TVET CERTIFICATE IV in CROP PRODUCTION

Module Title: Cereals cropping techniques

CRPCC401

Grow cereals

Competence

Learning hours

100

RTQF Level: 4

Credits: 10

Sector: Agriculture

Sub-sector: Crop production

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Purpose statement

This module describes the skills and knowledge required to apply cropping techniques for cereal crops production (Wheat, Maize and Sorghum, rice) mainly grown in Rwanda.

The module will allow the learner to:

- Establish cereal crops(Wheat, Maize and Rice)in the field ;
- Maintain cereal crops(Wheat, Maize and Rice) in the field
- Harvest cereal crops (Wheat, Maize and Rice)
- Handle the products of cereal crops (Wheat, Maize and Rice)

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Learning Unit 1 – Select site, tools, materials and equipment

Introduction/Overview

A cereal is generally defined as a cultivated grass grown for their edible starchy grains. Bulk of staple food crops all over the world comes from this group.

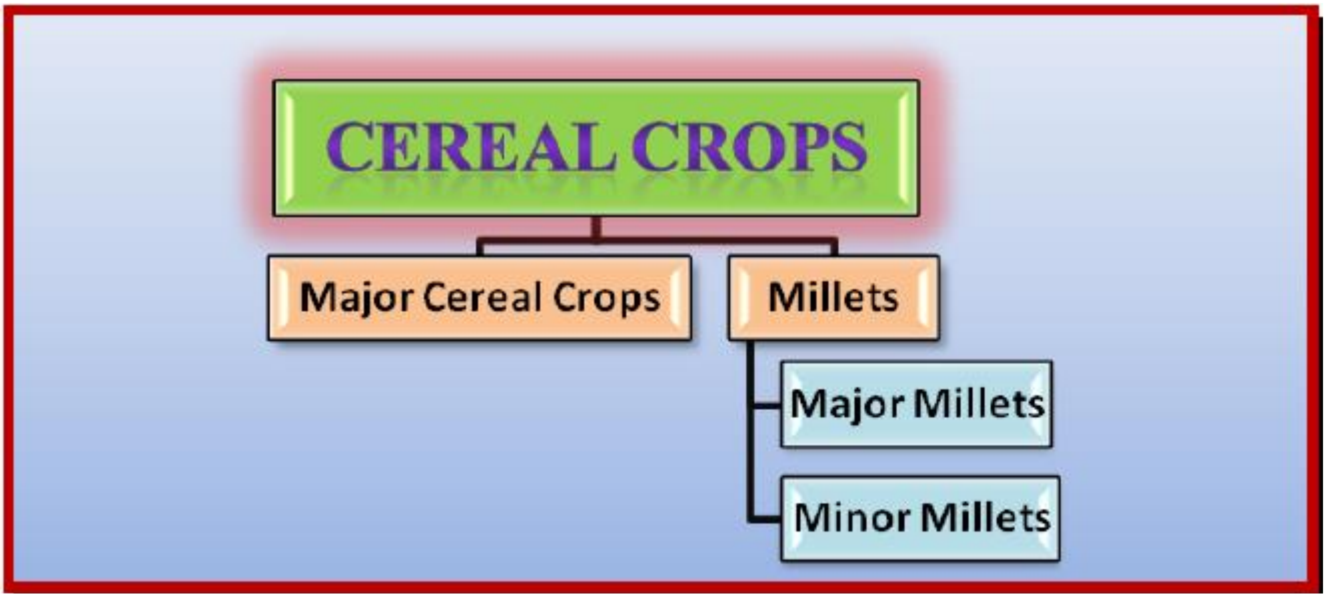


Fig: Classification of Cereal Crops.

A. Major Cereal Crops

In general, the larger grains are used as staple food is considered as major cereals.

1. Paddy/Rice: *Oryza sativa*
2. Wheat: *Triticum aestivum*
3. Maize/Corn: *Zea mays*
4. Barley: *Hordium vulgare*

B. Millets

Millets are a group of small grained cereals which are of minor importance as food and they have a single cover. Millets are further classified into two groups.

a) Major Millets

1. Sorghum/Great millet: *Sorghum bicolor*
2. Pearl millet: *Pennisetum typhoides*
3. Finger millet: *Eleusine corcana*

b) Minor Millets

1. Foxtail millet: *Setaria italica*
2. Little millet: *Panicum milliare*
3. Kodo millet: *Paspalum scrobiculatum*
4. Proso millet: *Panicum millaceum*
5. Barnyard millet: *Echinochloa frumentaceae*

The use of appropriate agricultural equipment and tools for cereals crop production contributes to the viability of the farm by enhancing production efficiency. Equipment and tools are necessary for plant propagation, soil preparation, planting, pest and weed control, irrigation, harvesting, postharvest handling, storage, and distribution. Sustainable agriculture can be a labor-intensive business and by selecting the appropriate tool for the task at hand, farmers can increase profits by increasing crop yields, improving crop quality, and reducing expenses. Factors to consider when choosing appropriate agricultural equipment and tools include the site location and growing conditions of the farm, the type of crops being grown, and the production practices being used.

LO 1.1 – Identify the site

Content/Topic 1: Criteria for site selection of maize, wheat, rice, and sorghum crops

A. *Background of the field:*

The selected area must have a suitable previous cropping system. All cereals yield more if they are sown in a well prepared seedbed with 5-8 cm of mellow surface soil. A good seedbed will help the young plants to emerge vigorously and compete with the weeds.

B. *Field accessibility:*

The field should be accessible to water and the area should be relatively level. This practice is usually applied in cereals for supplementary irrigation during drought periods.

C. *Ecological requirements:*

The region for cereals production should have a suitable climate and especially the severity of winter temperature and the amount of rain or moisture in the soil should be considered. The field should also be of suitable soil type, fertility and drainage and be free of weeds and soil borne diseases and pests for maize, wheat, sorghum and rice.

- ✓ **Climatic and soil requirement**

Rice is heat and water loving plant and hence requires high temperature and more water. For germination a minimum of 10^{o}C, flowering 22-25^{o}C, grain formation 20-21^{o}C and ripening 20-25^{o}C is considered an optimum. Low temperature particularly during 10-11 days before heading causes considerable loss in grain yield because of sterility. Rice can be grown in diversity of soils like alluvial, lateritic, red, black, brown, saline, alkaline, acid soils etc. It can be grown not only in flat lands but also on a wide range of slopes. In Rwanda, rice crop is grown in different ecosystems like rainfed lowland and irrigated situations. Rice can also be grown in rainfed upland where aerobic soil environment exists for major period of crop growth and development in monsoon season.

Fig: A view of upland rice cultivation in India

Wheat has hardening ability after germination. It can germinate at temperature just above 4ºC. After germination it can withstand freezing temperatures by as low as -9.4ºC (spring wheat) and as low as -31.6ºC (Winter wheat). Normal process starts above 5ºC under the presence of adequate sunlight. Wheat can be exposed to low temperature during vegetative and high temperature and long days during reproductive phases. Optimum temperature is 20-22ºC. Optimum temperature for vegetative stage is 16-22ºC. Temperature above 22ºC decreases the plant height, root length and tiller number. Heading is accelerated as temperature rose from 22 to 34ºC, but, retarded above 34ºC. At grain development stage, temperature of 25ºC for 4-5 weeks is optimum and above 25ºC reduces the grain weight. It is long day plant. Long day hastens the flowering and short day increase the vegetative period. But, after the release of photo-insensitive varieties, no issues of photo-sensitiveness. Wheat is cultivated in a variety of soils of Rwanda. Soils with deep well drained sandy loam, loam or sandy clay loam with nearly neutral pH are most suitable for wheat cultivation. In heavy soils crop may suffer due to poor drainage. Wheat can be successfully grown on lighter soils provided their water and nutrient holding capacities are improved.

Maize crop is cultivated on a very wide range of agro-climatic conditions, yet moderate temperature with sufficient supply of water are most favorable. Temperature below 12^{o}C and higher than 30^{o}C does not favor its cultivation. Maize requires well drained soil and cannot with stand water logged situation. It can be grown on the soils having pH ranging from 5.5-8.0.

Sorghum requires warm climate but can be grown under a wide range of conditions. It can tolerate drought conditions very well because it remains dormant during moisture stress conditions but resumes growth when favourable conditions reappear. Leaves possess waxy coating and presence of motor cells in leaves rolls the leaves under moisture deficit conditions. It has a high resistance to desiccation, low transpiration ratio and a large number of fibrous roots. Sorghum can also tolerate water logging conditions better than any other cereal except rice. Therefore, sorghum can be grown successfully in areas having an average annual rainfall between 600 and 1,000 mm. High rainfall at heading reduces pollination and gives poor yield, though crop is tolerant to water logging. Minimum temperature required for germination is 7-10 °C, germination does not take place if temperature is less than 7 °C. Optimum temperature for growth is 25-30 °C. Sorghum plants can tolerate high temperatures throughout their life cycle better than any other cereal crop. Crop is sensitive to low temperature. Temperature below 15 °C affects crop growth adversely. It is a short day plant. Sorghum is raised predominantly in vertisols and to lesser extent in alfisols. Soils having good water holding capacity, rich in humus are best suited. Black cotton soils are categorized as best soils for its cultivation. It does not thrive in sandy soils but does better on heavier soils. Crop is grown in pH range of 6.0-8.5. It tolerates considerable salinity and alkalinity.

LO 1.2. Prepare tools, materials and equipment

Content/Topic 1: Criteria for selection of tools, materials and equipment

When selecting tools, materials and equipment for cereals farming operations the first step is to consider which of these could be most appropriately targeted by the intervention.

They will of course depend upon the scale of the farming operations envisaged and on the local farming conditions, including the *soil types, crops, weed species and agro-ecological conditions* (climate, Field topography…). The farm household environment and the cultural conventions of the region should also be considered. Indeed, there may be additional and important local cultural factors such as the precise tool shape and the handle length.

The use of appropriate equipment and tools, both in terms of size and practicality, can increase production efficiency and profits while minimizing the disturbance to soil and to plant health.

Different tools and equipment used in Wheat, Maize, and Rice crops production

Equipment for small-scale intensive crop production tends to be simple and less specialized than equipment for larger-scale production. As a result, the equipment is often affordable and requires less capital. The economics of owning and maintaining farm machinery may appear to be complicated and even overwhelming. Renting or borrowing equipment may be an option for some farmers; however, investing in appropriate and practical equipment that matches the whole-farm cropping system can result in a minimal increase in cost per hour. The investment pays of in hand labor savings, even after costs such as labor for the driver, fuel, maintenance, and equipment depreciation are factored in.

A. Equipment for seedbed preparation

A.1 Hand tools for seedbed preparation

Hand tools can thoroughly prepare a small amount of land for planting. There are two key components to consider when selecting a hand tool for commercial crop production: *ergonomics and durability.*

Ergonomics refers to how a tool is best designed for comfort, efficiency, safety, and productivity. The more ergonomically designed a tool is, the easier it will be on the human body.

The length of a handle, the type of handle grip, the weight of the tool, and the angle of the tool head to the handle affect the ergonomics of a tool.

The more durable a tool is, the longer it will last without sustaining significant damage or wear. Durability can be measured in the strength of the handle and tool head. The harder the steel used for the tool head, the better it will hold an edge— which in turn improves efficiency and reduces wear. How the tool head and handle are joined together also affects the durability of the tool and determines whether parts can be replaced.

The following are the most common hand tools which have been used by Rwandan in crop production. In most cases, important aspects are highlighted that need to be mentioned during the identification stage for the tools.

1. HOE

The main types of hoes are as follows:

- ➢ Heavy digging hoes with short handles.
- ➢ Light weeding hoes with long handles to allow the operator to stand upright and easily manipulate the hoe with both hands.
- ➢ Light planting hoes with short handles for planting.

It is important also to specify the weight of the hoe which is required. Generally speaking, lighter models should be chosen for female or Rwandan beneficiaries.

Secondly, the manner by which the hoe is to be fitted to the handle must be detailed.

There are three possibilities (Figure 1):

- by a Spike (or tang)
- by a Raised Eye
- by a Sunken Eye

Preference for a particular "Eye" can depend on the preference of the potential user. However, experience has shown that a raised eye is more suitable for hard dry soils whereas a sunken eye is preferable for wetland, softer soils.

Figure 1: Digging hoes with Spike, Raised Eye and Sunken Eye

(Photograph: Chillington Tool Co.)

2. FORK HOE

Apart from the hoes described above, the target beneficiaries may prefer the fork hoe (Figure 2). As described above for the more conventional hoe, the farmer should determine the most suitable tool weight and the method for attaching the handle (spike, raised eye or sunken eye).

Figure2:

Fork Hoe - 2 kg and of rather poor quality

(Photograph: John Ashburner)

3. MACHETE OR CUTLASS

There is a wide range of blade shapes for machetes. The Model numbers are those assigned in China although the chosen supplier for an international tender does not necessarily have to be located in that country. The blade length required will also need to be specified as again, several options are normally available. It is strongly recommended that wooden rather than plastic handles are requested.

Figure 3:

Machete type M208 with blade length 19 inches

(Photograph: Dingzhou Jade Machete Tools Manufacturing Co. Ltd.)

FIGURE 7

Machete type M206 (normally with a blade length of 18 inches)

FIGURE 8

Machete type M212 (normally with a blade length of 16 inches)

FIGURE 9

Machete type M204 (normally with a blade length of 16 inches)

(All Photographs: Unknown)

4. MATTOCK AND PICKAXE

Mattocks are commonly used for opening up new land, the cutting edge being used to cut roots and the digging edge for primary tillage on very hard ground. Pickaxes are primarily used for digging and building works.

Figure 4:

Mattock with a digger point and wider cutter blade popular in South America

Photograph: Imacasa, El Salvador)

Pickaxe with chisel and point

(Photograph: Silverline, UK)

5. AXE

The most commonly requested axe is a 3.5 lb model known as a light felling axe and designed to cut across the grain of the wood. It is asymmetrical in that it has only a single cutting edge. Should an alternative model be required, the particular requirements should be described by the Farmer.

Felling axe with asymmetrical head

(Photograph: Faithfull Power Plus, UK)

5. SPADE AND SHOVEL

Spades are primarily digging implements whereas shovels are used to move loose or unconsolidated materials over short distances. Figure 5:

Rectangular spade with socket fitting to a D-handle

(Photograph: Corona, UK)

Round mouth shovel with socket fitting to handle

(Photograph: Ames, USA)

6. GARDEN RAKE

Rakes supplied to farmers generally have from 12 to 14 teeth, are made from a single forging and are supplied without handles (see Figure 6) but an alternative model should this be available.

Garden rake with 14 teeth

(Photograph: Unknown)

7. BILLHOOK

The billhook is a cutting tool for smaller woody material and for bushes and harvesting. The Farmer should record the principal dimensions as indicated and its weight. A photograph will further assist for the detailed specifications.

Principal dimensions to record for a billhook

(Photograph: Unknown)

11. GRASS CUTTER

This tool should be defined by the overall blade length, the blade width and its thickness. Preference should also be indicated for the type of handle (wooden is recommended).

Grass cutter

(Photo Chillington Tools)

A.2 Mechanized tools for seedbed preparation

Equipment should be selected based on the type of tillage desired and how the equipment works given the specific characteristics of the soil. The tools' ability to perform correctly also depends on the horsepower of the tractor. Soils that are heavy, compacted, or have significant amounts of residues, for example, may require greater horsepower. The same equipment is required for seedbed preparation for wheat, sorghum, barley, maize, and dry-land rice seed production. The exact type of equipment for seedbed preparation may vary from country to country and according to the customs of the farmers in an area. The capacity of the equipment will be governed by the size of the operation and by equipment availability. Basically, the requirements are those given in the following paragraphs.

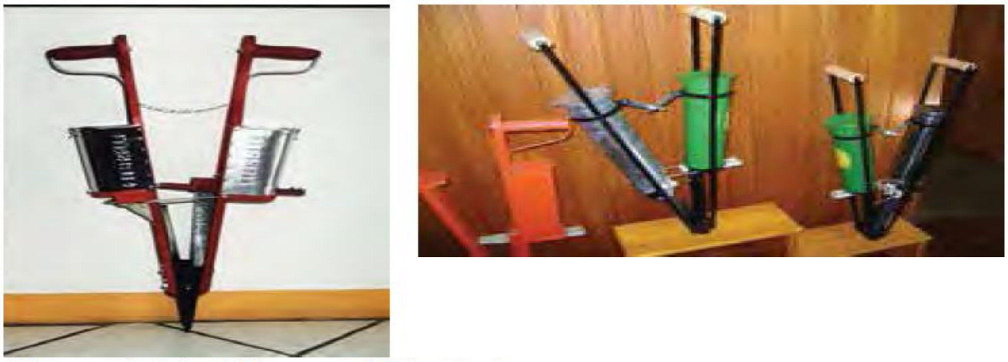
Fig: Tractor for land preparation

B. Equipment for sowing

B.1 JAB PLANTER

The jab planter facilitates seed to be planted through surface trash or through an existing crop cover without the soil being tilled previously. It is designed for use in systems where conventional mechanical tillage is not practiced, the technique being known as conservation agriculture. A wide range of jab planter models are available (Figure bellow) and It will be necessary to indicate the crops to be sown, whether graded seed will be available (rarely the case) and whether there is a requirement for the planter to also apply fertilizer.

Some of the models of jab planters available from two Brazilian manufacturers



(*Photographs: John Ashburner and Brian Sims*)

Fig: Seed drill machine Transplanter machine

Fig: Mechanical seed drill.

Fig: sowing by using drum seeder.

C. *Equipment for weeding*

Fig: Weeding.

Fig: Rotary weeder.

Fig: Motorised weeder.

D. Equipment for Irrigation

D.1 WATERING CAN

This is traditional irrigation equipment. Most watering cans have a capacity of from 10 to 12 litres although there have been exceptions – for instance a capacity of from 6 to 8 litres, most probably more suitable for women.

The material of construction should be indicated – either galvanized metal sheet or plastic. Note that plastic is strongly recommended if the watering.

Figure: Watering can of plastic and galvanized sheet

(Photographs: Unknown and Sunway Co. Ltd, China)

Fig: Surface Irrigation.

Fig: Sprinkler Irrigation.

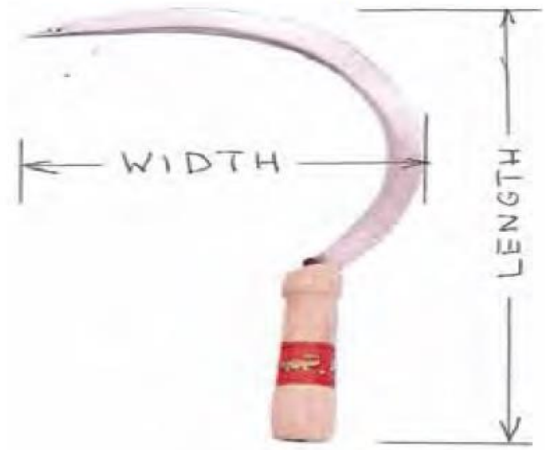
E. Tools and Equipment for harvesting

There are various designs of tools and equipment used for harvesting the crops and threshing it separately. Sickles, hand tools and reapers for grain crops and operated with different power sources are used. Combine harvesters, both tractor mounted and self-propelled, are being very widely used for different grain crops. Functional requirements and principles of working of tools and equipment for harvesting and threshing are given below:

E. 1. SICKLE

The harvesting of crops is traditionally done by manual methods. Harvesting of major cereal crops are done by using sickle. All these traditional methods involve labor and consume long time. The size and shape of sickles can vary from region to region and so it is important that the Famer makes a careful study of the type which will be suitable the cereal crops grown. A commonly used shape is illustrated in Figure 7 bellow.

Principle dimensions to supply for sickles



(Photo Chillington Tool Co.)

E.2 Mechanical harvesting equipment

The use of machines can help to harvest at proper stage of crop maturity and reduce drudgery and operation time. Considering these, improved harvesting tools, equipment, combines are being accepted by the fanners.

Fig: Combined harvester cum thresher.

Fig: Harvesting machine

F. Equipment for threshing

Fig: Threshing of cobs.

Fig: Mechanical harvester cum thresher.

G. ***Equipment for transportation***

G.1 WHEEL BARROW

Wheelbarrows are manufactured in many developing countries and hence local procurement should again be seriously considered for at least part of the order. There is a wide range of designs for wheel barrows and hence if there is any particular preference, a photograph bellow shows two alternative design of wheel barrow (figure 13). Wheelbarrow is used for transportation of agricultural input, organic manure, produce and other related agriculture products.

Two alternative designs of wheel barrow

(Photographs: Unknown)

Content/Topic 2: Utilization of tools, materials and equipment in Wheat, Maize, and Rice crops production

Many small-scale farmers today are generating high profits from land bases that are five acres or less. Practical farmers at this scale are able to sustainably manage their production and their farm finances, which are the result of reasonable capital costs and low annual operating expenses. Farms intensively producing on five acres or less rely on the versatility of their manual labor but also may utilize mechanized equipment to maximize production efficiency.

Tools and equipment should relate to the scale of production, and compromises are necessary as farming systems transition from a hand-labor scale to a tractor scale. Limiting the number of different row spacing, limiting the number of different bed widths, and designing beds that consider slope, soil erosion, and tractor-wheel widths are important considerations when scaling up production to include a tractor and implements. It is also important to consider how best to match the right equipment to the cropping system, including such factors such as how the soil and plants are managed and how the use of cover crops and crop rotations is incorporated. Diversified cropping systems can complicate matters because various crops require different row spacing, which means the implements may need to be adjusted for each crop.

Maintenance of equipment

The cleaning of planting equipment involves more than merely removing the remaining seed from the seed box. The fertilizer box must also be cleaned, as seed frequently spills into this compartment. All cracks and crevices in the seed box, as well as around and under the collecting and distributing mechanism must be cleaned with a stiff wire or small rod with a flattened point. The seed- and fertilizer-distributing tubes must be inspected, and any material caked or compacted with moisture must be removed, as should all dirt or mud adhering to the frame of the machine or to the hoe or disk coulters.

L.O 1.3. Prepare seeds

Seeds intended for sowing should satisfy the following requirements:

- ✓ The seed should belong to the proper variety, which is proposed to be grown.
- ✓ The should be Cleaned of straw, gravel, weed seed and other impurities
- ✓ The seed should be mature, well developed and plump in size
- ✓ The seed should be free from obvious signs of age or bad storage (Sorted to eliminate small, deformed and visually different grains).
- ✓ The seed should have a high germinating capacity (Tested for germination percentage to help calculate the number of seed that needs to be planted and to see if the seed batch is suitable for trial purposes).

Before sowing, the seed should be treated with fungicides which protects the seed against soil-born fungi and also give a boost to the seedlings.For some species it may also be necessary to **treat the seed** to help them germinate. The kind of treatment depends on the species and variety. Crops like cereals and pulses normally do not need any treatment, but rice may benefit from hot water treatment (see below). Grass and pasture legumes may need either hot water treatment or cold treatment.

Content/Topic 1: Different steps for seeds preparation (Maize, Rice, wheat and Sorghum)

A. Cleaning and Sorting

Cleaning and sorting can in most cases he done manually in the type of winnowing tray used by farmers to clean their rice. If large seed quantities are needed it may be economical to use winnowing machines and sieves if available. Seed obtained from commercial suppliers and research stations is normally already cleaned already. Seed obtained from farmers should be checked carefully. Preferably, such seed should be taken from field plots that were monitored during the previous year or season. This is to make sure that the seed is of the right kind and from healthy plants.

B. Grading

B.1 Length separations

Seed lots are length-sized (graded), after being cleaned with the basic cleaner, for one or more of the following reasons:

a. to remove weed seed and cross-broken crop seed that is shorter than the desirable crop seed;
b. to remove materials longer than the desired crop seed;
c. to upgrade general appearance *(e.g.,* by making sure all crop seed are uniform in length); and
d. to size grade for precision planters (Fig. 21).

There are two types of length separators, indented-cylinder separators and disk separators, both of which make separations by ''lifting" the shorter product out of the seed mixture (Figs. 22, 23). Length separators are available in a fairly wide range of makes, sizes, and models of the two separators the indented-cylinder type is the more universally used in the processing of cereal-grain seed lots; disk separators, on the other hand, cannot be used in the processing of maize.

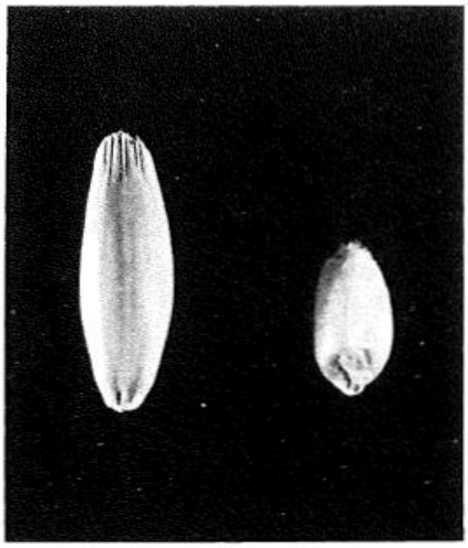


FIGURE 21. A length separator separates oats (*left*) from wheat (*right*).

FIGURE 22. Cross-section view of an indented-cylinder separator (USDA Agr. Handbook No. 179).

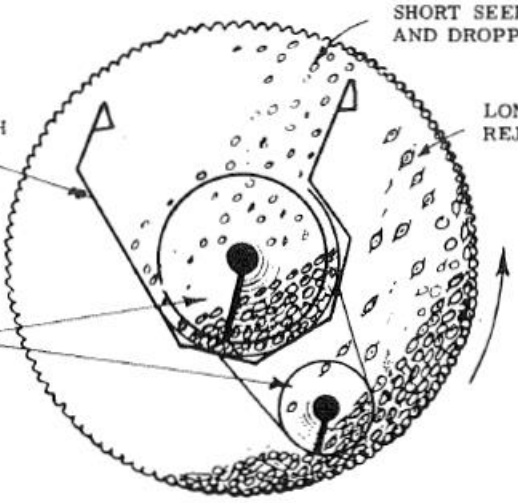


FIGURE 23. Cross-section view of a disk separator (USDA Agr. Handbook No. 179).

B.2 Width and thickness separations

Smaller-grained cereals, such as wheat or rice, may require additional sizing for width or thickness, in order to remove weed seed and cross broken crop seed that cannot be removed by the air-sieve cleaner. Width and thickness separators size ·more precisely than air-sieve cleaners. For this reason, seed of short-grain rice varieties can be separated from seed of long-grain varieties by utilizing the difference in seed width on a width and thickness grader, which cannot be done by an air-sieve machine. Mixtures of short- and medium-grain rice varieties are best separated by using a length separator.

Maize seed lots always contain desirable seeds which differ widely in width and thickness (Fig. 24). Consequently, maize that is to be planted mechanically should be size graded on a width and thickness separator. Maize is size graded into "flats" and "rounds" by using slotted or oblong shaped sieve openings; separation into small, medium, and large size classes is accomplished with round-hole sieves. Grading maize into more size classes than required should be avoided, as size grading is expensive in terms of both time and equipment costs.

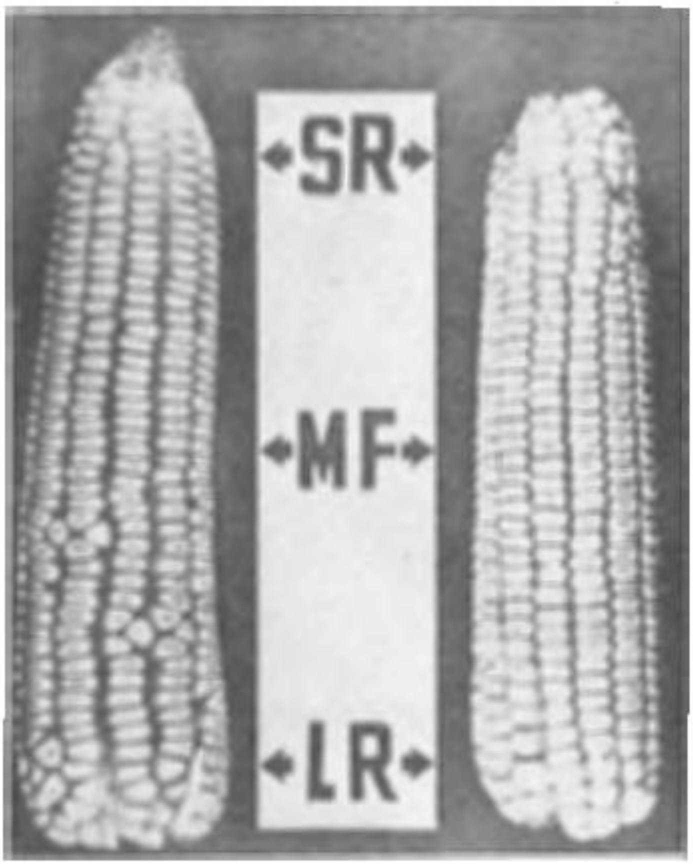


FIGURE 24. Kernels of different sizes are found on every ear of maize. Approximate locations of small and large "rounds" and medium "flats" are shown.

C. **Pre-treatment (coating seeds**)

Hot water treatment is done by heating water to 70-80 degrees (boil the water and let it cool for 10 minutes) and pour it into a container with the seed. The seed should remain in the water for 5 minutes to one day depending on the species. This method is also effective for many tree species. **Cold treatment** may be suitable for temperate zone crops and done by putting the seed in a refrigerator or deep freezer for 1-2 days. Some tree seed may need **burning or scratching** of the surface to have them germinate.

D. Testing seed for germination rate

A germination test is done to check if the vitality of the seed is sufficiently high. The acceptable lower limit of germination percentage depends on the species and varieties. Cereals and maize should not have less than 80 % germination and pulses no less than 60 %. Pasture species can have as little as 10 % germination and still be considered suitable.

The test is also done to calculate how many seed needs to be planted. For instance, if we want four plants to emerge per planting hole and the germination percentage is 80, it is safest to plant five of six seed per planting hole. Before carrying out the germination test the seed should be treated (hot water, cold or no treatment) in the same way as will be used in the trial. Otherwise we would not get an impression of the germination percentage expected in the field.

The germination test can be done in flat, closed containers, e.g., Petri dishes. Moist filter paper, cloth of tissue paper is put in the bottom to provide the necessary moisture for germination. Large seeds, such as many tree seeds, may be testing in trays containing moist sand, into which the seed are pressed lightly. Samples or 50-100 seed are counted and transferred to the containers. Two to four samples are usually adequate to obtain reasonably precise data.

The samples are stored in the shade, ideally, at a temperature of 20-25 degrees. The containers should be inspected every day to see if the seeds have started to germinate and to see if more water is needed. There should be a bit of condensation inside the lid, but there should not be free water in the container. Records are kept of the number of seed that has germinated each day.

Work is easier if seeds are removed from the container after they have germinated and been recorded. This eliminates the need of counting seed more than once, reduces the risk of the samples drying out, and prevents sprouts from entangling or lifting off the lid. A data collection form should be filled out for each batch of seed being tested. The form should also contain information on the source, price and 1000 grain weight of the seed. The form may look like the example below. The entries in *italics* are an example of a soybean test.

Seed testing form		Researcher:		Date:
Species: *Soybean*		Variety: *Sor Jor 4*		Price: *1000 K/kg*
Seed source: *HDK station, Vientiane*			Seed treatment: *none*	
Harvest year *1996* month *March*			Start of test: *15 April 1996*	
1000 grain weight: *138* g/1000 grain			Germination: *93* %	
Container no. *1 /1, 2, 3*	No. of seed germinated			
Day	Sample 1	Sample 2	Sample 3	Sample 4
15/4 0				
17/4 2	3	4	3	
18/4 3	10	9	12	
19/4 4	22	19	28	
20/4 5	32	31	23	
21/4 6	22	30	22	
22/4 7	3	0	5	
23/4 8	0	0	0	
24/4 9	0	0	0	
24/4 10	0	0	0	
Total	92	93	93	
Seed at start no.	100	100	100	
Germination %	92	93	93	
Comments:	*Mean germination percentage = 92 + 93 + 93 / 3 = 278 / 3 = 93%* *High and uniform germination between samples*			

Learning Unit 2 –Conduct maize, wheat, Sorghum and rice cultivation

L.O2.1. Establish of maize, wheat, sorghum, and rice crops into the field

Content/Topic 1: Land preparation (first and second ploughing)

The preparation of soil is the first step before growing a crop. One of the most important tasks in agriculture is to turn the soil and loosen it. This allows the roots to penetrate deep into the soil. The loose soil allows the roots to breathe easily even when they go deep into the soil. Why does the loosening of soil allow the roots to breathe easily?

The loosened soil helps in the growth of earthworms and microbes present in the soil. These organisms are friends of the farmer since they further turn and loosen the soil and add humus to it. But why the soil needs to be turned and loosened?

You have learnt in the previous classes that soil contains minerals, water, air and some living organisms. In addition, dead plants and animals get decomposed by soil organisms. In this way, various nutrients in the dead organisms are released back into the soil. These nutrients are again absorbed by plants. Since only a few centimeters of the top layer of soil supports plant growth, turning and loosening of soil brings the nutrient-rich soil to the top so that plants can use these nutrients. Thus, turning and loosening of soil is very important for cultivation of crops.

The process of loosening and turning of the soil is called **tilling** or **ploughing**. This is done by using a plough. Ploughs are made of wood or iron. If the soil is very dry, it may need watering before ploughing. The ploughed field may have big clumps of soil called crumbs. It is necessary to break these crumbs. *Levelling* the field is beneficial for sowing as well as for irrigation. Levelling of soil is done with the help of a leveller. Sometimes, manure is added to the soil before tilling. This helps in proper mixing of manure with soil. The soil is moistened before sowing.

All cereals yield more if they are sown in a well-prepared seedbed with 5-8 cm of mellow surface soil. A good seedbed will help the young plants to emerge vigorously and compete with the weeds. Except for maize seed production under the "plough-plant" minimum tillage system, seedbed preparation should start well in advance of the sowing season. Ploughing should be performed with great care to allow satisfactory tilth preparation.

Frequent cultivation kills germinated weeds when they are small and brings new weed seeds near the soil surface for germination and destruction before the crop is sown. The depth of cultivation is governed by moisture conditions and the need to conserve soil moisture. Repeated cultivation prior to planting tends to firm the soil. A firm seedbed is necessary for ensuring proper contact of the seed with the soil, so as to utilize soil moisture for rapid germination.

Land preparation for Maize, wheat and sorghum crops

A.1. Field sanitation before cultivation

In case residues of earlier crops remain in the field, the larva of the pest and disease of the previous crops stay alive in soil, and attack the new crops as well. Therefore, field should be cleaned after harvesting.

A.2 Application of FYM (Farm yard manure)

- Around 50-60 bamboo baskets (*IBITEBO*) of well-fermented FYM per Acre of land should be applied during the land preparation or first ploughing (1-2 month earlier of cultivation).
- Use of unfermented FYM (farm yard manure) can increase pest such as white grubs, cut worms and other worms.
- In case, heaps of FYM put in the field for long time, the nutrients in the FYM will be lost and insect may lay eggs in the heaps. So, it should be better spread the manure and plough the field immediately.

A.3 First ploughing

- 1-2 month before planting, during June -August first ploughing should be done.
- Ploughing should be done after putting the well fermented FYM (50-60 *IBITEBO*/ Acre) as organic fertilizer on the field.

- Plough the field two times, which will make the soil loose, and make easy for aeration and root growth. In the first time, plough the filed 5-8 cm deep and second time 10-15 cm deep should be done.
- In case, there is big size of soil clods present in the field after first ploughing, the breaking of those clods should be done manually with the help of spade or other equipment before those clods become hard.

A.4 Second plowing & sowing of maize and wheat

- The field should be ploughed second time just before seed sowing in line with the application of basal dose of chemical fertilizers. Apply 2.6 kg of Urea, 3 kg of DAP, 2.5 kg of Potash per Acre as a basal dose of fertilizer.
- Line sowing has an advantage over broadcasting as it requires less seed, facilitates easy weed control and field inspection.
- Just after sowing of seeds, we should press the soil, which will conserve the moisture and will help, for easy germination.

B. Land preparation for Rice:

The land has to be ploughed thoroughly with the help of mould board plough. Ploughing is followed by puddling which is nothing but churning of soil in presence of excess or standing water. Puddling reduces percolation loss of water. Puddling is done by using puddler drawn either by bullocks or power tiller or tractor. Puddling is followed by leveling operation by using leveler. Leveling helps for maintaining uniform standing of water in the plot.

Fig: Land preparation

Land preparation is important to ensure that the maize, wheat and rice fields are ready for planting. A well-prepared field controls weeds, recycles plant nutrients, and provides a soft soil mass for transplanting and a suitable soil surface for direct seeding.

***Content/Topic 2:* Crop sowing methods of maize, wheat and rice**

The oldest and simplest method of sowing is broadcasting, but drilling is the most efficient. The aim is to deposit the seed in the desired amount at a uniform depth. Wheat, rice, and maize should normally be planted 4-6 cm deep. Wheat and maize are sown on dry soil, whereas rice can be either broadcast or drilled on mud, broadcast in water, and drilled on dry soil.

Rice grown in paddies is either sown directly or from seedlings raised in a special seedbed before transplanting in the fields. For raising seedlings the wet-bed, dapog, and dry-bed methods are used. Dapog seedlings can be transplanted after 9-14 days, while wet-bed and dry-bed seedlings are ready for transplanting about 20-30 days after sowing. In countries with well-controlled irrigation systems, such as the United States, Portugal, Italy, and Greece, direct sowing is very common. In most African countries such as Rwanda transplanting is used.

The sowing method influences the seed quality and density. The seed rate is generally 100-200 kg/ha for wheat and direct-sown rice, 45-65 kg/ha for transplanted rice, and 20-30 kg/ha for maize. Smoothing for sowing might be done with combinations of the disk harrow, cultipacker, tooth harrow, and rotary hoe. Wheat, maize, and upland rice respond similarly to soil conditions and fertilization. Rice grown under lowland conditions requires different techniques.

A. Rice sowing

A.1 Irrigated Rice

Generally yields are higher in irrigated rice than the rainfed conditions because of assured irrigation facility. The irrigation may be well irrigation, tank irrigation or canal irrigation. But all these irrigations depend on rainfall as source. It is common techniques used in Rwanda.

A.1.1 Time of Sowing

For achieving higher yields early planting in January in the wet season and the first week of June in dry season are considered essential. Progressive delay in planting results in reduction in grain yield.

A.1.2 Seed Rate

Broadcasting of seeds require about 75 kg/ha while, transplanting requires about 40- 60 kg/ha depending on size of the seeds. Select healthy, bold and good seeds by following the procedure.

1. Prepare salt solution by mixing salt (1.65 kg) in water (10 liters).
2. Test the salt solution concentration with fresh egg which would float in the solution. If egg sinks, add more salt to increase the concentration.
3. Pour the seeds in to the solution, stir well and allow it to settle down.
4. Discard the floating seeds and select the seed which has settled down in the solution.
5. Wash the seeds thoroughly with fresh water.
6. Same salt solution may be used again to test other lots of seeds.

Fig: Salt water preparation.

Fig: Testing of salt water with egg.

Fig: Mixing of seeds in salt water.

Fig: Selection of good seeds.

A.1.3. ***Spacing***

The spacing followed in broadcasting or dibbling of seeds or transplanting of seedlings is 20 cm in between rows and 10-15 cm between plants.

A.1.4. Method of Sowing

There are two methods of crop stand establishment under irrigated situation. They are direct seeding on puddled soil and transplanting.

1. ***Direct Seeding on Puddled Soil*****:** In this system the land is well puddled and sprouted seeds are either broadcasted or dibbled. Drum seeder can also be used for sowing. Direct seeding saves labour as it does not involve nursery raising, uprooting and transplanting of seedlings.

Fig: sowing by using drum seeder.

2. ***Transplanting System:*** It is more common in irrigated condition in Rwanda. Here nurseries are raised well in advance to produce the seedlings. Later transplanting is done using the seedlings. It is highly labour intensive system. But it has got the advantage of less weed problems. When choosing the appropriate nursing system of rice, consider the availability of sunlight, water, labour, land, and agricultural implements.

For raising nursery, fertile well drained field is selected near source of water. To raise seedlings for one hectare 750 m2 area is required. After adequate land preparation 1,000 to 1,500 kg of well decomposed farm yard manure has to be incorporated 2-3 weeks before sowing. Prepare raised beds of 7.5 m length, 2.0 m width and 10 cm height. For one hectare area nearly about 50 beds are required. For each bed, 90 g N + 45 g P_2O_5 + 45 g K_2O/bed should be applied.

There are three types of nurseries are followed for raising the seedlings for transplanting. Those are dry bed nursery, wet bed nursery and dapog method of nursery.

a) ***Dry Bed Nursery:*** It is followed in areas where the water is insufficient. In this method, dry tillage is followed. Sowing of pre-germinated seeds may be done by broadcasting or sown in hand drawn shallow furrows spaced at 8-10 cm and covering with soil. Irrigation is done frequently to keep the beds moist. Dry nurseries are well suited for wet season and the seedlings obtained from these nurseries are hardy and can tolerate adverse conditions better. But weeds problem is more than wet bed method.

b) ***Wet Bed Nursery:*** In wet bed nursery, wet tillage is practiced and pre-germinated seeds are broadcasted uniformly on raised beds of puddled soil.

The seedlings are ready in 20-25 days. The seedlings produced from the well managed nurseries are expected to give better yields. Line planting ensures proper crop stand and facilitates working of rotary weeder for controlling weeds as well as incorporation of N fertilizers. Shallow planting of 3-4 cm deep with a spacing of 20 x 10-15 cm @ 2-3 seedlings per hill is desirable. If need arises, gap filling has to be done.

Fig: Application of compost.

Fig: Sprouted seeds.

Fig: Broadcasting of seeds.

Fig: Covering of seeds with soil.

Fig: Wet bed nursery.

Fig: Transplanting of seedlings.

c) ***Dapog Method of Nursery***: Dapog method of nursery is used for machine transplanting. In this method, the raised beds of one meter width, 10 cm height and convenient length are prepared. On these beds a polythene sheet is placed and above which a mixture of FYM and soil (1:1) of 2.0 cm thickness is placed. Pre-germinated seeds are broadcasted @ 1.0 kg/m2 and covered with straw mulch. Irrigation is done frequently to keep the beds moist. Seedlings are ready for transplanting in 18-20 days. For machine transplanting mats of seedlings are used.

Fig: Bed preparation.

Fig: Covering of polythene sheet.

Fig: Spreading of soil.

Fig: Sprouted seeds ready for sowing.

Fig: Covering of straw mulch.

Fig: Nursery ready for transplanting.

Nursery rising by using trays

Fig: Filling of trays with soil & F.Y.M.

Fig: Seedlings in nursery trays.

Fig: Seedlings ready for transplanting.

Fig: Rolling of seedlings mat.

Fig: Seedlings are first raised in seedbeds before they are planted in the field by farmers

Fig: Loading of seedlings.

Fig: Machine transplanting.

Fig: Machine transplanting.

Fig: Machine transplanted field.

A.2 Rainfed Upland Rice

A.2.1 Time of Sowing

Optimum time of sowing is one of the important non-monetary inputs for raising crop production. It is decided by the onset of monsoon rains. Second fortnight of June is the optimum time for realizing higher yields from rainfed uplands.

A.2.2 Seed Rate: Seed rates of 70-90 kg/ha for drilling and 100-120 kg/ha for broadcasting is recommended.

A.2.3. ***Spacing:*** Inter-row spacing of 20 cm and intra-row spacing of 10-15 cm is being followed.

A.2.4. Method of Sowing

Farmer's traditional practice of broadcasting method of sowing results in uneven stand. Dibble seeds behind the plough at proper depth (5 cm) proved superior in establishing optimum crop stand. Row seeding can be done by making furrows with a country plough and seeding in those furrows. Line sowing is better method than broadcasting as it ensures better crop stand and facilitates easy mechanical weed control. Alternatively seed drills may be used for establishing good crop stand.

A.3 Rainfed Low Land Rice

A.3.1 Time of Sowing: Optimum time of sowing is decided by the onset of monsoon rains. First fortnight of June is the optimum time for getting higher yields from rainfed lowlands.

A.3.2 Seed Rate: Seed rates of 75-100 kg/ha is recommended for rainfed lowlands.

A.3.3 Spacing: Seeds are placed at a spacing of 20 x 15 cm is considered more useful than broadcast method of seeding which results in uneven crop stand.

A.3.4. Method of Sowing

In the rainfed lowland areas, rice crop is either through direct seeding in relatively dry soil or are transplanted after accumulation of water in the field. Transplanting in excess water results in a shock to the seedlings and greater part of the plant remains in water, resulting in poor stand establishment. Direct seeded crop does not experience any such shock and the crop already established acclimatizes faster to the greater depths of water stagnation and maintain most of the plant parts above the water, thereby resulting in greater survival.

Therefore, direct seeding is better than transplanting under rainfed flood-prone condition. Country plough or seed drills are used for the purpose of row seeding.

B. Wheat Sowing

B.1 Time of Sowing

Time of sowing depends on climatic conditions, soil conditions and irrigation facility. In irrigated areas sowing should be done during the month of September and in rainfed areas during second fortnight of January to early February to realize the maximum advantage from the residual soil moisture.

B.2 Seed Rate

Broadcasting of seeds require 150 kg/ha while seed drills 100-125 kg/ha and dibbling 25-30 kg/ha. Under late sown situation or when the soil moisture is less at the time of sowing seed rate should be increased by 25 per cent.

B.3. Spacing

Irrigated wheat is spaced 22.5 cm between rows and 8-10 cm between plants. Rainfed wheat is spaced 25-30 cm between rows and 5-6 cm between plants. When sowing is delayed a closer spacing of 15-18 cm between rows is recommended.

B.4 Method of sowing

Sowing of wheat is generally done by following methods.

1. **Broadcasting**: It the most prevailing and simple method of wheat sowing in Rwanda. Seeds are broadcasted on soil surface, then worked in by hoe or harrowing and covered by hoe or planking respectively.
2. **Behind the Plough**: In this method, the seeds are dropped by hand into the furrows that have been opened with local plough (hoe). The seeds are dropped at a desired depth by hand or special attachment with local plough.
3. **Drilling**: Drilling of seeds with the help of seed drill or seed-cum-fertilizer drill is the best method of sowing.
4. **Dibbling:** Sowing of seeds is done with the help of a small implement known as dibbler. Dibblers are pressed into the soil to make the holes and one or two seeds are dropped by hand in each hole and seeds are covered. Though this method greatly economies the seed, it is time consuming and labour intensive.

C. Maize sowing

C.1 Time of sowing

Time of sowing is indirectly determined by the soil and atmospheric temperature as well as by the supply of water. Thus, there is a general preference for sowing of the crop at the time of onset of monsoon. Late planting in mid-monsoon period creates numerous problems.

C.2 Seed Rate

The quantity of seed required for dibbling method is about 15 kg/ha. However, in planting by other mechanical methods one may use as high as 25 kg seeds/ha. The seed rate should be so adjusted as to obtain the desired plant population.

C.3 Spacing

To obtain desired plant population one may sow the seeds into rows spaced from 60- 90 cm apart and seed to seed distance of 20-30 cm within the row. However, for practical ease a spacing of 75 x 20 cm is more appropriate which is convenient for machine drawn by tractor or bullock power.

C.4 Depth of sowing

For obtaining perfect germination and uniform stand, placement of seed at a desired depth is one of the most important factors. A uniform depth of 5.0 cm is ideal for better germination.

C.5 Method of Sowing

Three methods of sowing are commonly followed under Indian conditions.

1. **Flat Sowing:** On light soils crop is sown on the smooth seed bed. If necessary crop can be earthen up subsequently to avoid plant lodging.
2. **Ridge Sowing**: Ridges are prepared and the sowing is done on top. This system of planting is very useful under high rainfall area of heavy soil. Excess water flows through the trenches and thus contact with seed or plant is avoided.
3. **Furrow Sowing**: Under low moisture condition, this is one of the most effective methods of sowing. Moisture in furrows continues to be available for longer period.

4. **Transplanted Maize**: Can be successfully cultivated by transplanting in winter season. The nursery sown from 10-20 November can be transplanted from mid-December to mid-January. Only one month old seedling may be used for transplanting.

Fig: Mechanical seed drill.

Fig: Mechanical seed drill.

Fig: Seedling stage.

Fig: Seedling stage.

Fig: Two-leaf stage.

Fig: Four-leaf stage.

Fig: Knee-hight stage.

Fig: Rapid growth stage.

Fig: Roots.

Fig: Reproductive stage.

Fig: Tassels (Male).

Fig: Cob with silk (Female).

Fig: Immature cobs.

Fig: Matured cob.

Fig: Types of cobs.

D. Sorghum sowing

D.1 Time of Sowing

Late sown crop is susceptible to shoot fly and midge. Dry sowing just before onset of monsoon is the best. Sorghum should be sown around middle of December. Summer sorghum is mainly raised for fodder and crop is generally sown in March-April in East Rwanda.

D.2 Seed Rate and Spacing: Sorghum crop is sown at 45 x 12 cm using 9-10 kg seeds/ha.

D.2 Method of Sowing

Crop is sown with country plough; however, seed cum fertilizer drill is efficient. Sowing sorghum in ridge and furrow system is recommended in low rainfall areas. Generally, the depth of sowing is 3-4 cm.

Fig: Sowing of seeds.

Fig: Seedling stage.

Fig: Vegetative stage.

Fig: Reproductive stage.

Fig: Ripening stage.

L.O 2.2. Maintain maize, wheat, sorghum, and rice

Content/Topic 1: Different maintenance techniques of maize, wheat, sorghum, and rice

a. Weeding

In a field many other undesirable plants may grow naturally along with the crop. These undesirable plants are called **weeds**. The removal of weeds is called **weeding**. Weeding is necessary since weeds compete with the crop plants for water, nutrients, space and light.

Thus, they affect the growth of the crop. Some weeds interfere even in harvesting and may be poisonous for animals and human beings.

a.1 Rice Weeding management

The competitive effects in transplanted rice are generally lower than puddled seeded system because generally rice seedlings of some age are planted in this system which has a head start over weeds initially. In puddled seeded rice the extent of competition is higher due to the fact that young seedlings suffer more from simultaneously emerging weed seedlings. Generally flooded conditions reduce the grassy weeds to a large extent.

The common weeds found in irrigated rice are sedges like *Cyprus difformis, C. iria*, *Fimbristylis miliacea*, dicots like *Ludwigia parviflora, Marselia quadrifolia, Monochoria vaginalis* and monocots like *Echinochloa crusgali*, *E. colonum*, etc.

There is a need to keep fields weed free for the first four weeks after transplanting. Hand weeding twice at 20 and 40 days after planting is a common practice for controlling weeds in irrigated rice. Alternatively, rotary weeder can be used in row seeding or transplanted crop very effectively. Chemically, pre-emergence herbicides like Butachlor, Thibencarb, Pretilachlor @ 1.0-1.5 kg/ha and Anilofos @ 0.4 kg/ha and post-emergence herbicides like Propanil, 2,4-D and MCPA @ 0.5 kg/ha are applied for controlling weeds.

a.2 Wheat weeding management

Weeds emerge with the crop and if not controlled in the early stages of crop growth they may cause reduction in yield. First 30 to 40 days are regarded highly critical for crop weed competition.

The major dicot weeds like *Chenapodium album*, *Melilotus alba*, *Circium arvense* and monocot weeds like *Phalaris minor*, *Avena fatua*, *Cyperus rotundus*, *Cynadon dactylon* are most commonly found in wheat fields.

Generally, weeds are controlled by hand weeding with hoe. First hand weeding is done with the appearance of thick flush of weeds. Second hand weeding may be repeated after two weeks.

Pre-emergence application of Pendimethalin @1.0 kg/ha and post-emergence application of 2,4-D (ethyl ester) @ 0.3-0.4 kg/ha, Isoproturon, Metoxuron @1.0-1.5 kg/ha in 700-800 litres of water within 30-35 days after sowing effectively control broad spectrum of weeds in wheat. During initial growth stages, the morphological features of *Phalaris minor* (little canary grass) and *Avena fatua* (wild oats) are closely resemble the traits of wheat seedlings. Therefore, it is difficult to recognize them during hand weeding. They can be controlled by post emergence application of Isoproturon, Metoxuron @1.0-1.5 kg/ha.

Fig: Weeding.

Fig: Weeding.

a.3 Maize Weeding Management

Weeds have an inherent fast growing and fast multiplying capacity. They pose a serious threat in fields of wider spaced crops like maize. Most common weeds in maize are *Cyperus rotundus*, *Cynadon dactylon*, *Digitaria sanguinalis* among monocots and *Tribulus terrestris*, *Trainthema portulacastrum*, *Traintheme monogyna*, *Corchorus actangulus* among dicots.

Weeding may be undertaken as soon as the crop germinate and attains 3-4 leaf stage (about 25 days after sowing) and may be continued till 75 days after sowing. Any delay in weed removal may cause fall in grain yield. Unweeded crop is likely to give 50 per cent less yields as compared to clean seed bed. Weeds are usually controlled by manual labourers in 2-3 operations. Atrazine at 2.5 kg/ha is one of the most efficient herbicides which remains effective for a maximum period of 30 days.

In legume-cereal mixture, Pendimethalin at 2.5 l/ha has been found to be the most effective and protects both the legume and cereal crop in pre-emergence application.

Fig: Manual weeding.

Fig: Interculitivation.

Fig: Polythene mulching.

a.4 Weed Management for Sorghum

Most common weeds found in sorghum fields are *Amaranthus viridis*, *Euphorbia macrocephylla, Phyllanthus niruri, Commelina benghalensis* among broad leaf weeds; *Cyperus rotondus, Cynodon dactylon, Sorghum halepense, Dactyloctenium aegyptium* among grassy weeds.

First 30-40 days after sowing is considered as critical period for weed competition. Inter row weeds may be controlled mechanically by running blade har row, but intra row weeds remain. Hand weeding with *khupi* or hand hoe is most common practice. Two hand weedings at 15 and 30 days after sowing effectively control the weeds. Both in inter and intra row weeds can be controlled by using herbicides efficiently. Pre-emergence application of atrazine or Simazne @ 0.25-0.75 kg/ha and post-emergence application of 2,4-D @ 0.50-0.75 kg/ha 15-20 days after sowing direct spraying in between rows control the weeds effectively.

Striga (Striga lutea) a parasitic weed causes 15-100 per cent loss depending on severity of infestation. Following are the ways to check its infestation and control.

1. Grow *Striga* resistant varieties as Co-20, N-13 etc.
2. Crop rotation with trap crops as cotton, sunflower and groundnut, destroys the seeds and minimize the losses.
3. In standing crop, hand pulling when population is less or spraying 2.0 kg 2,4-D sodium salt as directed spray check its infestation and damage.

b. Fertilizers application (fertilization)

The substances which are added to the soil in the form of nutrients for the healthy growth of plants are called **manure** and **fertilizers.**

Soil supplies mineral nutrients to the crop plants. These nutrients are essential for the growth of plants. In certain areas, farmers grow crop after crop in the same field. The field is never left uncultivated or fallow. Imagine what happens to the nutrients?

Continuous cultivation of crops makes the soil poor in nutrients. Therefore, farmers have to add manure to the fields to replenish the soil with nutrients. This process is called **manuring**. Improper or insufficient manuring results in weak plants.

Manure is an organic substance obtained from the decomposition of plant or animal wastes. Farmers dump plant and animal waste in pits at open places and allow it to decompose. The decomposition is caused by some microorganisms. The decomposed matter is used as organic manure. Hope You have already learnt about vermicomposting in the previous Class.

Fertilizers are chemicals which are rich in a particular nutrient. How are they different from manure? Fertilizers are produced in factories. Some examples of fertilizers are— urea, ammonium sulphate, super phosphate, potash, NPK (Nitrogen, Phosphorus, and Potassium).

The use of fertilizers has helped farmers to get better yield of crops such as wheat, paddy and maize. But excessive use of fertilizers has made the soil less fertile. Fertilizers have also become a source of water pollution. Therefore, in order to maintain the fertility of the soil, we have to substitute fertilizers with organic manure or leave the field uncultivated (fallow) in between two crops. The use of manure improves soil texture as well as its water retaining capacity. It replenishes the soil with nutrients.

Another method of replenishing the soil with nutrients is through crop rotation. This can be done by growing different crops alternately. Earlier, farmers in northern India used to grow legumes as fodder in one season and wheat in the next season. This helped in the replenishment of the soil with nitrogen. Farmers are being encouraged to adopt this practice. In the previous classes, you have learnt about *Rhizobium* bacteria. These are present in the nodules of roots of leguminous plants. They fix atmospheric nitrogen.

Table 2.1: Differences between Fertilizer and Manure

S. No.	Fertiliser	Manure
1.	Fertiliser is a man-made inorganic salt.	Manure is a natural substance obtained by the decomposition of cattle dung and plant residues.
2.	Fertiliser is prepared in factories.	Manure can be prepared in the fields.
3.	Fertiliser does not provide any humus to the soil.	Manure provides a lot of humus to the soil.
4.	Fertilisers are very rich in plant nutrients like nitrogen, phosphorus and potassium.	Manure is relatively less rich in plant nutrients.

Advantages of Manure:

The organic manure is considered better than fertilizers. This is because:

- ✓ it enhances the water holding capacity of the soil.
- ✓ it makes the soil porous due to which exchange of gases becomes easy.
- ✓ it increases the number of friendly microbes.
- ✓ it improves the texture of the soil.

Fertilizers application for Maize crop

Requirement of nutrients by hybrids is higher because of its greater potentially for grain production.

Manures

Application of 10 tons of well decomposed farm yard manure per hectare helps in improving the yield under irrigated condition and 7.5 t/ha under rainfed condition.

Fertilizers

Nitrogen: Nitrogen level in the range 100-120 kg/ha is applied. There is gradual increase in the requirement of nitrogen by the growing crop, the highest nitrogen requirement being exhibited at the flowering stage. Subsequently, the demand for nitrogen starts declining. Therefore, adequate nitrogen supply should be ensured from germination to the flowering stage. To achieve this, nitrogen is usually applied in three equal splits at sowing, knee high stage and tasseling stages.

Phosphorus: It is the next most important plant nutrient after nitrogen which is found deficient in most soils. It has a beneficial effect on root growth and plant health. Application of 40-60 kg/ha of phosphorus is necessary for getting better yields. Its application in single dose as a placement below seed is highly desirable.

Potassium: Potassium is essential for vigorous growth of the plant and for so many other metabolic activities. Placement of 30-40 kg/ha potassium little away from the seed is generally found to be quite adequate.

Zinc: Higher uptake of other nutrients increases the demand of zinc. It is, therefore, advisable to apply zinc sulphate @ 20-25 kg/ha in those conditions where its deficiency is more conspicuous.

Fertilizer application for wheat crop

Application of nitrogen up to 40-60 kg/ha for rainfed condition and 120-150 kg/ha for irrigated condition is recommended. Use of farm yard manure, green manure, nitrogen fixing micro-organisms like *Azatobacter*, *Azospirillum*, etc. reduces nitrogen requirement by one third.

Nitrogenous fertilizers should be applied in two splits; 50 per cent each as basal dose at the time of sowing and top dressing at 30 days after sowing. Requirement phosphorus for the wheat crop is up to 60 kg/ha and potassium is 40-50 kg/ha and both are applied at the sowing as basal dose. Zinc deficiency soils require application of 25 kg/ha of zinc sulphate or foliar spray of $ZnSo_4$ @ 0.5 per cent. For this 5 kg of $ZnSo_4$ and 2.5 kg of slaked lime is dissolved in 1,000 litres of water to spray an area of one hectare. For manganese deficient soils, foliar spray of 0.5 per cent $MnSo_4$ is recommended.

Fertilizer application for Rice crop

Responses to fertilizer application are higher in dry season as compared to wet season. This is mainly due to higher solar radiation and lack of rains and better possibility of irrigation water management. Incorporation of well decomposed farm yard manure @ 10 t/ha or green manure @ 5 t/ha 2-3 weeks in advance is essential. Nitrogen @ 60-100 kg/ha, phosphorus and potassium 50 kg/ha may be considered desirable for wet season; for the dry season, a rate of 80-120 kg N/ha, 60 kg P_2O_5 and K_2O/ha may be considered.

Regarding the form of nitrogenous fertilizers, ammonical forms are better than nitrates. However, urea, which is the cheapest fertilizer, is widely used in the country. Nitrogen recovery in low land rice is less (30-40 %). Nitrogen use efficiency can be increased by effective water control, use of slow releasing nitrogen fertilizers, split application and method of application.

Fertilizers application for Sorghum crop

Application of FYM at 8-10 t/ha prior to sowing not only provide essential nutrients but also improve germination by reducing crust and also increases water retention capacity of soils. Sorghum is a heavy feeder of plant nutrients.

General recommendation is 60 kg N, 30 kg P2O5 and 30 kg K2O for rainfed areas and 80 kg N and 40 kg P2O5 and 40 kg K2O for irrigated areas. For hybrids 100 kg N/ha is beneficial under irrigated conditions. In intercropping system with pulses, sorghum is to be supplied with 50 per cent of recommended levels of nitrogen, phosphorus and potassium.

Full quantity of phosphorus and potassium and half quantity of nitrogen should be drilled at 10 cm below at the time of sowing. Remaining half quantity of nitrogen should be given 30-35 days after sowing at knee high stage of crop. If moisture is scarce, avoid top dressing. In zinc deficient area, apply 20-25 kg ZnSO4 or 0.2 per cent ZnSO4 with half quantity of lime to prevent burning of laves.

c. Watering or irrigation of maize, wheat and rice crops

All living beings need water to live. Water is important for proper growth and development. Water is absorbed by the plant roots. Along with water, minerals and fertilisers are also absorbed. Plants contain nearly 90% water. Water is essential because germination of seeds does not take place under dry conditions. Nutrients dissolved in water are transported to each part of the plant. Water also protects the crop from both frost and hot air currents. To maintain the moisture of the soil for healthy crop growth, fields have to be watered regularly.

The supply of water to crops at regular intervals is called **irrigation**. The time and frequency of irrigation varies from crop to crop, soil to soil and season to season. In summer, the frequency of watering is higher. Why is it so? Could it be due to the increased rate of evaporation of water from the soil and the leaves?

Watering of Rice crop

In rice, water requirement is the total amount of water needed from sowing till ripening, to meet the losses due to evaporation, transpiration and economically unavoidable losses in the form of deep percolation and seepage. It also includes water required for raising nursery and for special purposes like puddling. The total water requirement of rice varies from less than 800 mm to more than 2,500 mm depending upon the duration of the variety, characteristics of the soil and climatic conditions of the locality. Rice is grown under continuously flooded condition with 2-7 cm standing water throughout the season to achieve higher yield and weed control.

Watering of wheat crop

The response of wheat to irrigation depends upon the soil and climatic conditions. About 4-6 irrigations are required for wheat. Flooding method of irrigation is commonly practiced by the farmers in India. The most critical stage for moisture stress is crown root initiation stage (20-25 days after sowing) and flowering stage (80-85 days after sowing). Rain fed wheat is commonly practiced in Rwanda than irrigated wheat.

Watering of Maize crop

A total rainfall in the range of 500-600 mm during the crop season would be quite enough for maize, if the water losses through different sources are kept to the minimum. It is important to note that few hours water logging at germination stage may cause complete wipe out of the crop. Flooding the crop for duration of 24 to 72 hours may cause 30-40 per cent damage in crop yield. It is, therefore, essential to prevent such a high loss by proper water management. Wherever possible, maize sowing may be undertaken before onset of monsoon preferably 10 to 20 days in advance. By doing so the high rainfall period will coincide with grand growth period of the crop and may not have any adverse effect on the crop yield. Under moisture stressed conditions to achieve higher water use efficiency, crop has to be sown in furrows instead of ridges.

Adequate soil moisture content throughout the crop growth period resulted in maximum grain yield. The optimum availability of moisture may be maintained by irrigation crop at critical stages. Six critical stages i.e. early knee, late knee, flowering, silking, milk and dough stages for growth and development have been identified for the purpose of irrigation.

Watering of Sorghum crop

Sorghum is drought tolerant crop. They have extensive and deep root system capable of extracting soil moisture from deeper soil layers. High yielding varieties respond well to irrigation. Early seedling stage and flowering primordial stages are considered most critical for moisture stress. Generally, 1-8 irrigations are needed, depending on soil and climatic conditions.

Content/Topic 2: Pests and diseases control for maize, wheat, rice, and sorghum crops

A. Main pests of maize, wheat sorghum, and rice

A.1 Main pests of maize crop

The main pests for maize crop are insect pests such as:

1. **Stem Borer**: Pull out all dead hearts and destroy them to kill the lingering stages of the pest in the stubbles. Plough up the field soon after harvesting of maize, collect and burn the stubbles. Grow resistant/tolerant varieties. Sowing of crop in the first week of July evades borer infestation. Use higher seed rate and remove the plants showing severe borer injuries at thinning. Spray Endosulfan 35 EC 0.1 per cent, Lindane 20EC 0.05 per cent or Carbaryl 50 WP 0.1 per cent.
2. **White Grubs:** Hand collection of adults and their killing in kerosene water helps in reducing future generations. Spray Carbaryl 50 WP or Monocrotophos 36 WSC 0.05 per cent or Quinalphos 25 EC 0.3 per cent on host trees. Use Phorate 10 per cent or Quinalphos 5.0 per cent granules in rows @ 25 kg/ha before sowing crop in endemic areas.
3. **Termites:** Mix 4.0 per cent Endosulfan dust @ 25 kg/ha in the soil before sowing in termite prone areas.
4. **Hairy Caterpillars and Climbing Cutworms**: Spray Endosulfan 35 EC 0.1 per cent after the appearance of pests.

Fig: White Grubs.

Fig: Stem Borer.

5. **Fall army worm (FAW):** Attacks more than 80 plant species, causing damage to cereals such as maize, rice, sorghum, and also to vegetable crops such as tomatoes, sugarcane and cotton. FAW can cause significant yield losses if not well managed. It can have several generations per year and the moth can fly up to 100 km per night.

Eggs *Larva* *Adult moth*

Fall army worm damage on maize crop

How to control/ manage FAW

Organic control

- ***Nimbecidine®-***This is a neem-based biopesticide that can control the fall armyworm, aphids, leaf miners, mites, whiteflies, thrips, wireworms and even nematodes in maize, cabbages, potatoes, beans and any crop that is under threat from pests.
  - One characteristic of this biopesticide is that it is an antifeedant meaning that the pest cannot be able to feed on the target crop.
  - Nimbecidine also interferes with the pest's ability to lay eggs.

Homemade solutions

- ***Pyrethrum flowers -***The white flowers in pyrethrum have active ingredients called pyrethrin.
  - Farmers who opt to use pyrethrum can pick the flowers on a warm day when the flowers are open, dry and store them in an airtight container in the dark (light reduces the effectiveness of the flowers). Later the dried flower can be ground into powder.
  - Mix 20g of pyrethrum powder with 10 litres of water.
  - Add soap as a spreader and sticker and apply immediately especially in the evenings when the armyworms are active.
- ***Garlic, oil and soap solution***
  - Like neem, garlic has anti-feedant properties and can also repel most pests.
  - Mix 85g of crushed garlic with 50ml of vegetable oil.
  - Add 10ml of liquid soap (use bar soap).
  - Allow the mixture to stand for 24 hours.

- Mix 50ml of the garlic and vegetable oil emulsion with 1 litre of water (or make enough fill a 20litre knapsack sprayer by multiplying the same amount by 20) shake thoroughly before spraying preferably in the evening when the armyworms come out to feed

- ***Ash and Chili powder***
  - Buy ripe chilli powder (pepper) from the market or prepare your own using ripe pepper.
  - Dry the pepper and make powder by either grinding or pounding, remove the big particles and leave the fine powder.
  - Sieve cold wood ash from the fireplace.
  - Get 1 tin (2kg tin or plastic) of ash.
  - Mix each 2kg tin of wood ash with 5 teaspoonful of chilli powder.
  - Mix the chilli and ash properly by shaking them in a container.
  - Put the mixture in a used pesticide container that has small holes.
  - Apply the mixture from the container by shaking it once into each plant funnel.
  - For good results, apply the mixture immediately you see the worms in the maize and repeat the same if you notice any pests in the maize or pest damage to your crop.

Biological control

- **Sugary sprays, oil or lard, 'fish soup'**
  - Or other material to attract ants and wasps to the maize plants.
  - The predatory ants are attracted to the lard, oil, bits of fish parts, or sugar; once on the maize plants, they also find and eat FAW larvae
- ***Push*-pull *IPM method***
  - Push-pull is a habitat management strategy developed and implemented to manage pests such as stem borers, striga weed and address soil degradation, which are major constraints in maize production in Africa. The technology entails using a repellent intercrop (Desmodium as a "push") and an attractive trap plant (Napier/Brachiaria grass as a "pull"). The Napier grass planted around the maize farm attracts stemborers and FAW to lay eggs on it but it does not allow larvae to develop on it due to poor nutrition; so very few larvae survive. At the same time, Desmodium, planted as an intercrop emits volatiles that repels stemborers or

FAW, and secretes root exudates that induces premature germination of striga seeds and kills the germinating striga; so this depletes seed banks of striga in maize farms over time; covers the ground surface between maize, thus smothering weeds enriches the soil with nitrogen, preserves soil moisture and protects the soil from erosion.

Chemical control

- There are a number of pesticides used to kill or repel insects, diseases, plants, animals and other living organisms which are invasive, harmful and cause damage and therefore are considered to be pests.
- Pesticides with the followingactive ingridients amongst others have been registered Benfuracarb/Fenvalerate, Carbosulfan, Chlorantraniliprole, Chlorantraniliprole/ Lamda-cyhalothrin, Chlorpyrifos, Chloropyrifos/Cypermethrin *(and many more)*
- *NB: Farmers experiences noted that no single chemical pesticide is effective in control of FAW.*

A.2 Main pests of wheat crop

The following are main insect pests for wheat crop:

- **Termites**: Infestation of termites is more under un-irrigated conditions and in the field where un-decomposed compost is applied. Termites can be controlled by the use of 4 per cent Endosulfan dust @ 20-25 kg/ha or Ash substance.
- **Gujhia Weevil**: Control measure is same as of termites.
- **Army Worm**: Army worms feed on plants during night time and during day time pick them and kill. They may be controlled by dusting 4 per cent Endosulfan @ 20-25 kg/ha or by spraying Carbaryl @ 2.5 kg/ha.

Fig: Army worm.

Field Rats

Rats cause heavy loss to wheat crop in the field. For their control fumigate the burrows of rats with Aluminium phosphate at one tablet of 0.5 g for small burrow and 3.0 g for large burrow.

Fig: Field Rats.

A.3 Main pests of Rice crop

Generally, rice pests can be categorized into three main groups depending on the stage of the rice growing cycle when they are most likely to attack:

a. **Seedling pests** which attack seedlings during the younger stages of the rice crop include African rice gall midge, snails, crabs and thrips.
b. **Leaf and tiller feeding pests, sucking leafhoppers and stem borers** which bore in the tillers include striped borer, white borer, and yellow borer, pink borer common in uplands, stalk-eyed fly and African rice gall midge common in lowland rice.
c. **Pests in ripening rice** include birds, rats and bugs (stink bug, rice bug, mealy bug and rice weevil). While bugs stay on the young panicles and suck the milky juice causing staining of the grains (lowering grain quality), rodents (e.g. rats) cut down the rice plant and feed on the soft parts and on the mature grains. Birds feed on the filling grain as well as mature grains.

The following are main insect pests for Rice crop:

- **Termites:** Termites infest upland rice and can be effectively controlled by seed treatment with Chlorpyriphos @ 0.5 kg/100 kg seed.

- **Gundhy Bug:** Spray the crop with Monocrotophos or Chloropyriphos @ 0.5 kg a.i./ha in the forenoon hours.
- **Mealy Bug:** Spray Phophamidon or Malathion at 0.1 per cent.
- **Stem Borer and Gall Midge:** Stem borer attack results in dead hearts. Root dipping prior to transplanting in 0.02 per cent Chlorpyrifos for 12 hours or 0.02 per cent Chlorpyriphos + 1.0 per cent Urea for three hours will control up to 30 days. Soil incorporation of Carbofuran or Phorate or Quinolphos @ 1.0 kg a.i./ha gives good control in vegetative stage. At heading stage, two rounds of foliar sprays of Quinalphos or Chlorpyriphos or Phosphamidon @ 0.5 kg a.i./ha.
- **Green Leaf Hopper:** Foliar spray with Phosphamidon, Monocrotophos, Carbaryl @ 0.5 kg a.i./ha.
- **Cut Worm**: Spray Chlorpyrifos, Quinalfos, Methyl parathion and Endosulfan @ 0.4 kg a.i./ha at dough stage.
- **Case Worm, Leaf Folder, Hoppers and Whorl Maggot**: Spray Quinalfos, Endosulfan, Chlorpyriphos @ 0.5 kg a.i./ha.
- **Brown Plant Hopper (BPH):** Spray Carbaryl 0.75 kg a.i./ha or Carbofuran @ 0.75 kg a.i./ha or apply Phorate granules @ 1.25 kg a.i./ha.

Fig: Brown plant hopper.

A.3 Main pests of Sorghum crop

The following are main insect pests for Rice crop:

- **Shoot Fly:** Insect causes damage from 1-4 week after emergence, Maggot feeds on tips resulting into wilting of central leaf. Leaf dries and gives a typical appearance of dead heart. At later stages, infested plant produces side tillers. Infestation can be avoided by sowing crop within 7-10 days of onset of monsoon. Seed treatment with Furadan at 100 g/kg seed or Furadan 3G or Phorate 10 G at sowing @ 20 kg/ha also check incidence. In case of infestation in standing crop, spray 0.025 per cent Metasystox. Repeat spraying after 15 days.

Fig: Shoot fly.

Fig: Seed treatment device.

- **Stem Borer:** Infest crop from 15 days till maturity. Larvae initially feed on leaves. Later, the larvae bore into the main stem causing stem tunneling leading to breakage of stem. Preventive measures are to uproot and burn the stubbles of previous crop. Infestation may be checked by applying Endosulfan 4G or Malathion 10D or Furadan 3G in whorl @ 8-12 kg/ha at 20-35 days after emergence after any visual symptom of insect.

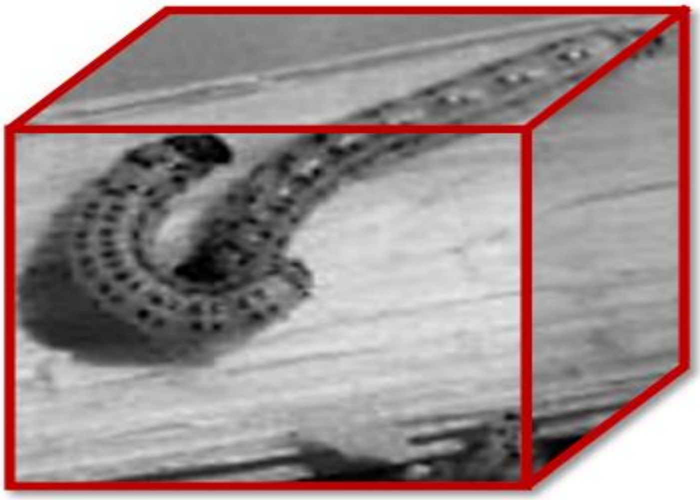


Fig: Stem borer.

B. Main Disease of maize, wheat sorghum, and rice

B.1 Major Disease of maize crop

The crop has a list of diseases which are generally considered to be major constraint in production, however, their economic importance varies according to environmental conditions and cultural practices applied by farmers. The diseases like maize stem borers, maize streak, leaf blight, Rust and Maize Lethal Necrosis disease (MLND) are currently considered as main disease for maize.

1. **Maize stem borers:** controlled by:
    - ✓ cutting maize stalks after harvest to ground level and leave to dry
    - ✓ Clear all remains of the previous maize crop after harvest if the field was heavily attacked by stalk borers.
    - ✓ Plough deeply, then harrow
    - ✓ Plant early, at the beginning of the rains or in the next 2 two weeks



Chemical control

- Start looking for signs of damage when plants are 2 to 4 weeks old, depending on the area.
- If you find damage holes in the leaves then use any of the following chemicals:
- Thiodan - a pinch into the funnel of each plant (1.2 - 1.6 kg/acre)
- Dipterex - a pinch into the funnel of each plant (1.2 - 1.6 kg/acre)
- Bulldock - one shake in the funnel of each plant (3-4 kg/ acre).
- Ambush - one shake per plant in the funnel (3 - 4 kg/acre)
- Pymac (the residue from pyrethrum processing) - a spoonful of Pymac should be applied into the funnel of each plant

2. **Maize streak virus:** The virus is transmitted by leafhoppers (Cicadulina spp. (C. mbila/C. bipunctella **zeae)).**

Damage/ symptoms

- The virus causes a white to yellowish streaking on the leaves.
- The streaks are very narrow, more or less broken and run parallel along the leaves.
- Eventually the leaves turn yellow with long lines of green patches
- Plants infected at early stage usually do not produce any cobs.
- Yield losses in East Africa vary between 33 and 55% under natural infection conditions

Fig: Maize streak disease

Control

- Use of tolerant/resistant varieties
- Early rouging
- Eradication of grass weeds
- control vector by spraying with dimethoate, malathion

- Avoid overlap of two maize crops
- Crop rotation
- Use certified maize seed

3. **Leaf Blight:** Currently controlled by growing resistant or tolerant maize cultivars such as tamira, katumani, isega, and magumba. Good field sanitation (removal of crop residue after harvest or deep ploughing of crop residues), and use crop rotation. Use protective fungicides of Dithane M-45, Zineb @ 2.0-3.0 kg/ha as soon as first symptoms of the disease appear at knee high stage of the crop growth.

Fig: Leaf blight disease

4. **Rust:** Select resistant maize cultivars for planting in areas where rust becomes problem, e.g., hybrid tamira, katumani, isega, and magumba. The severity of the disease during short season can be reduced by spraying Mancozeb or Zineb @ 2.5-3.0 kg/ha. The first spray should be given as soon as rust pustules appear on the foliage and then two or three more sprays at 10-15 days intervals.

Fig: Maize Rust

5. Maize Lethal Necrosis Disease (MLND):

Identification

- *Preferred Scientific Name:* Maize lethal necrosis disease
- *Other Scientific Names:* Corn lethal necrosis disease, Maize chlorotic mottle virus, Sugarcane mosaic virus
- MLND is mainly spread by a vector, transmitting the disease from plant to plant and field to field.
- The most common vectors are maize thrips, rootworms and leaf beetles.
- Hot spots appear to be places where maize is being grown continuously (over time)

Control:

- Do not plant a new maize crop near an infected field. Wind-blown insect vectors can transmit the disease.
- Avoid growing maize in consecutive seasons, opting for crop rotation or grow alternative crops

Note: Maize Lethal Necrosis does not occur on other crops, so avoid growing maize after maize. Diversify by planting different crops each season. A break interrupts the disease cycle.

B.2 Main Disease of Rice crop

B.2.1. Category: Bacterial diseases

1. **Bacterial blight**

Symptoms

- Water-soaked stripes on leaf blades;
- Yellow or white stripes on leaf blades;
- Leaves appear grayish in colour; plants wilting and rolling up;
- Leaves turning yellow;
- Stunted plants; plant death;
- Youngest leaf on plant turning yellow

Management

- Bacterial blight can be effectively controlled by planting resistant rice varieties;
- Avoid excessive nitrogen fertilization;
- Plow stubble and straw into soil after harvest

2. **Bacterial leaf streak**

Symptoms

- Small, water-soaked streaks between leaf veins which are initially dark green and then turn translucent;
- Streaks grow larger, coalesce and turn light brown in colour;
- Tiny beads of yellow coloured bacterial exudate are common on the surface of the streaks;
- Leaves turn brown and then gray-white in colour before they die

Cause

- Bacterium

Comments

- Bacteria survive on infected seed and straw;
- Bacteria may enter the plant through wounds;
- Bacterial exudate can be spread in irrigation water;

- Emergence of the disease is favored by high humidity and high temperatures

Management

- Control of bacterial leaf streak is dependent on the use of resistant rice varieties and on planting of treated seed

B.2.2. Category: Fungal diseases

1. **False smut**

Symptoms

- The pathogen infect the rice plant during flowering stage and causes chalkiness of grain. The individual grains are covered with orange fungal mass in the beginning, later turns into greenish velvet colour during sporulation stage and finally into charcoal black during spore maturation stage.
- It infects only few grains in spikelet.

Cause

- Fungus

Comments

- It is seed born disease and may also affect seed germination.

Management

- Treat seeds with hot water (52^{0}C) for 10 min.
- Roughing the infected plants from field and from harvested grains.
- Keep the rice field and surrounding clean. Use resistant varieties.
- Maintain humidity in field by alternate wetting and drying.

2. **Rice blast**

Symptoms

- Lesions on all parts of shoot;
- White to green or grey diamond-shaped lesions with dark green borders;
- Death of leaf blades;
- Black necrotic patches on culm;
- Rotting panicles

Cause

- Fungus

Comments

- Most common disease of rice worldwide;
- Causes most damage in areas of intense cultivation;
- Disease emergence favours high soil nitrogen content

Management

- If disease is not endemic to the region, blast can be controlled by planting resistant rice varieties;
- Avoid over-fertilizing crop with nitrogen as this increases the plant's susceptibility to the disease;
- Utilize good water management to ensure plants do not suffer from drought stress; disease can be effectively controlled by the application of appropriate systemic fungicides, where available

3. **Stem rot**

Symptoms

- Symptoms generally begin to appear after the mid tillering stage;
- Black lesions appear on outer leaf sheath at the water-line;
- Lesions expand and begin to infect inner leaf sheaths and culm begins to rot;
- Infections which reach the culm can lead to lodging of plants, unfilled panicles and death of tillers

Cause

- Fungus

Comments

- Fungus survives in crop debris in soil after harvest;
- Fruiting bodies are carried to the surface when fields are flooded where they then infect leaf sheaths at the water line

Management

- Bury crop residue deeply in the soil after harvest;
- Avoid excessive nitrogen fertilization; plant less susceptible rice varieties

B.2.3. Category: Viral diseases

1. **Grassy stunt**

Symptoms

- Stunted plants;
- Short, narrow pale green or yellow leaves;
- Mottled or striped pattern on newly unfolded leaves;
- Irregular dark brown spots on leaves;
- Few or no panicles produced;

Cause

- Virus

Comments

- Transmitted by leaf hoppers;

Management

- Several varieties of rice resistant to the leaf hopper vectors have been developed but the insects have overcome the resistance in several countries;
- Applications of appropriate insecticides can help to reduce populations of vectors in temperate regions

2. **Rice Yellow Mottle**

Symptoms

- Yellowish streaking of leaves;
- Smaller leaves than normal and have fewer tillers;
- Panicle does not emerge from the sheath and is of a bad shape;

Cause

- Virus

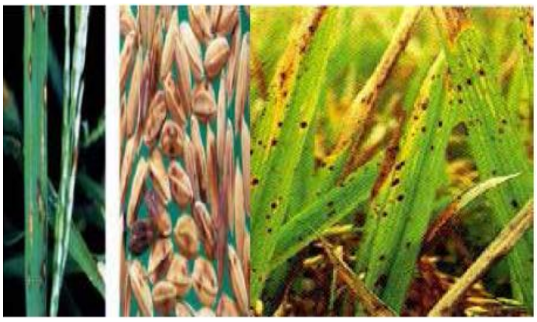
Comments

- Transmitted by plant to plant by feeding insects, especially by various beetles and grasshoppers;

Management

- Use disease resistant disease varieties such as Mpembuke, Nemeyubutaka, Rumbuka and Ndamirabahinzi.
- Weed the field regularly to remove all other hosts of the virus.
- If a nursery is diseased, change its location for the next growing season.
- Surround your plot with a water-border to prevent rodents moving through the crop.

3. Leaf blight for rice



Symptoms

- Caused by fungus, it attacks all parts of the plant at any time.
- Grey diamond-shaped lesions on leaves.

Management

- Use of certified seeds,
- Proper land preparation,
- Use of fertilizers at recommended rates
- Proper water channeling,

4. Stalk-eyed fly

Symptoms

- It is an insect in the family of flies which has a black colour around its head, and pink on the other part. It attacks plant leaves and stem.
- Its eggs become worms which destroy the plant leaves.

Management

- Proper land preparation and weeding,
- Increase water level in the plot once its symptoms are observed.
- Burn plant residues after harvesting

Use pesticides

- Use Deltamethrine, Cypermethrine, Imidachloprid: 1ml of drug in 1L of water.

B.3. Main Disease of Wheat crop

Currently in Rwanda, there is no serious pest problem, except head smut reported in Burera district. This would require a continuous field monitoring and reporting as soon as possible any infestation observed on minor scale. Most of wheat pests and diseases can be managed by cultural methods with a combination of resistant varieties without need for pesticides use. The best and sustainable strategy for smallholder farmers is the use of resistant varieties. It is also important to note that the resistance to some pathogens, such as rust, is short-lived and cultivars may need to be changed at short intervals as pathogens adapt to overcome the resistance of locally grown cultivars. Seed dressing using fungicide is often effective against seed-borne or soil- borne pathogens.

The major diseases of wheat are mainly rusts and head smut leaf and glume botch, and root rot, seedling blight and spot blotch.

Fig: Stem rust.

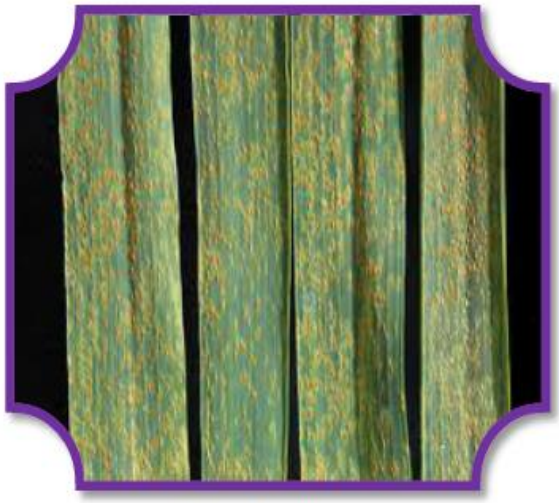


Fig: Leaf rust.

B.4 Main disease of sorghum crop

1. **Downey Mildew**: Appearance of vivid green and white stripes on leaves. Stunted growth and failure to produce head at advance stage is observed. Seed dressing with Metalaxyl (Ridomil 25) at 1.0 g/kg control infection. In field, spray of' Metalaxyl 0.01 per cent 40 days after germination check spread of Downey mildew.
2. **Grain Moulds**: This disease is caused by many fungal species. Grains infected with *Fusarium moniliforme* have white or pinkish colour, while grains infested with

Curvularia lunata have black appearance. Discolouration of grain, reduction in grain weight leading to 75-100 per cent damage. The harvested grains are also toxic to animals. Seed treatment with Captan 4 g/kg seeds is a preventive way. In field, three sprays of Aureofungin 200 ppm + Captan 0.3 per cent from 50 per cent flowering at 10 days interval is costlier but very effective. Spraying three times Dithane M-45 and Bavistin 0.2 per cent from flowering at 10 days interval control grain mould.

3. **Rust: Rust** pustules invade the lower leaves. In susceptible varieties entire leaf tissues are destroyed by pustules. Use of clean seed, crop rotation and use of resistant varieties are preventive ways against this disease. Effective control in field could be achieved by four sprays of Dithane M-45 at 0.2 per cent at 10 days interval from 30 days after germination.

Learning Unit 3– Harvest and handle harvested products

L.O. 3.1 Identify maturity physiological signs of maize, wheat and rice

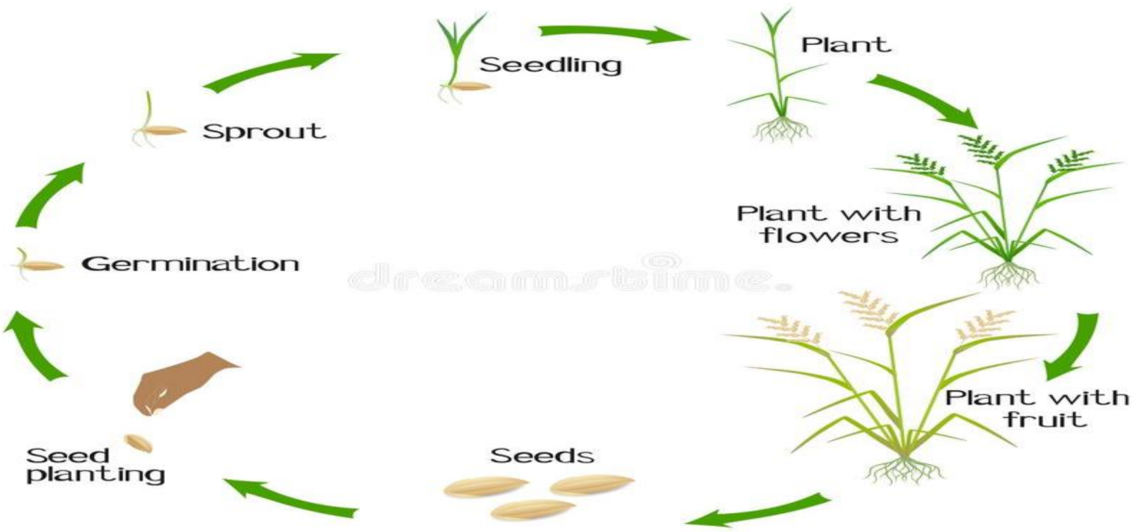
There is an optimum time for harvesting cereals, depending on date of seeding, the maturity of the crop and the climatic conditions during the growing season. This has a significant effect on the quality of the grain during storage.

Harvesting often begins before the grain is ripe and continues until mould and insect damage are prevalent. Grain not fully ripened contains a higher proportion of moisture and will deteriorate more quickly than mature grains because the enzyme systems are still active.

If the grain remains in the field after maturing, it may spoil through wetting caused by morning dew and rain showers. There is also an increased risk of insect damage.

Content /Topic1: Life cycle of maize, wheat, Sorghum, and rice crops

A. Life cycle of rice crop



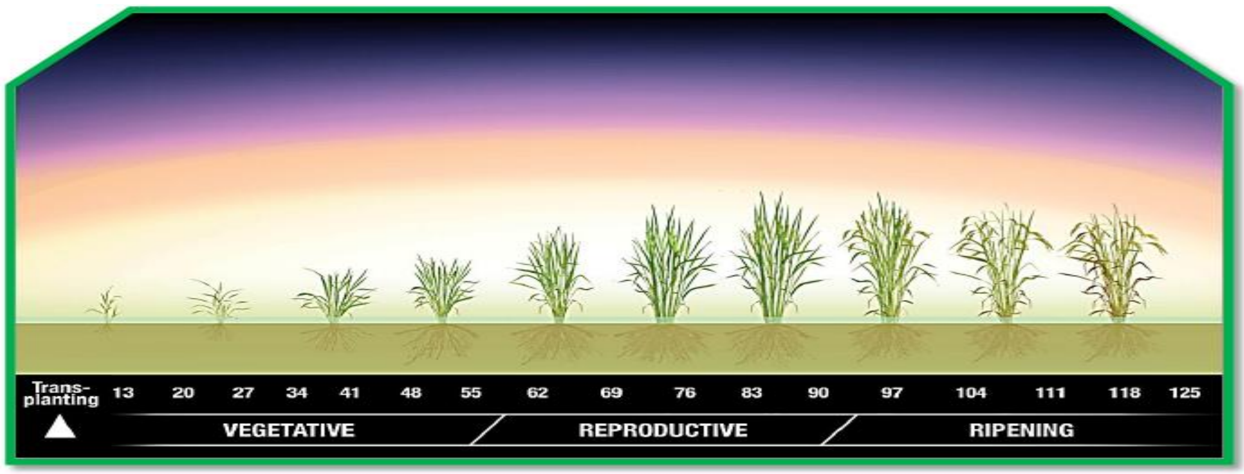


Fig: Stages of plant growth.

B. Life cycle of maize crop

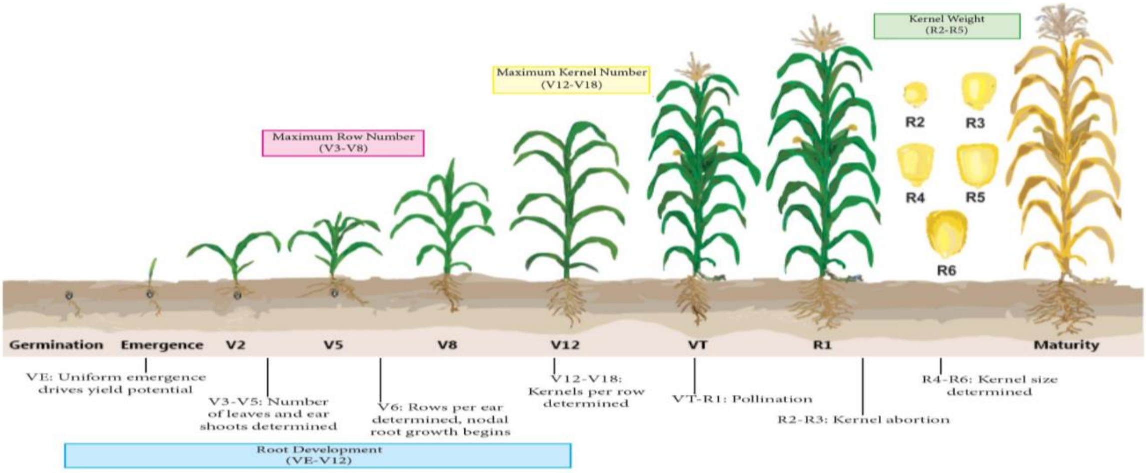
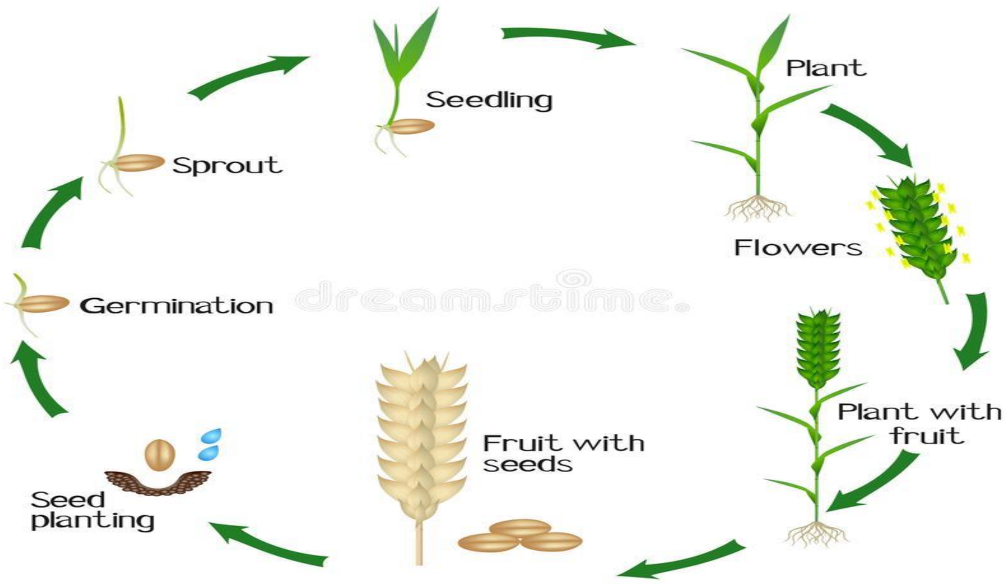


Fig: Maize growth stage

Maize takes 90-120 days to be fully matured.

C. Life cycle of wheat crop



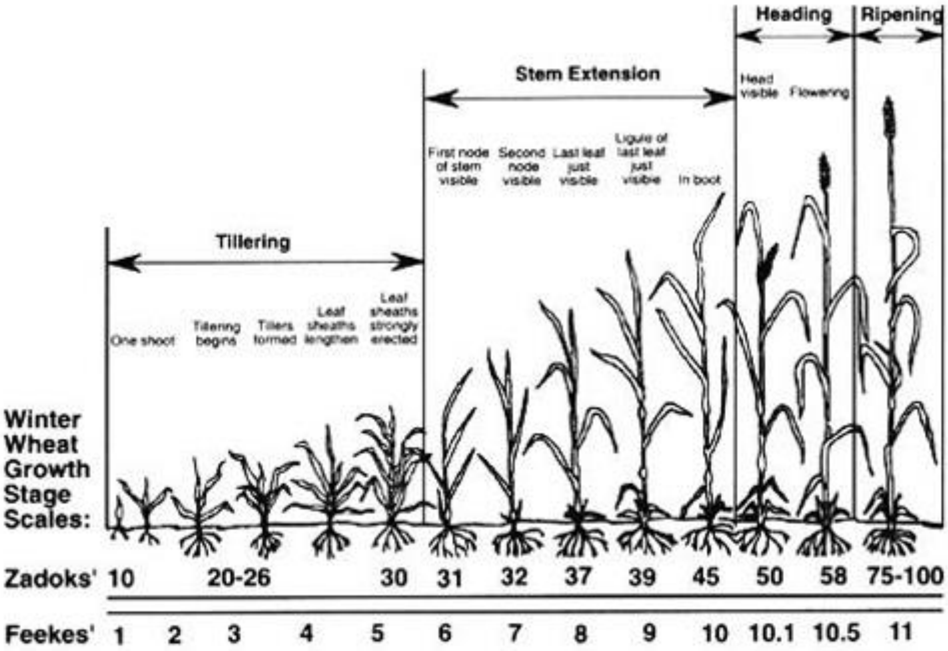


Fig: Wheat growth stage

D. Sorghum life cycle

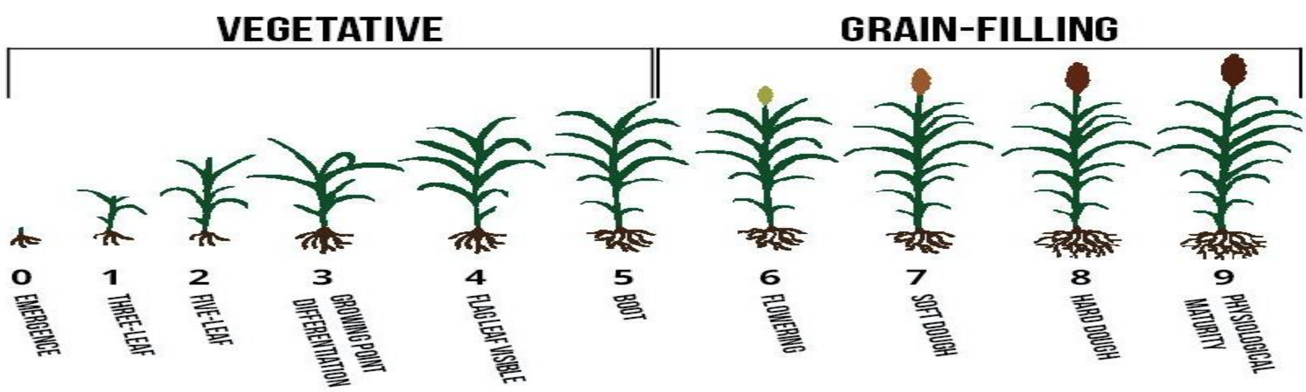


Fig: Growth stage of sorghum

Content/Topic 2: Types of maturity of cereal crops

Maturity is the process for the determination of perfect moment or stage to pick up the crop. The moment or stage at which the harvest of the crop is done is an important fact for good quality.

Maturity in virtually all crops can be divided into two **types**, physiological **maturity** which describes that period when sexually induced reproductive growth has ceased, and harvest **maturity or utility maturity**, where the seed, fruit, or other economically important organ of yield has reached a state of "ripeness" and can be removed from

Physiological maturity

- In general, the harvest takes place 10 or 15 days after the grain has reached physiological maturity.
- At the time of maturity the grain has a specific moisture content and special physical characteristics.

Harvest maturity

- For the harvest to take place at the most propitious time, account must be taken not only of the length of the growing cycles (which differ according to the varieties), but also of the degree of maturity of the grain.

Physiological signs of maturity of maize, rice wheat, sorghum crops

The following table shows the degrees of moisture content considered appropriate for good harvest conditions and the characteristics permitting assurance of physiological maturity.

GRAINS	MOISTURE	PHYSICAL CHARACTERISTICS
Maize	**23-28%**	Cobs almost dry and husk has turned yellow, hard and glassy kernels resistant to scoring with the thumbnail, black dot in the caryopsis.
Rice	**22-28%**	The panicles bend with their own weight, yellowed hulls, full grains, neither too ripe (cracked), nor too green.
Wheat	**20-25%**	Hard grain, straw turns to yellow and dry is the visual indicator for harvesting of wheat crop.
Sorghum	**20-25%**	Dried stems and leaves, hard grains resistant to the thumbnail, glassiness depending on variety.

The harvest may, nevertheless, take place at a time when, because of varying weather conditions and even though it has reached physiological maturity, the grain has a moisture content higher or lower than shown above. Monitor moisture content of grain regularly to start harvesting as soon as possible to reduce grain losses.

Clearly, the higher the moisture content of the grain at harvest time, the greater the risks of losses from moulds, insects and germination. On the other hand, the longer the grain remains in the field (to further the drying of the product), the greater the risks of losses from spontaneous fall of grain, or from attacks by birds, rodents and other pests. Delay harvesting leads also to shredding, breaking of spikes and shattering of grains. The following figures show different growing stage of wheat crop.

Key growth stage of Wheat crop

Fig: Reproductive stage.

Fig: Maturity stage.

Fig: Matured panicle.

Fig: Harvesting.

L.O 3.2. Apply harvesting techniques of maize, wheat and rice

Content/Topic 1: Harvesting techniques on maize, wheat, sorghum, and rice

Harvest operations

- Harvesting can be done by hand, with simple farming implements, or by mechanized systems.
- Choice of the degree of mechanization to adopt depends on the anticipated use of the machines.
- Choice of the machine must be justified by the estimate of the areas to be harvested annually and by a cost-benefit analysis.

1. Harvesting maize

- Maize can be harvested when the process of nutrients uptake into the kernels (physiological maturity) is complete.
- When maize reaches physiological maturity, the moisture content of the grains can be as high as 37-38 percent.
- For this reason, before proceeding to hand-harvest the ears, maize is often pre-dried standing in the field.

This cereal can be harvested by hand (harvesting ears) or mechanically (harvesting ears or grains).

a. Hand harvesting

- To harvest maize by hand, the ears are pulled from the stalk of the plant and no tool is used.
- The techniques generally used for this operation are:
    - leave the ears on the whole plant, just as it grew;
    - break the stalks of the plants or the ears so that their tips are pointing downward; this is a frequent practice in South America where it is called "doblado";
    - cut the tops of the plants to encourage exposure of the ears to the sun.

- Shucking the ears, that is, the removal of the husks covering the ears, may be done by hand or by machine at the same time as the harvest.
- Indicatively, the average duration of a manual maize harvest varies from 120 to 200 man-hours (15-25 man-days) per hectare.
- If this operation is done by hand, it requires about 130 man-hours (about 16 man-days) per hectare.
- Hand harvesting of maize is considered practicable for crops of under 12 hectares, if climate and availability of labour permit.

Field pre-drying techniques are fairly widespread, but they entail great risks of product loss, especially if the varieties grown are particularly sensitive to unfavourable weather (rain, humidity, etc.) and pests (insects, birds, rodents, etc.).

In addition, the time taken up by pre-drying in the fields decreases the possibilities for exploiting the land.

Fig: Harvesting of cobs.

Fig: Removal of husk from the cobs.

b. Mechanized harvesting

- Mechanized harvesting of maize is done with corn-pickers, corn-shellers or combine-harvesters.
- Still in use, but with decreasing frequency, are simple corn-snappers, which do only harvest of ears.

Corn-pickers are machines that simultaneously harvest and shuck ears. They are therefore equipped with picking devices, shucking tables and loading gear. Generally coupled to a trailer for transport of the ears picked, one- or two-row corn-pickers can be tractor-drawn, carried, or self-propelled.

- The work capacity of these machines varies from 1.6 to 3.45 h/ha, with 75 to 80 percent of the ears completely shucked, and total grain losses lower than 4.5 percent.

- Two operators - a driver and a worker - are generally necessary to run these machines. His use of one-row corn-pickers is economically advantageous for harvesting a minimum of 2530 hectares a year; for two-row machines the minimum harvest should be 30-60 hectares.
- Corn-shellers resemble corn-pickers but have a device for shelling and cleaning grains. These machines can thus simultaneously harvest, shuck and shell the ears and pre-clean the kernels.
- The use of combine-harvesters, like that of corn-shellers, offers an economic advantage for harvests of a minimum of 40-75 hectares a year.


Fig: Mechanical harvester cum thresher.

2. Harvesting rice crop

- Drain out the water from the field when grains in the lowest portion of the panicle are in dough stage (two or three weeks after draining the rice-field from 50 per cent flowering).
- Allow the grains to harden. Harvest the crop at 30-35 days after flowering when stalks still remain green to avoid grain shedding.
- At this stage at least 80 per cent of the grains are straw coloured. Moisture content in the grains should be around 20 per cent.

N.B:

- Premature cutting of the rice keeps the grain from reaching maturity, and can cause serious losses in the quality of the product.

- On the other hand, too low a moisture content can cause the panicles to shatter at the time of cutting, leading to serious losses of product.

Furthermore, it is important to accomplish the harvest while the moisture content of the grain is acceptable. Excess grain moisture can create big problems during the ensuing treatments, by fostering alteration of the final characteristics of the rice.

Hand harvesting

- Harvesting by hand is done with a sickle or a scythe; the ears of rice are cut at about 2030 cm above the ground. The improved design requires less muscle power and results in saving of human energy.
- After cutting, the ears of rice are left to dry on the stubble for two or three days.
- For guidance, about 80 to 160 man-hours per hectare are calculated as the average time required for manual harvesting of rice.
- In some tropical regions, it is still the custom today to harvest only the panicles, using a knife; in this case, the ears of rice are cut 30-50 cm below the panicles.

By comparison with hand-harvesting with a sickle or scythe, this method requires about 175 percent more labour.

Mechanized harvest

- Manual harvesting of rice, which is still relatively common, especially in tropical areas, is being increasingly replaced by mechanical harvesting with combine-harvesters.
- Combine harvesters are machines that do the cutting, threshing and pre-cleaning of the rice in one operation.
- Use of combine-harvesters offers an economic advantage for harvests from a minimum of 70 hectares a year upward.

Generally self-propelling, combine-harvesters have cutting apparatus, a threshing chamber composed of a revolving threshing drum (with teeth) and a stationary counter-thresher, and devices for cleaning the paddy.

In any case, mechanical harvesting of rice presents some problems.

For example, machines must frequently work on muddy ground offering poor traction. For this reason, combine-harvesters are generally equipped with tracks, rather than wheels, so that harvesting can be done even on very wet ground.

At the time of the harvest, the rice panicles do not stand up straight but are bent downward. In order to avoid excessive losses, the machines must be placed so that the ears are cut about 30 cm above the ground: this obviously necessitates coping with large quantities of straw.

Fig: Manual harvesting.

Fig: Machine harvesting.

3. Grain sorghum harvesting

Sorghum is harvested, by hand or machine, when the grain is very ripe.

Hand harvesting

- Hand harvesting is done by cutting the panicles of grain or the sorghum plants with machetes or sickles.
- When the ears of sorghum have been cut, they are allowed to pre-dry on the threshing-floor or in sheaves in the field.
- Indicatively, the average duration of a manual sorghum harvest varies from 120 to 160 man-hours (15-20 man-days) per hectare.

Mechanized harvest

- When physiological maturity has been reached, sorghum can have a moisture content of about 35 percent. However, mechanized harvesting can be effective only when the moisture content is below 20-25 percent.
- Mechanized harvesting is done with combine-harvesters, equipped for cutting and threshing.
- These machines, whose work capacity varies from 0.8 to 1.5 h/ha, seem better adapted to the harvest of dwarf varieties, and preferably to those with sparse straw-development.

4. Harvesting wheat crop

Harvesting is generally done manually with sickle or serrated sickle. Bullock driven reapers are also used. After harvesting, the crop is dried for 3-4 days on the threshing floor and threshing is done by threshers. Combined harvester cum thresher is used for harvesting, threshing and winnowing in single operation. For storage purpose, the moisture content in the grains should be around 10-12 per cent.

L.O 3.3. Handle harvested products of maize, wheat, sorghum, and rice

Content/Topic 1: Techniques of products handling of maize, wheat and rice

General information

Each type of cereal requires a specific post-harvest treatment, however, there are certain general principles that apply to most of them.

Cereals undergo a number of processing stages between harvest and consumption. This chain of processes is often referred to as the total post-harvest system. The post-harvest system can be split into three distinct areas.

- The first is the preparation of harvested grain for storage.
- The second, which is referred to as primary processing, involves further treatment of the grain to clean it, remove the husk or reduce the size. The products from primary processing are still not consumable.
- The third stage (secondary processing) transforms the grains into edible products.

Primary processing involves several different processes, designed to *clean*, *sort* and *remove the inedible fractions from the grains*.

Primary processing of cereals includes drying, Threshing, winnowing, *second drying and storage*

Secondary processing of cereals (or 'adding value' to cereals) is the utilisation of the primary products (whole grains, flakes or flour) to make more interesting products and add variety to the diet. Secondary processing of cereals includes the following processes: fermentation, baking, puffing, flaking, frying and extrusion. This modules is interested only on primary processing which is going to be described below:

1. Drying

- Drying is the process of removal of excess moisture from the grains.
- After harvesting, harvested crops are left in the field or at home for a few days to dry before further processing.

2. Threshing

- Threshing is the removal of grains from the rest of the plant. It involves three different operations: Separating the grain from the panicle; sorting the grain from the straw; winnowing the chaff from the grain.
- Separation of the grain from the panicle is the most energy-demanding of the three processes. It is the first process to have been mechanized. Sorting the grain from the straw is relatively easy, but is difficult to mechanize. Winnowing is relatively easy, both by hand and by machine.

Most manual threshing methods use an implement to separate the grain from the ears and straw. The simplest method is a stick or hinged flail that is used to beat the crop while it is spread on the floor.

3. Winnowing

Winnowing is the separation of the grains from the chaff or straw. It is traditionally carried out by lifting and tossing the threshed material so that the lighter chaff and straw get blown to one side while the heavier seeds fall down vertically.

- Hand-held winnowing baskets are used to shake the seeds to separate out the dirt and chaff. They are very effective, but slow.
- There is a range of winnowing machines that use a fan to create artificial wind. This speeds up the winnowing process.
- Some of these contains sieves and screens that grade the grains as well.

4. Second Drying

- Prior to storage or further processing, cereal grains need to be dried. The most cost-effective method is to spread out in the sun to dry.
- In humid climates it may be necessary to use an artificial dryer.
- Simple grain dryers can be made from a large rectangular box or tray with a perforated base.
- The grain is spread over the base of the box and hot air is blown up through a lower chamber by a fan.
- The fan can be powered by diesel or electricity and the heat supplied by kerosene, electricity, gas or burning biomass.
- Cereal grains should be dried to 10-15% moisture before storage.

5. Storage

- Dried grains are stored in bulk until required for processing.
- The grains should be inspected regularly for signs of spoilage and the moisture content tested.
- If the grain has picked up moisture it should be re-dried. Grains are often protected with insecticides and must be stored in rodent-proof containers.

5.1. Moisture content management

- If the moisture in seed is more than 12 % at the time of storage, the level of both heat and water increases due to intensified respiration in seeds. In this condition, the risk of fungus attack increases and reduces the quality of seeds.
- Likewise, the moisture plays important role in increasing the infestation and invasion of disease and pests in seeds. Therefore, the seeds should be stored only after controlling the moisture in seeds. The following measures can be adopted to manage moisture in seeds:
    - ✓ The seeds should be stored only after drying in the sun for 4 – 5 times.
    - ✓ The experience seed producer farmer can also identify the moister of seed.

Moisture contents and storage duration

Moisture contents of seeds	Storage duration
10-12%	For 8-12 months
< 9%	For more than 1 year

5.2. Pest prevention

Pest and rodents control in storage

- The store should be cleaned properly before storing the seeds and after the seed are sold out.
- Fumigants pesticide like Aluminium phosphate or Methyl bromide can be used at the rate of 3 tablets for per ton (1000 kg) of stored seed for fumigation of the storage to control from the moths, mites and other storage pests.
- Fumigation by pesticides in the storage is done by keeping the fumigants in the centre of storage and let fumigation inside by closing all doors and windows for at least 24 hours during storage or before storage period.
- The place for storage should be safe from pests and mice.
- Use mouse trap in the storage to protect seeds from mice attack.
- Inspect the storage regularly to ensure occurrence of pests.

- Do not keep door open of storage for a long time for controlling birds, rodents & insect attack.
- For weevil, one Selphas tablet can be used for 100 kg seeds by wrapping in cotton cloth and placing it in the centre of the normal sack / metal bin filled with seed. It is not mandatory in case of hermetic or super grain bag.

5.2. Packaging and labeling

- Seed should be packed, labeled and stored on sunny day after well drying in sun for 4-5 times.
- To store the seeds, the seeds should be properly dried before the monsoon begins and stored in metal bin, hermetic bag or plastic sack. The bag or sack should be fastened air tight in order to protect seeds from possible moisture.
- Super-grain bag refers to the bag in which insects cannot enter that easily and it is air tight. Even if the insects enter into the bag, the insects and fungus die due to treatments done for such bag.
- The following ways can be followed to use super-grain bags:
    - ✓ Squeeze the air out of the bag after placing the seeds inside the bag.
    - ✓ Keeps the bag fastening properly after the air inside is squeezed out.
    - ✓ The pests can be controlled without using any chemical pesticides in this way.

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