2. The establishment of standards and the quality assurance practices to regulate and enforce them carries costs which have to be carefully considered to avoid imposing unnecessary expense for little improvement in quality.

3.5 Quality Characteristics of Grains

Consumers have become accustomed over the years to demanding grain with particular qualities. Where consumers are close to the source of the grain, e.g. in local markets, their own preferences and the laws of supply and demand will control the quality of the grain. However, where grain is traded over large distances, particularly internationally, the consumer will have no direct influence over quality, and regulatory standards must be established and imposed to protect consumer rights. Therefore criteria of grain quality must be established and accepted by all parties in the grain trade. The criteria assigned to grain are the intrinsic varietals qualities and those which are environment - or process induced. The more important quality criteria as they relate to grading of grain are described in the following sections.

Intrinsic qualities of grains

1. Colour

Cereal grains are pigmented and range through the colour spectrum from very light tan or almost white, to black. Where extractive milling is required, highly-pigmented varieties may give low yields of white flour.

2. Composition

Composition, e.g. protein, carbohydrate, lipids and their breakdown products, qualitatively influences product acceptability, by affecting texture and taste. Quality changes evolve slowly in stored grain and more rapidly in milled or processed intermediary products.

Some grain components, for example husk, are inedible and quantitatively influence product yield and gross nutrient available to the consumer.

3. Bulk density

Each type or variety of grain when in optimum health, fully mature, etc. has a characteristic bulk density. This is defined as the weight per standard volume measured in a standard manner. The same characteristic is variously known as 'test weight', 'bushel weight' or 'specific weight'. If the bulk density varies the trend is usually downwards and indicative of reduced overall quality of the grain. Hence it is often measured in the grain trade. Factors which commonly affect bulk density are insect infestation, excessive foreign matter and high percentage moisture content. In wheat, bulk density is considered to be a reasonable indicator of milling yield.

Bulk density should not be confused with 'specific volume'. The terms are related, but the distinction is necessary because it is an established fact that the 'bulk density' of grain increases when it is stored in large quantities, bag or bulk, due to compaction.

4. Odour, aroma

Most grain types, when fresh, have a distinctive natural odour or aroma. This is generally accepted as an indicator of good quality, although some people prefer grain which smells 'old' or even fermented.

As with most natural produce, some grain varieties are better-liked than others because of their odour. Certain cultivars of rice, for example, possess aromatic qualities which are considered desirable by some consumers.
See also mixed

5. Size, shape

Rice, as a whole-grain food, is classified by size (length) and shape (length: breadth ratio). Other grains also have size considered in their specification. In general a small range in size assists with processing and handling.

Induced qualities of grains

1. Age

During the post-harvest phase, grain undergoes complex biochemical changes termed 'aging'. Changes to carbohydrate, lipids and protein fractions result in, for example, firming of texture in rice on cooking, and increased gas-retention capability in wheat flour. For most consumers, the effects of these changes are considered to be desirable. When plotting consumer acceptability of a grain product against its age since harvesting, generally it is considered to be maturing during the upward curve of the graph, and deteriorates only when the curve changes direction downwards.

2. Broken grain

Grain is marketed normally in whole grain form and is considered to be of inferior quality if broken. Breakage may occur from fissures as a result of excessive drying/weathering conditions in the field or during handling. Breakage reduces quality by reducing acceptability and by increasing susceptibility to infestation during storage. This affects milling yield by contributing to weight loss.

3. Chalky or immature grain

Empty grains result from sterility and pre-harvest infections and insect attack. Immature grain content is affected by time of harvest. In rice, immature grains are greenish in color. Thin white (usually opaque) grains are caused by incomplete grain filling and may result from pests or disease. Chalkiness is caused by incompletely filled starchy endosperm which disrupts light transmission, causing opaque regions. In most cereals, chalky areas have lower mechanical strength on crush tests and may break during handling. The broken portion is more easily invaded by certain storage pests.

4. Foreign matter

Dilution of the prime product by foreign matter reduces the value, and also may affect handling and processing. Foreign matter may be sub classified as:

- Animal origin - insects and their products, rodent excrete, etc.
- Vegetable origin - straw, weeds, seeds, dust, micro-organisms/toxins
- Mineral origin - stones, mud, dust, glass, metals, oil products, pesticide residues.

Elements from all three subclasses may render the grain unfit for consumption. Potentially the greatest threat to health probably is from micro-contamination with the bacterial products of poor sanitation, and with toxins and chemical pesticide residues.

5. Infested, infected grain

Grain mass, and therefore yield, is reduced by infestation. Contamination not only has direct food hygiene implications but also indirect ones, as invading micro-organisms may produce toxins under certain conditions which may lead to acute or chronic illness.

6. Mixed varieties

A mixture is an indication of poor pre- and post-harvest management and supervision, e.g. seed selection, lot segregation and treatment, contamination, etc. Grains differing in size and other characteristics affect processing potential. Whilst preference for a particular variety may be influential nationally or regionally, internationally-traded grain is recognised usually by grain type rather than by variety e.g. yellow or white maize. Exceptions do occur, e.g. basmati rice, (see odour, aroma).

7. Moisture content

Moisture content (mc) of grain plays a crucial role in post-harvest processing and is associated with most of the induced characteristics. Water vapour will diffuse throughout a bulk of grain and the mc will tend to equalise. 'Hot spots' may occur at a site of increased respiration (caused by sprouting, infestation or microbial activity), and condensation may occur on cold grain or containers.

4.0 CONCLUSION

Timely harvesting of crops ensures grains of good quality and storability while delayed or premature harvesting could lead to loss of yield, quality and poor storability. Various methods of harvesting, thrashing, cleaning, drying, grading and standardisation of grains were treated. Parameters of grain quality and factors affecting them were discussed. Harvest and threshing methods of rice, maize, millet and sorghum where examined in details. Mechanical and manual methods of harvesting field crops were also treated and the factors militating against effective mechanisation of harvesting of field crops in Africa were examined.

5.0 SUMMARY

This unit treated harvesting of field crops particular emphasis was paid to harvesting, thrashing, and shelling of rice, maize, sorghum and millet. The various methods of cleaning, drying and grading of crops as well as how these aspects affect grain quality were discussed. The intrinsic and induced qualities were explained. Standardisation and grading of crops were also treated

6.0 TUTOR-MARKED ASSIGNMENT

1. a. State the effects of the following:
   - o Premature harvesting of crops.
   - o Delayed harvesting of crops.

   b. List the factors affecting mechanised harvesting of crops.

   c. Discuss any three of rice harvesting methods.
2. a. Briefly describe rice harvesting methods.

   b. Briefly describe maize thrashing methods.

   c. What are the advantages of quality grading and standardisation?
3. a. State the methods of drying of grains.

   b. Give a brief explanation of any two methods of drying grains.

   c. What are the effects of drying on grain quality?
4. a. Briefly describe the intrinsic qualities of grain.

   b. Give a brief description of any 5 of induced qualities of grains.

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UNIT 4 STORAGE OF FARM PRODUCE

CONTENTS

1.0 INTRODUCTION

The storage of crops and other agricultural products for food in periods of scarcity and famine is probably as old as agriculture. The need for the storage and preservation of agricultural products has been necessitated by:

1. the alternation of cycles of favourable and unfavourable periods for the optimum growth and production of crops as characterised by the dry and rainy seasons in the tropics and the winter and summer in the temperate regions

2. by vagaries of nature such as floods, drought or major pest and disease outbreaks causing complete crop failure.

Poor storage is one of the major causes of food shortages and low agricultural supply in the world. According to the Food and Agricultural Organisation (FAO), post-harvest losses for grains amounted to over 200 million tonnes yearly, yet only about 20 million tonnes of grain are enough to feed adequately a population of 500 million for one year.

In Nigeria and other developing countries loss of agricultural products during storage could amount up to 30% for grains and up to 50% for root and tuber crops. These figures indicate the importance of food storage if the country is to feed its rapidly growing population and attain some level of food sufficiency and security. This unit treats the importance of storage, short and long term methods of grain storage, pest and rodents of importance in grain storage, integrated method of rodents control and safety measures during carrying out rodent control programme.

2.0 OBJECTIVES

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

- define storage and state the importance of storage to the economy of Nigeria
- describe the different methods of storage of farm produce
- identify the most effective methods of grain storage
- describe rodents pest of stored product and state the principles of rodent control
- describe the integrated stored pest management system.

3.0 MAIN CONTENT

3.1 Storage

Storage may be defined as the act of preserving and keeping agricultural produce or any commodity for future use without necessarily losing its quality. There should be little or no change in chemical or physical condition as to reduce its quality. Thus, the main objective of storage is to preserve the produce such that it will still be valuable and useful to the ultimate consumer.

3.2 The Role of Storage in the Economy

In most countries grains are among the most important staple foods. However they are produced on a seasonal basis, and in many places there is only one harvest a year, which itself may be subject to failure. This means that in order to feed the world's population, most of the global production of maize, wheat, rice, sorghum and millet must be held in storage for periods varying from one month up to more than a year. Grain storage therefore occupies a vital place in the economies of developed and developing countries alike.

i. To stabilise the prices

The market for food grains is characterised by fairly stable demand throughout the year, and widely fluctuating supply. Generally speaking, people's consumption of basic foods such as grains does not vary greatly from one season to another or from year to year. The demand for grain is 'inelastic', which means that large changes in the market price lead to relatively small changes in the amount of grains which people purchase.

ii. Even out fluctuations in supply

Market supply, on the other hand, depends on the harvest of grains which is concentrated within a few months of the year in any one area, and can fluctuate widely from one year to the next depending on climatic conditions. New varieties that have shorter growing periods, and variation in climatic conditions and farming systems in different regions of a country, can help to even out the fluctuations in market supply.

The main function of storage in the economy is to even out fluctuations in market supply, both from one season to the next and from one year to the next, by taking produce off the market in surplus seasons, and releasing it back onto the market in lean seasons; this in turn smoothes out fluctuations in market prices. The desire to stabilise prices of basic foods is one of the major reasons why governments try to influence the amount of storage occurring, and often undertake storage themselves.

iii. Avoid wastage of produce

Storage prevents wastage of output especially highly perishable product such as vegetables and fruits. Storage preserves products and ensures freshness and good quality. Effective storage encourages farmers to produce more leading to high income, living standard and general wellbeing of the society.

3.3 Storage Methods

i. Traditional farm/village storage methods

a. Temporary storage methods

Such methods are quite often associated with the drying of the crop, and are primarily intended to serve this purpose. They assume the function of storage only if the grain is kept in place beyond the drying period.

b. Aerial Storage

Maize cobs, sorghum or millet panicles are sometimes tied in bundles, which are then suspended from tree branches, posts, or tight lines, outside or inside the house. This precarious method of storage is not suitable for very small or very large quantities and does not provide protection against the weather (if outside), insects, rodents, or thieves.

c. Storage on the ground, or on drying floors

This method can only be provisional since the grain is exposed to all pests, including domestic animals, and the weather. Usually it is resorted to only if the producer is compelled to attend to some other task, or lacks means for transporting the grain to the homestead.

d. Open timber platforms

A platform consists essentially of a number of relatively straight poles laid horizontally on a series of upright posts. If the platform is constructed inside a building, it may be raised just 35-40 cm above ground level to facilitate cleaning and inspection. Platforms in the open may be raised at least 1 meter above ground level. They are usually rectangular in shape, but circular or polygonal platforms are common in some countries.

Grain is stored on platforms in heaps, in woven baskets or in bags. In humid countries fires may be lit under elevated platforms, to dry the produce and deter insects or other pests.

Instead of being horizontal and flat, the platform may be conical in shape, with the point at the bottom. Up to 3 meters in diameter, such platforms facilitate drying because of their funnel shape at the top. They consist of a frame of horizontal poles which is square, circular or polygonal in shape, against which the timbers which form the cone rest. These timbers meet at the bottom on a wide central supporting post.

Platforms with roofs (but no walls), of whatever shape or form, may be regarded as transitional types between temporary and long-term stores. In southern Benin, Togo and Ghana, for example, maize cobs in their sheaths are laid in layers on circular platforms with their tips pointing inwards. The platforms are usually between 2 and 3 meters in diameter, but some may be more than 6 meters wide, with a maximum height of 2.5 meters at the centre and 1.5 meters at the periphery. In Ghana such a granary is called an "ewe" barn.

ii. Long-term Storage Methods

a. Storage baskets (cribs) made exclusively of plant materials

In humid countries, where grain cannot be dried adequately prior to storage and needs to be kept well ventilated during the storage period, traditional granaries (cribs) are usually constructed entirely out of locally available plant materials: timber, reeds, bamboo, etc. Under prevailing climatic conditions most plant material rots fairly quickly, and most cribs have to be replaced every two or three years - although bamboo structures may last up to 15 years, with careful maintenance.

Basically similar to the outdoor type of platform described above, in all its variations, the traditional crib differs in always having a roof and wall(s). It may even be elevated at least one meter above ground level, with a fire maintained underneath to assist drying of the contents and, allegedly, to reduce insect infestation. However, such cribs (especially the larger ones) are more commonly raised only 40 to 50 cm above ground level.

Access to the interior of a crib is gained usually over the wall. This may involve raising the roof, but some cribs have a gap between the top of the wall and the roof to facilitate entry. Relatively few cribs have sealable gaps in the wall or floor for the removal of grain.

b. Calabashes, gourds, earthenware pots

These small capacity containers are most commonly used for storing seed and pulse grains, such as cowpeas. Having a small opening, they can be made hermetic, by sealing the walls inside and out with liquid clay and closing the mouth with stiff clay, cow dung, or a wooden (cork?) bung reinforced with cloth.
If the grain is dry (less than 12% moisture content) there is usually no problem with this kind of storage.

c. Jars

These are large clay receptacles whose shape and capacity vary from place to place. The upper part is narrow and is closed with a flat stone or a clay lid: which is sealed in position with clay or other suitable material. Generally kept in dwellings, they serve equally for storing seeds and legumes. So that they may remain in good serviceable condition, they should not be exposed to the sun and should not be either porous or cracked.

d. Solid wall bins

Such grain stores are usually associated with dry climatic conditions, under which it is possible to reduce the moisture content of the harvested grain to a satisfactory level simply by sun-drying it. Solid wall bins are therefore traditional in the Sahel region of Africa, and in southern African countries bordering on the Kalahari Desert.

The base of a solid wall bin may be made of timber (an increasingly scarce resource), earth or stone. Earth is not recommended because it permits termites and rodents to enter. The better base is made of stone.

Mud or clay silos are usually round or cylindrical in shape, depending on the materials used. Rectangular-shaped bins of this type are less common, because the uneven pressure of the grain inside causes cracking - especially at the corners. Clay, which is the basic material, varies in composition from one place to another. That most commonly used for such construction work is obtained from termitaries, because the termites add a secretion which gives it better plasticity. To give it added strength, certain straw materials such as rice straw may be mixed with it; while, in some countries, néré juice is added to make it almost as durable as concrete. The diversity of materials used explains why the capacities of such silos can vary from 150 kg to 10 tones.

The roof is usually made of thatched grass, with a generous overhang to protect the mud wall(s) from erosion. Where a side door or a detachable 'cap' is not provided, the roof has to be lifted for access to the bin. Such silos can serve for 30 or even 50 years.

e. Underground storage

Practiced in India, Turkey, Sahelian countries and southern Africa, this method of storage is used in dry regions where the water table does not endanger the contents. Conceived for long term storage, pits vary in capacity (from a few hundred kilograms to 200 tonnes). Their traditional form varies from region to region: they are usually cylindrical, spherical or amphoric in shape, but other types are known. The entrance to the pit may be closed either by heaping earth or sand onto a timber cover, or by a stone sealed with mud.

iii. Alternative storage technology at farm/village level

a. Sacks

Wherever grain is grown on a commercial basis, buying agencies often issue empty sacks to producers so that they may be filled on the farm.

The buying agency may then collect the bagged grain from the farm, or the producer has to deliver it to the nearest collection point. In either case, the producer has to store the sacks of grain for some time before they are sold. During this period precautions have to be taken to ensure the safety of the grain and maintain its quality.

At the very least, the bagged grain must be kept off the ground to prevent spoilage by translocating water and/or termites. Low platforms, tarpaulins or plastic sheeting may serve this purpose; but if there is a risk of damage by rodents or other animals, high platforms fitted with rodent barriers should be used. If there is a risk of rain during the temporary storage period, the bags should be covered with waterproof sheeting (but not all the time if the grain has moisture content much in excess of 12%). Alternatively, the sacks of grains should be stacked on dunnage or waterproof sheeting, away from walls, in a rodent proofed barn. The need for chemical methods of pest control should not arise if the storage period is short.

Where sacks are used for domestic grain storage, similar conservation measures should be adopted. However, it will be necessary to employ some form of insect pest control. Second-hand sacks must be thoroughly cleaned and disinfested before use.

b. Metal or plastic drums

Drums are often used as storage containers in the house and serve notably for the storage of cereal seeds and pulses.

Plastic drums are used intact or after having the upper part cut off to facilitate loading and unloading. Otherwise, plastic lends itself poorly to adaptation because it is relatively weak at most, a lockable outlet can be added. If the lid is tight fitting and the drum is completely filled with grain, any insects present will deplete the oxygen in the drum and die.

Metal drums can be adapted for domestic grain storage in a similar way. A removable lid permits easy loading, but it is also possible to weld half of the lid to the rim of the drum, and provide a riveted hinge on the remaining half of the lid so that it alone can be opened.

Fitted with a padlock, such a modified drum is more secure. To make a store of greater capacity, two metal drums can be welded together end to end and fitted out as described above. Well modified and/or fitted with gaskets, metal drums can also be made airtight.

Inaccessible to rodents, efficient against insects, sealed against entry of water, drums make excellent grain containers. However, they should be protected from direct sunshine and other sources of heat to avoid condensation by being located in shaded and well ventilated places.

iv. Alternative solid wall bins

In some countries grain storage workers, rather than modifying traditional storage structures, have developed significantly different storage bins. A few examples of these are described below.

a. The "Pusa" bin

Developed by the Indian Agricultural Research Institute (I.A.R.I.), these silos are made of earth or sun-dried bricks; they are rectangular in shape and have a capacity of 1 to 3 tonnes.

A typical "Pusa" bin has a foundation of bricks, compacted earth, or stabilised earth. A polyethylene sheet is laid on this, followed by a concrete slab floor 10 cm thick. An internal wall of the desired height (usually 1.5 to 2 metres) is constructed of bricks or compacted earth, with a sheet of polyethylene wrapped around it. This sheet is heat-sealed to the basal sheet, and the external wall is then erected. During the construction of the wall an outlet pipe is built into its base.

The concrete slab roof is supported by a wooden frame and, like the floor, is constructed of two layers separated by a polyethylene sheet. During its construction, a man-hole measuring 60 x 60 cm is built into one corner.

The "Pusa" bin has been widely adopted in India, and has been demonstrated in some African countries. It gives good results when loaded with well dried grain.

b. The "Burkino" silo

Based on a traditional dome shaped type of bin, this silo is constructed with stabilised earth bricks. Various models and capacities are available.

The base is made of stabilised earth resting on the ground or on concrete pillars. The dome shaped roof is also made of stabilised earth bricks, using special wooden formers. The technique of making a dome-shaped roof is not easy to master, and usually has to be done by skilled masons. A variant has been developed with the roof resting upon a wooden frame, which can be erected by unskilled farmers.

c. The "USAID" silo

This silo is based on the "Burkino" silo and examples have been erected in Nigeria, holding one tonne of maize grain, the silo rests on stone or concrete pillars supporting a reinforced concrete slab 1.5 meters in diameter. The walls are made of stabilised earth bricks and are plastered inside and out with cement reinforced with chicken wire mesh. The top is dome shaped with a central round opening, and covered with a cone-shaped earthen cap. This is plastered with cement, and rests on bamboos or on a metallic drum base. An outlet door, consisting of a 15 x 30 cm plate 1.5 mm thick which is smeared with grease for easy sliding, is let into the base concrete slab.

d. Concrete/cement silos

Such silos are 'cement rich', and often include other materials which normally have to be imported into developing countries. Therefore they are potentially (and usually) expensive structures, which can be seriously considered only when improvements to traditional storage bins cannot be practically applied. Their redeeming feature, given that they are properly constructed and used, is that they are robust and should give many years of satisfactory service.

e. The Ferrocement bin ("Ferrumbu")

Developed in Cameroon and tested in a number of African countries, this bin is similar to the "Burkino" bin in shape but consists mainly of chicken wire plastered inside and out with cement mortar.

The wall varies in thickness from 3.5 cm for a bin of 0.9 m^3 capacity, to 6 cm for one of 14.4 m^3 capacity.

f. The "Dichter" stave silo

This cylindrical silo was developed in Benin, and is constructed with trapezoidal section concrete blocks (staves) supported externally by tightened steel wire. Both internal and external surfaces are rendered smooth with cement, and the outside may be treated with coal tar to ensure water-proofness. The floor and cover slab consist of reinforced concrete cast in-situ, and the whole structure is raised off the ground on four concrete block pillars. A manhole is located in one side of the cover slab, and an 'anti-theft' outlet is built into the bottom of the wall.

A principal technical difficulty with such bins is that they are poorly insulated, which encourages the development of moulds if the moisture content of the grain is higher than 13%. This means that the bins must be constructed indoors, or at least protected by shelters with a wide overhang to reduce extreme variations in temperature. With tall bins, such as the larger Ferrumbu, this is not very practical.

g. Metal silos

Economically valid for storing large quantities (over 25 tonnes), metal silos are often regarded as too costly for small scale storage. Nevertheless certain projects have been successful in introducing small metal silos, of 0.4 to 10 tonnes capacity, at farm/village level in developing countries. Such silos are made of smooth or corrugated galvanised metal, and are cylindrical in shape with a flat metal top and, usually but not always, a flat metal bottom. A man-hole with a cover, which may be hinged but is nevertheless lockable, is located, usually to one side, in the top panel; and an outlet pipe provided with a padlock is fitted at the base of the wall.
Metal silos should be placed on platforms or plinths, to facilitate emptying. Large capacity silos are usually constructed without base plates on raised concrete slabs. In this case, bitumen or cement mortar is plastered around the base of the wall to prevent penetration by water and pests.

As with concrete silos, it is essential to provide cover, to avoid excessive variations in temperature and moisture translocation.

h. Synthetic silos

Various attempts have been made to develop small scale storage bins, using synthetic materials such as butyl rubber and high density polyethylene. However, such bins proved to be either too expensive or prone to damage by pests. Also the management level required by such storage facilities is probably too high for most rural situations.

3.4 Integrated Pest Management (IPM) in the Control of Storage Insects

Integrated pest control can be defined as the acceptable use of practicable measures to minimise, cost-effectively, the losses caused by pests in a particular management system. For the measures to be cost-effective they must be appropriate to and acceptable into that system. They may be simple or complex but they must suit the system objectives and its technical capabilities. Furthermore, in this context, cost-effectiveness requires that all costs and benefits, including sociological and environmental effects, should have been taken into account.

The term integrated pest management is used to imply that a flexible and technically informed approach is also required. In defining this term it may be considered necessary to specify the inclusion of scientific and cost-effective pest monitoring procedures which permit judicious adjustments to the timing, choice and intensity of control actions. It may also be advisable to point out that specific pest control measures, as distinct from general crop or commodity husbandry practices, should generally be omitted unless the circumstances warrant and permit their cost-effective inclusion.

The current emphasis upon integrated pest management is, in effect, a reassertion of the need to put traditional good husbandry in place as the fundamental basis of pest control. In grain storage, as with other durable agricultural products, it is good commodity management and good store management which are the major prerequisites.

The various options for more intensive insect pest control, which are also listed in Tables l and 2, include several which are themselves based upon traditional concepts of pest management. Thermal disinfestations, cooling and hermetic storage are examples. These latter two methods are also examples of the opportunities, provided by the process of storage, to manage the generally enclosed storage environment in such a way that insect pests are prevented from multiplying or, as in efficient hermetic storage, effectively eliminated. Pre-harvest problems of insect pest control are rarely, if ever, so easily managed!

Control of the storage environment is thus an essential element in grain storage pest management. It involves, primarily, the controls on in-store climate and infestation-pressure which can be achieved by technically sound store design and construction. Equally important, however, is the climatic control attainable by scientific management of the commodity to ensure that the stored grain is itself both dry and cool when loaded or, in ventilated stores and bins with aeration equipment, that the storage procedure achieves drying and cooling sufficiently rapidly. In a fully loaded store it is the stored grain itself which largely determines and stabilises the temperature and humidity conditions in the store.

Commodity management can also control, to a considerable extent, the initial insect infestation level in the stored grain. However, in tropical countries, where pre-harvest infestation by storage insects is hardly ever completely preventable, the ideal of loading insect-free grain into the store is not often attainable. Special facilities to completely disinfest the grain before loading may not prove cost-effective. The common alternatives, if early disinfestations is required, are to treat the grain, at intake, with a suitable admixed insecticide or to disinfest the loaded grain by in-store fumigation.

Control of grain quality before storage, to minimise the intake of heavily infested and badly damaged or unclean grain, is feasible and is commonly practiced to a considerable extent. Even at the small farm level it is possible to segregate the crop at harvest, especially with maize on the cob and unthreshed sorghum and millet, selecting relatively undamaged material with good storage potential and setting aside the more evidently infested or otherwise damaged material which, if there is no other option, can at least be used first. By such means, the rate of deterioration due to insect infestation can be considerably retarded in the main stock of stored grain. There is little doubt that some subsistence farmers use this form of commodity management fairly effectively. Certainly, one can sometimes observe on farm grain stocks that have received no special insecticidal treatment, with relatively little insect damage after several months' storage at an ambient temperature that would permit the rapid increase of any well-established initial insect population.

Scientific approaches to grain storage pest management, having regard to grain storage as a part of the food production and distribution management system, have sometimes referred to the biological ecosystem concept as a means of comprehending grain storage processes and problems.

Table 4.1: Prerequisites and Options for on-farm Storage Pest Management

Essential	**Optional**
Basic IPM	**Additional measures**
Site and store management (protection from birds, rodents and weather plus basic hygiene)	Maintenance of conditions favourable to natural control: - by cooling (where feasible) by insect parasites, pathogens, etc. and/or Thermal disinfestation by solar heat and/or Treatment with traditional additives (if sufficiently available and effective)
Commodity management (cleaning, drying, etc.)	or Treatment with synthetic insecticides (if suitable formulations sufficiently available and effective) or Hermetic storage (pits or metal drums, etc.).

Source: Proctor, D. I. (1994)

Table 4.2: Prerequisites and Options for Storage Pest Management at Main Depots

Essential	**Optional**	
Basic IPM	**Disinfestation**	**Prevention of re-infestation**
Site and store management (protection from birds, rodents and weather plus basic hygiene)	Insecticide admixture * Fumigation! or Thermal *	Provided by the treatment Residual insecticide sprays! Physical protection! (Sheeted stacks or packaging) or
Commodity management (cleaning, drying, etc.) - with bulk storage if appropriate	Irradiation * Hermetic! Controlled atmosphere! Grain cooling!	Insecticidal space treatments! Provided by the system Provided by the system Provided by the system

Source: Proctor, D. I. (1994)

Notes: * May entail double handling for in-bag storage. Efficacy is doubtful. Extra management skills and/or other inputs required.

Modern theories of pest management have also generated the concept of economic control thresholds (ECTs). An ECT is most simply defined as the level of pest damage which justifies, in cost/benefit terms, the expenditure of resources upon control actions. It is always a variable threshold because the costs and benefits of any action will depend upon the situation and its circumstances. An ECT is situation specific. This is especially true, and not only for post harvest pest control, when one considers the great differences in opportunities and constraints between the small farm level in developing countries and more sophisticated levels of operation. Nevertheless, it is possible to generalise to some extent. For insect control in grain storage the ECT is likely to be at or very close to zero:

a. where consumer demands place a high value on freedom from insect damage and/or freedom from any sign of insect infestation;

b. Where there is a definite intention to store grain for a protracted period, in which substantial insect damage can be predicted, and where the eventual market is not insensitive to loss of quality.

3.5 The Economic Importance of Rodent Pests

There are three major reasons why rats and mice are considered pests:

a. They consume and damage human foods in the field and in stores. In addition they spoil it in stores by urine and droppings reducing the sales value.

b. Through their gnawing and burrowing habit they destroy many articles (packaging, clothes and furniture) and structures (floors, buildings, bridges, etc.). By gnawing through electrical cables they can cause fires.

c. They are responsible for transmitting diseases dangerous to man.

It is impossible to put an exact estimate on these losses, but it is obvious that the damage caused by rodents is enormous.

Diseases transmitted by rats to man pose a serious public health problem in tropical countries. Apart from causing human suffering, they are responsible for financial losses incurred through work-days lost and additional medical bills.

While this topic is not directly related to post-harvest problems, it bears relevance to post harvest rodent control. As rodent pests in stores and households are controlled the rate of disease transmission will be reduced. Just as it is difficult to put exact figures on losses caused by rodent pests, it is not easy to estimate the exact benefits of rodent control. However, it is apparent that rodent control is mostly if not always cost effective.

3.5.1 Rodent Species of Post-Harvest Importance

There are more than 4000 species of mammals, of which about 1700 are rodents. The rodents' family ***MURIDAE*** contains the most species, of the *genus Rattus*. However, not all the 1700 rodent species are pests. About 150 species have been defined as pests at some localities to some crops at some time or another, but only 20 could be termed important. Very few species indeed are regularly described as pests in the literature. In connection with post-harvest losses, the number of species occurring in and around human habitation drops to below ten.

Of these, three species are found throughout the world: the house mouse (*Mus musculus*), the house or roof rat (*Rattus rattus*) and the brown rat (R. *norvegicus*). The multimmate rat (*Praomys natalensis*) and the spiny mouse (*Acomys cahirinus*) are found in Africa; while the Pacific rat (*R. exulans*), and the bandicoot rat (*Bandicota bengalensis*).

3.5.2 Principles of Rodent Control

Before the various techniques, methods or strategies of controlling or managing rodents are described, the general principles involved need to be discussed. An understanding of these principles by all those involved will assist in devising specific control strategies for a given situation. It will also help when explaining the need for certain activities to the staff actually executing the control work.

In tropical countries rodents pose a continuous problem because of the climatic conditions, uninterrupted food supply and relatively open structures. Therefore, the control of rodent pests should be approached as a management problem much more so than a simple and single poisoning action. For a control strategy to be effective, staff responsible need to be trained and informed, their activities must be coordinated, responsibilities confirmed, inputs and equipment readily available and the entire action must be planned.

Control strategies should aim at preventing losses and thus require a proactive rather than the more normal reactive approach. Once a large population of rodents has established itself in a store, considerable losses, that cannot be retrieved, have already occurred and subsequent control action is expensive. It should stressed that information from different sources should be incorporated into a control or management strategy and not just the techniques.

There are many more techniques and methods of controlling rats than are described here. Those given here have been selected as being the most practical for use in tropical countries.

i. Monitoring

An important element of any rodent programme is monitoring. Usually it means surveillance for the presence of rodents. However it could also mean looking for features in the environment which would encourage rodents to migrate into it. Monitoring should be organised formally and regularly; that is, specific staff should be made responsible for it and report regularly, maybe once a week to a superior on the situation. The report should include the following aspects:

a. dates monitored

b. number, types and positions of signs of rats

c. condition of the building (broken pipes, walls, state of produce, tidiness or cleanliness)

d. conditions immediately outside the building with respect to potential infestation points

e. qualitative reports by others

f. dates of baiting

g. number of bait stations used and positions

h. amount of bait and labour used

i. recommendations for improvement, such as repairs to structures, or further action required.

Control of a rodent infestation is rarely completely successful; but if it is, it is usually only for a very short period. Therefore, there is a need for continuous monitoring even after a successful control campaign regardless of the techniques and bait used.

ii. Co-operation

If an area is made rat-free due to good management and/or effective control measures, rats from near-by areas will migrate into it. It is therefore more efficient if control campaigns are conducted in several adjacent areas simultaneously. In the case of a village all households should be motivated and organised to control rats at the same time. While control in one household will still benefit the owner, benefits increase as the number of participating neighbours increases.

In the case of stores, large and small, surrounding areas including other stores should also be disinfested. This means that all the store keepers or managers involved should coordinate and synchronise their rodent control activities for maximum effect.

3.5.3 Preventive Measures

The maxim: 'prevention is better than cure' is just as true for rodents as it is for other pests and diseases. Therefore the prime objective of any rodent control campaign should be to create environmental conditions which will discourage or prevent the pests from re-entering an area after its rodent population has been removed by one means or another.

i. Sanitation

Rodents require food and shelter. Therefore, it is most important to reduce the availability of these two key factors, which should be central in devising any kind of strategy. In the case of buildings the most effective method of rodent prevention is the improvement of hygiene or sanitation in and around them. Primarily, this means sweeping the store and keeping both it and the surrounding area neat and tidy, i.e. free from any objects such as empty containers, idle equipment or discarded building materials, which could provide cover or nesting places for rodents. It also means removing food scraps left over from feeding pets or domestic stock (i.e. poultry farms) at the end of the day's work.

Observations have shown over and again that these simple actions, even in the tropics, are the most effective preventative measures that can be taken.

In a tidy store any infestation will be noticed at a very early stage, making other control measures far more effective. With reduced access to food and no places to hide, rats will not become established; that is, live and breed, inside a building. Regular disturbance is something rats and mice avoid.

Control procedures should take the life history and behavior of species present into account. Therefore, by keeping a strip of two or more meters around a building clear of vegetation will reduce the chance of rats entering the building.

This should be augmented by keeping a strip of about one meter on the inside from the wall totally clear and swept. Branches overhanging the building should be lopped off to prevent climbing species to enter from above.

The above suggestions are enough to eliminate serious problems with rats and mice in buildings, even in stores where large quantities of food items are stored. Rats feel uneasy if their 'paths' and 'markings' are removed or cleaned daily by sweeping. They will not feel secure enough to remain in a building and damage packaging in their search for food. If they do, the damage is minimal and immediately noticeable.

ii. Proofing

Since it is not practical to remove all food from stores and households, it is necessary to restrict access by rats. This is accomplished by proofing buildings or keeping food in -rat proof containers.

When rodent-proofing a building, only materials which they cannot gnaw through should be used. Also, it should be remembered that some rodent species are good climbers and jumpers, and most can squeeze through surprisingly small holes and cracks (young mice need no more than a 0.5 cm wide crack to gain access).

Hard metal strips should be fitted to the bottom edges of all wooden doors and their frames, and vulnerable windows should be protected with tight wire netting screens in hard metal frames. Steel rat guards fitted to drainpipes and other attachments to the building should be at least one meter above ground level. Door hinges and similar fittings should be so placed or protected that rats cannot use them for climbing.

Floors and walls should be kept in good repair. New holes dug by rats should be filled in immediately, with cement reinforced with pieces of crumpled chicken wire. If cement is not immediately available a temporary seal can be effected with tightly packed earth between the wire mesh. The important point is that repairs should be carried out as soon as the damage is noticed, which should be within a few hours of it being done if the building is inspected daily.

Although rats are active mainly after dark, they will move about during day as well when there is no human activity. Therefore doors of stores should stay tightly shut during the day as well, when the store is not in use.

If the building itself cannot be made rat proof, then foods and other valuables should be kept in earthenware containers or metal drums with good lids.

iii. Natural prevention (predation)

Normally, predation will not keep rats and mice at economic population levels. One exception is the keeping of cats. Cats do not directly control rats and mice by feeding on them. It is their presence, which keeps most rats and mice away. A survey conducted in a Myanmar village has clearly shown that households with cats had no rats while those without cats in the same village were visited by rats.

3.5.4 Mechanical Control

Mechanical rodent control as a rule is not very practical. It is cumbersome, labour intensive, and often not very efficient. Mechanical techniques are more appropriate in households, and can be used if the owner has no access to poisons or is averse to their application.

The method most commonly used in buildings is trapping. Often local traps are available and in some cultures people are very good at using them. They should be placed where rats move regularly. If placed along a wall, the trap should be perpendicular to it and the treadle with the bait should face the wall.

Sticky or glue traps are another way of catching rats and mice They are boards made of wood, hard- or cardboard covered with very sticky material. There are different types of glue available and they should be checked for suitability (stickiness, and usability in humid or dusty conditions) before large quantities are ordered. The boards are placed in the same way as traps, and normally there is no need for bait to attract rats. These traps should be checked daily, but are not regarded as very 'humane'.

Flushing rodents out of their burrows, with smoke or by flooding them with water, can be very effective and suitable in some situations.
Ultrasonic devices are mentioned regularly, particularly by manufacturers of these devices, as a good repellent of rats and mice in buildings. However there is no scientific evidence of their effectiveness. It appears that rats become habituated to the sound or stay in 'sound shadows'.

3.5.5 Chemical Control

In large stores, particularly if situated in the city, it may be necessary to complement hygienic practices with chemical control. Because acute poisons invariably cause bait shyness, especially if applied over longer periods, it is strongly recommended that only anticoagulant rodenticides are used in buildings. Therefore, acute rodenticides will not be discussed here.

It should be remembered that rats living in and around buildings are particularly suspicious of new objects, such as bait, bait stations and traps. Therefore it may take some time before these are accepted by rats. For this reason it is important that once these objects are placed they are not touched or removed again. If the bait or trap has not been touched after, say, a week rats are probably not nearby and it should be moved to another location. However chemical control is only useful in connection with strict hygienic practices.

As a rule operators should be supplied only with ready-to-use rodenticide baits. Firstly, mixing can be dangerous to the operator. Secondly, a wrong concentration can lead to bait shyness if too high, or to sub-lethal dosing if too low. Normally, ready-to-use baits do not increase costs substantially.

All rodenticides can also harm other animals including man. Therefore great caution should be observed at all times when they are used.

i. Anticoagulant rodenticides

Anticoagulant rodenticides interfere with the blood clotting mechanism of the body - the animal gradually dies because of loss of blood through external and internal wounds that is hemorrhage. Very small internal wounds (breaking of small capillaries) are constantly caused by normal movements. The rat feels almost nothing; it simply feels more and more tired and eventually dies. Therefore bait shyness with anticoagulants is unusual even with higher concentrations of active ingredient.

Resistance to some anticoagulants has been observed in industrialised countries, where they have been used very extensively over long periods. So far, resistance has been of no serious consequence in tropical countries, particularly in view of the fact that new compounds (e.g. difenacoum, brodifacoum, bromadiolone) are now available in most countries. The antidote to anticoagulant rodenticides is Vitamin K.

ii. Multiple dose anticoagulant rodenticides

Multiple dose anticagulant rodenticides, such as coumachlor or coumatetralyl, need to be available at all times because rats have to feed on the bait several times over a period of up to seven days (depending on the species) before death is caused.

The poison bait should be placed inside bait-stations. To save resources each bait station should contain 50 to 100 gm of bait at all times. Bait availability should be checked each morning and bait taken by rats or which has become moldy should be replaced. The quantity of bait used depends on the level of infestation and should be adapted to local conditions; and the number of bait stations necessary depends on the size of the building. As a rule of thumb, a station should be placed every five to ten meters along the wall. Additional bait stations should be located in positions where rats are likely to enter a building, along obvious rat runways, or in places where rats may hide. The distance between bait-stations depends on the species involved: house mice, for example, normally have a smaller feeding range than rats. However an operator will quickly learn how and where to place bait-stations, if the situation is regularly monitored and the operator is not changed.

If no more bait is taken and it appears that no more rats are present, baiting can be discontinued. However surveillance should continue and baiting must be re-started at the first signs of rats.

iii. Single dose anticoagulant rodenticides

Single dose anticoagulant rodenticides, such as brodifacoum, flocoumafen or bromadiolone act in the same way as described above but rats normally have to feed on the poisoned bait once only (1.5-2.0 g for rats in the case of the most potent compounds such as brodifacoum). In some situations and for some species it appears that more than a single feed is necessary. Overall, though these anticoagulants are by far the most poisonous to rats and very useful to practical rodent control.

If loose bait is available, the use of bait-stations is recommended. These prevent spillage and spoilage. If blocks are used they can be laid down at regular intervals and in places frequented by rats, but should not be accessible to other animals or children.

iv. Pulsed baiting

The technique of pulsed baiting was introduced with the new single-dose anticoagulants, such as bromadiolone and brodifacoum. This contrasts with saturation baiting, in which bait is available to rats continuously over long periods until the population has declined to nearly zero. Pulse baiting is not necessarily more effective, but it is certainly cheaper, because the amount of labour and the quantity of bait required is much lower than in saturation baiting.

As mentioned earlier, death is delayed by three or more days after ingestion (depending on the species of rat and the type of rodenticide). This means that rats will continue to feed on bait even though they have received a lethal dose, which would be a waste of bait. In addition in some species (e.g. R. norvegicus), animals of lower hierarchal ranking cannot feed until 'higher' animals are removed from the population.

This behavioral characteristic is exploited by baiting in pulses. Poisoned bait is laid for 13 days (depending on the rodenticide) and discontinued for about a week, allowing the first batch of animals to die and thus be removed from the population. The next baiting pulse will remove another batch of rats. Normally, three baiting pulses are sufficient to remove almost the entire population. The intensity of baiting periods (pulses) depends on the rat population in and around the building and the rate of immigration from neighboring areas. In spite of the above, the intervals between and number of pulses has to be decided each time based on the results of monitoring.

v. Perimeter baiting

The idea of perimeter baiting is to place bait in a circle around and outside the immediate area of interest and hopefully prevent rats from immigrating. However it is very difficult to give exact guidelines on the diameter of the circle, the distance between baiting points and the quantity of bait to use. The idea has its merits and an operator should experiment with this technique; for example, by placing baiting points between the store and places through which rodents might reasonably be expected to immigrate.

vi. Fumigation

Individual rodents may be killed incidentally during the fumigation of grains and buildings for the control of insects. The control of rodents by fumigation can be very effective, but it may be expensive and dangerous. It should be remembered though that the gas must have access to burrows, if these are present in the building. That is, the burrows should be open and the fumigant used must be heavier than air.

If the species concerned make burrows which are easy to spot (e.g. R. norvegicus, B. bengalensis or P. natalensis) they can be fumigated directly. The simplest method is to use a powder which releases hydrogen cyanide, or aluminium (magnesium) phosphide tablets which release phosphine when placed into the burrows. The gases are generated when the powder or tablets come into contact with moisture in the soil. Alternatively, methyl bromide gas may be pumped into the burrow system.

As soon as the fumigant has been applied all burrows must be closed, by filling the entrance holes with earth. However, fumigants cannot be used in loose or sandy soils as too much gas escapes, and the treatment may not be effective. Occasionally, rats have been known to block tunnels and prevent complete distribution of the gas, so that some individuals survive.

It is important therefore, always to check for reopened burrows or other signs of survival a few days after the prescribed fumigation period.

Fumigation gases used for rodent control are also dangerous to man and other animals. Therefore, strict safety precautions must be observed. Only trained and properly qualified operators should be employed to use fumigants. They should be seen to be observing the following basic principles of fumigation:

1. two operators must always be present at a fumigation

2. suitable respirators must be worn

3. operators should stand upwind when gassing

4. fumigants should not be used in strong winds or when it is raining

5. fumigants must not be used near buildings inhabited by man or animals as open burrows may be inside; and

6. operators should know about first aid and have appropriate first aid equipment with them.

vii. Contact dusts

Contact dusts are dusts containing rodenticide which are placed on runways and other places frequented by the house mouse, for example near burrow entrances. Such dusts, while serving also as tracking powders (see earlier), are favoured in the control of house mice which, because of their erratic feeding behavior, are not easily controlled by baiting. The dust is picked up on the fur and feet and, since mice groom themselves often and regularly, it is automatically ingested.

However care must be taken when using such dusts, as they may easily contaminate stored products like grains and may be undetectable.

3.5.6 Safety Measures of Handling Poisons

Rodenticides, whether chronic (i.e. anticoagulants) or acute, are poisons and should be treated as such and at all times. Some may be more toxic to humans or non-target animals than others; some non-targets may be less affected by certain rodenticides than others.

Nevertheless, it is important that safety procedures are rigidly enforced wherever they are used.

Standard safety precautions when handling poisons include:

- wearing protective clothing during operations;

- not eating, drinking or smoking during operations;

- not breathing in dust during operations (wear dust mask);

- keeping baits out of reach of others, especially children and domestic animals;

- thoroughly washing the skin, clothing and equipment after operations.

Unwanted poisoning

Much has been written about the potential danger to non-targets of feeding on bait (primary poisoning) or animals feeding on poisoned rats (secondary poisoning). It is difficult to assess the exact effect under practical conditions. Unwanted poisoning reported by large scale operations or through accidents, usually involves domestic animals. The danger of unwanted poisoning can be virtually eliminated in buildings if some simple rules are adhered to:

- bait should be laid so that no other animals, including man, can have access to it; in buildings this should be fairly simple;

- the amount of bait laid out should be adapted to the anticipated population of rats, that is as little as necessary and placed in small quantities per station;

- application should be late in the afternoon, just before rats become active and as birds retire; in stores this is not so important;

- bait should be removed entirely after a control programme is terminated;

- dead rats, if found, should be buried or burnt; and

- rodenticides should be under lock and key and empty containers should be disposed of properly.

Stray dogs and cats (and crows and vultures in some countries) may be at risk through feeding on dying or dead rats (secondary poisoning). Normally, these animals, because of their size, would need to feed on several rats before they would be affected and more to receive a lethal dose. The chance is very low with most anticoagulants and even with zinc phosphide, because most of the poison is broken down in the stomach. Nevertheless, operators should be aware of these potential dangers at all times.

4.0 CONCLUSION

The important role which the reduction of the losses in stored products can play in the solution of the overall problem of food supply in tropical Africa cannot be over-emphasised. The most substantial losses in stored produce are caused mainly by insects, mites, fungi and rodents. Understanding the various methods of controlling pests and rodent is a precondition for successful rodents and pests control programme in storage.

5.0 SUMMARY

This unit has analysed the various functions of storage, described the short and long term methods of storage, the menace of storage pest and their control measures. Damages caused by rodents, identification of important species of rodents that causes loss of produce in storage, the principles of rodents control, methods of rodent control and sanitary measures were discussed. Emphasis is generally on prevention rather than control. Control strategies should aim at preventing losses and thus require a proactive rather than the more normal reactive approach.

The most effective control method for rodent is storage under rodent-proof conditions. General sanitary condition when the crops are growing in the field, in and around the store and ware house and observation of principles of rodent control have proved to be the most effective methods of minimising the menace of rodents during storage of farm produce.

6.0 TUTOR-MARKED ASSIGNMENT

1. a. Discuss the significance of storage to Nigerian economy.
   b. Discuss the methods of temporary storage commonly employed by local farmers in your locality.
2. a. State the alternative storage technology at the farm level.
   b. Briefly discuss any three mentioned above.
3. a. Discuss the integrated pest management of stored products.
   b. Briefly explain the basic principles upon which any rodent control strategies should be based.
4. a. What are the preventive measures of rodent infestation?
   b. Briefly describe chemical method of rodent control.
   c. State the safety measures to be observed to avoid unwanted poisoning of stray animals.

7.0 REFERENCES/FURTHER READING

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