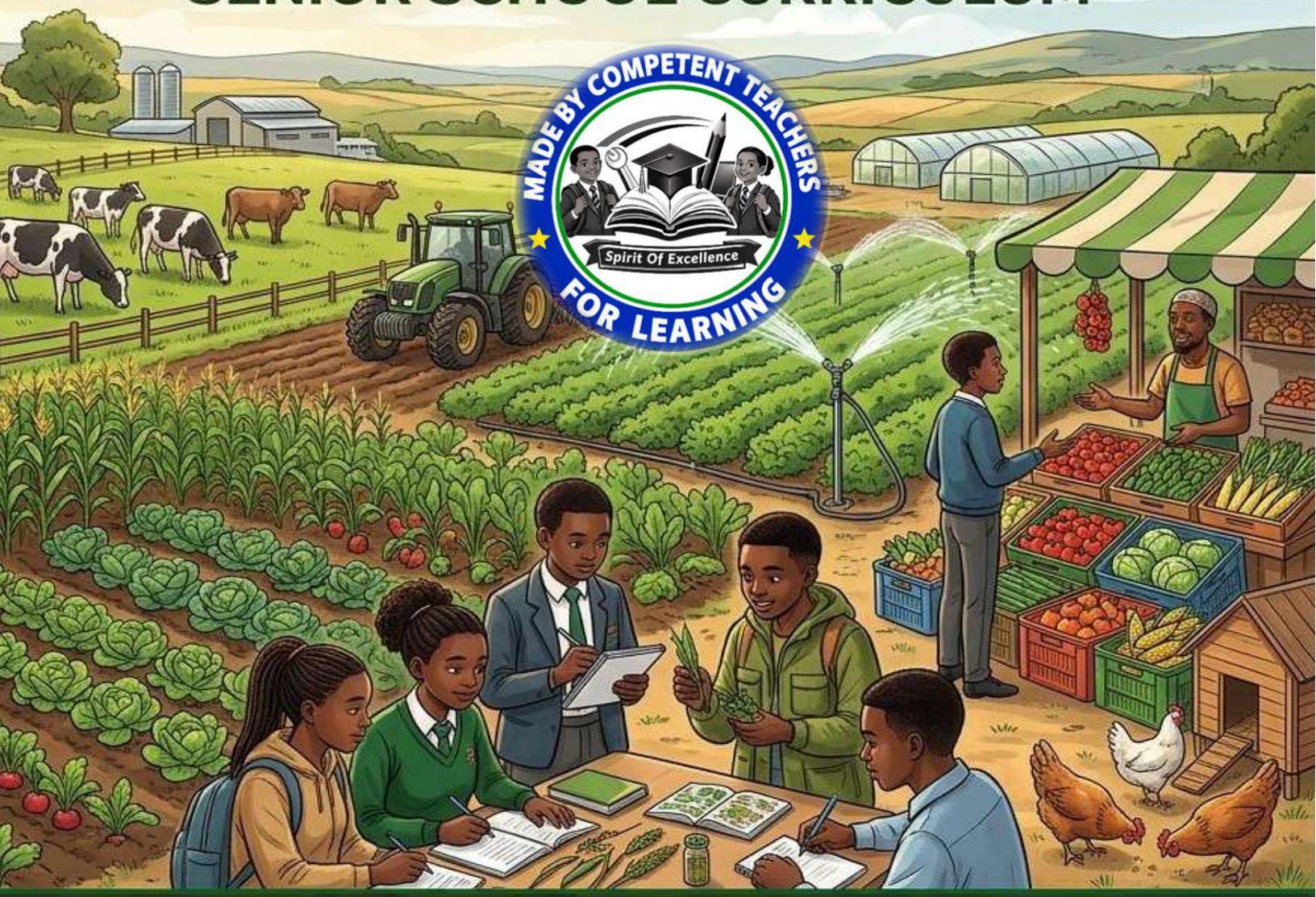
GRADE 11

AGRICULTURE NOTES

COMPETENCY BASED EDUCATION SENIOR SCHOOL CURRICULUM



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STRAND 1.0: CROP PRODUCTION
SUB-STRAND 1.1: INORGANIC FERTILISERS
1.0 INTRODUCTION TO INORGANIC FERTILISERS

- ✓ Inorganic fertilisers are manufactured or processed mineral substances containing essential plant nutrients that are added to the soil or applied directly to plants to improve soil fertility and promote healthy crop growth.
- ✓ They supply nutrients required by crops for proper growth, development, flowering, fruit formation and seed production.
- ✓ Inorganic fertilisers are also known as mineral or chemical fertilisers.

Examples of inorganic fertilisers include:

1. Calcium ammonium nitrate (CAN).
2. Diammonium phosphate (DAP).
3. Triple superphosphate (TSP).
4. Muriate of potash (MOP).
5. NPK compound fertilisers.
6. Urea.
7. Ammonium sulphate.
8. Magnesium sulphate.
9. Sulphate of ammonia
10. Ammonium sulphate nitrate
11. Blood meal
12. Single supper phosphate
13. Double super phosphate

Importance of inorganic fertilisers in crop production

1. They supply essential nutrients required for healthy plant growth.
2. They improve soil fertility by replacing nutrients removed through harvesting and other losses.
3. They promote rapid vegetative growth, especially when nitrogen fertilisers are applied appropriately.
4. They encourage strong root development through adequate phosphorus supply.
5. They improve flowering, fruiting and seed formation.
6. They increase crop yields when applied correctly.
7. They improve crop quality, including grain size, fruit size and marketability.
8. They correct specific nutrient deficiencies in soils.
9. They support continuous crop production where soil nutrients are depleted.
10. They enable farmers to achieve better returns from agricultural production.

Limitations of inorganic fertilisers

1. Excessive application may cause soil acidity or nutrient imbalance.
2. They may be expensive for small-scale farmers.
3. Some nutrients may be washed away through leaching.
4. Excess fertiliser may contaminate rivers, lakes and underground water.
5. Incorrect application may cause fertiliser burn on crops.
6. They do not directly improve soil structure or add organic matter.
7. Repeated inappropriate application may reduce soil productivity over time.

2.0 SOIL NUTRIENTS REQUIRED BY PLANTS

2.1 Meaning of soil nutrients

Soil nutrients are essential chemical elements found in the soil or supplied through fertilisers and other sources that plants absorb and use for growth and development.

Plants require different nutrients in varying quantities. Each nutrient performs specific functions in the plant, and deficiency of any essential nutrient may interfere with normal growth.

Plant nutrients are broadly classified into two main categories:

1. Macronutrients.
2. Micronutrients.

2.2 Macronutrients

Macronutrients are essential plant nutrients required in relatively large quantities for normal growth and development.

They are divided into:

- Primary macronutrients.
- Secondary macronutrients.

A. Primary macronutrients

The primary macronutrients are:

1. Nitrogen (N).
2. Phosphorus (P).
3. Potassium (K).

They are commonly used to classify fertilisers according to their nutrient composition.

1. Nitrogen (N)

Nitrogen is an essential plant nutrient responsible for promoting vegetative growth and the formation of green plant tissues.

Functions of nitrogen in plants

1. Promotes rapid growth of leaves and stems.
2. Promotes the formation of chlorophyll, which gives plants their green colour.
3. Chlorophyll enables plants to manufacture food through photosynthesis.
4. It is a major component of amino acids, which form proteins.
5. Promotes the development of healthy foliage.
6. Encourages the formation of enzymes involved in plant metabolic activities.
7. Supports the development of crops such as maize, wheat, rice and vegetables.

Symptoms of nitrogen deficiency

1. Older leaves turn yellow (chlorosis).
2. Plants develop stunted growth.
3. Leaves become smaller than normal.
4. Premature leaf fall may occur.
5. Crops develop thin and weak stems.
6. Crop yields decrease.
7. Plants mature prematurely in severe cases.

Examples of nitrogen fertilisers

- Urea.
- Calcium ammonium nitrate (CAN).
- Ammonium sulphate.
- Ammonium nitrate.

2. Phosphorus (P)

Phosphorus is an essential macronutrient that plays an important role in root development, energy transfer and reproductive growth.

Functions of phosphorus in plants

1. Promotes strong root development.
2. Encourages early establishment of seedlings.
3. Supports energy transfer within plant cells through ATP.
4. Promotes flowering and fruit formation.
5. Encourages seed formation and maturation.
6. Supports early crop maturity.
7. Improves the development of strong and healthy plants.
8. Supports cell division and the development of new tissues.

Symptoms of phosphorus deficiency

1. Plants develop stunted growth.
2. Leaves may develop a dark green colour.
3. Some crops develop purple or reddish discolouration on leaves and stems.
4. Root development becomes poor.
5. Flowering and maturity may be delayed.
6. Seed and fruit production may decrease.
7. Crop yields become low.

Examples of phosphorus fertilisers

- Diammonium phosphate (DAP).
- Triple superphosphate (TSP).
- Single superphosphate (SSP).
- Monoammonium phosphate (MAP).

3. Potassium (K)

Potassium is an essential macronutrient that regulates several physiological processes in plants and improves crop strength, quality and resistance to environmental stress.

Functions of potassium in plants

1. Regulates the opening and closing of stomata.
2. Controls water movement within plant cells.
3. Improves resistance to drought.
4. Strengthens plant stems and reduces lodging.
5. Promotes the movement of manufactured food from leaves to other plant parts.
6. Improves fruit quality, size and colour.
7. Supports the activation of enzymes involved in plant metabolism.
8. Improves resistance to certain diseases.
9. Promotes proper development of tubers, fruits and seeds.
10. Improves crop quality and storage properties.

Symptoms of potassium deficiency

1. Yellowing begins at the edges of older leaves.
2. Leaf edges develop brown, scorched patches.
3. Plants develop weak stems.
4. Crops become more susceptible to lodging.
5. Fruit quality and size decrease.
6. Plants become less resistant to drought.
7. Crop growth and yields decline.

Examples of potassium fertilisers

- Muriate of potash (MOP).
- Sulphate of potash (SOP).
- Potassium nitrate.

B. Secondary macronutrients

Secondary macronutrients are essential nutrients required by plants in relatively large quantities compared with micronutrients, although generally in smaller quantities than the primary macronutrients.

They include:

1. Calcium (Ca).
2. Magnesium (Mg).
3. Sulphur (S).

4. Calcium (Ca)

Calcium is an essential plant nutrient responsible for the formation and strengthening of cell walls and the development of growing plant tissues.

Functions of calcium in plants

1. Strengthens plant cell walls.
2. Promotes the development of strong roots.
3. Supports the growth of root tips and shoot tips.
4. Maintains the stability of cell membranes.
5. Supports cell division and development.
6. Promotes the healthy development of young leaves.
7. Improves fruit firmness and quality.
8. Helps prevent physiological disorders such as blossom-end rot in tomatoes.

Symptoms of calcium deficiency

1. Young leaves become distorted.
2. Growing points may die.
3. Root tips may become damaged or die.
4. Young leaves may develop necrotic patches.
5. Tomato fruits may develop blossom-end rot.
6. Plant growth becomes stunted.

Examples of calcium sources

- Calcium nitrate.
- Agricultural lime.
- Gypsum.
- Calcium ammonium nitrate (CAN).

5. Magnesium (Mg)

Magnesium is an essential plant nutrient that forms the central component of the chlorophyll molecule.

Functions of magnesium in plants

1. Forms the central component of chlorophyll.
2. Promotes photosynthesis.
3. Activates several enzymes involved in plant metabolism.
4. Supports the formation of proteins.
5. Promotes the movement of carbohydrates within plants.
6. Supports healthy leaf development.
7. Contributes to proper seed development.

Symptoms of magnesium deficiency

1. Older leaves develop yellowing between the veins.
2. Leaf veins may remain green while the surrounding tissues turn yellow.
3. Leaves may develop reddish or brown patches.
4. Premature leaf fall may occur.
5. Photosynthesis decreases.
6. Plant growth becomes weak.

Examples of magnesium fertilisers

- Magnesium sulphate.
- Kieserite.
- Dolomitic lime.

6. Sulphur (S)

Sulphur is an essential plant nutrient involved in protein formation and the development of healthy plant tissues.

Functions of sulphur in plants

1. Promotes the formation of certain amino acids.
2. Supports protein synthesis.
3. Contributes to the formation of enzymes and vitamins.
4. Promotes chlorophyll formation indirectly.
5. Supports the development of healthy leaves and stems.
6. Improves the quality of crops such as onions, garlic and brassicas.
7. Supports nitrogen utilisation in plants.

Symptoms of sulphur deficiency

1. Young leaves turn yellow.
2. Plants develop stunted growth.
3. Stems become thin and weak.
4. Leaves may become pale green.
5. Crop maturity may be delayed.
6. Protein formation is reduced.

Examples of sulphur fertilisers

- Ammonium sulphate.
- Single superphosphate.
- Magnesium sulphate.
- Potassium sulphate.
- Elemental sulphur.

2.3 Micronutrients

Micronutrients are essential plant nutrients required in very small quantities for normal growth and development.

Although plants require them in small amounts, they are equally important because they perform specific functions in plant metabolism, enzyme activation, photosynthesis and reproductive development.

The major micronutrients covered in this sub-strand are:

1. Iron (Fe).
2. Manganese (Mn).
3. Zinc (Zn).
4. Copper (Cu).
5. Boron (B).

1. Iron (Fe)

Iron is an essential micronutrient that supports chlorophyll formation and several metabolic processes in plants.

Functions of iron in plants

1. Supports chlorophyll formation.
2. Plays an important role in photosynthesis.
3. Helps in respiration within plant cells.
4. Supports enzyme activities involved in plant metabolism.
5. Promotes healthy development of leaves.
6. Participates in electron transfer during photosynthesis and respiration.

Symptoms of iron deficiency

1. Young leaves develop yellowing between the veins.
2. Leaf veins may remain green while the surrounding tissues become yellow.
3. Severe deficiency causes leaves to become almost white.
4. Photosynthesis decreases.
5. Plants develop stunted growth.
6. Crop productivity decreases.

Examples of iron fertilisers

- Ferrous sulphate.
- Iron chelates such as Fe-EDTA.

2. Manganese (Mn)

Manganese is a micronutrient that activates enzymes and participates in photosynthesis and other plant metabolic processes.

Functions of manganese in plants

1. Supports photosynthesis, particularly water splitting during the light reactions.
2. Activates enzymes involved in plant metabolism.
3. Supports nitrogen metabolism.
4. Participates in chlorophyll formation and maintenance.
5. Promotes healthy plant growth.
6. Supports the formation of certain plant compounds.

Symptoms of manganese deficiency

1. Young or recently matured leaves develop yellowing between the veins.
2. Small brown or grey spots may appear on leaves.
3. Plants develop weak growth.
4. Photosynthesis becomes less efficient.
5. Crop yields decrease.

Examples of manganese fertilisers

- Manganese sulphate.
- Manganese chelates.

3. Zinc (Zn)

Zinc is an essential micronutrient that supports enzyme activity, hormone production and normal plant growth.

Functions of zinc in plants

1. Supports the production and regulation of plant growth hormones such as auxins.
2. Activates enzymes involved in plant metabolism.
3. Promotes normal stem elongation.
4. Supports leaf development.
5. Promotes healthy root growth.
6. Supports protein synthesis.
7. Participates in carbohydrate metabolism.

Symptoms of zinc deficiency

1. Plants develop short internodes.
2. Leaves become unusually small.
3. Plants develop a rosette-like appearance.
4. Young leaves may develop yellowing between the veins.
5. Crop growth becomes stunted.
6. Flowering and fruit development may be affected.

Examples of zinc fertilisers

- Zinc sulphate.
- Zinc chelates.

4. Copper (Cu)

Copper is a micronutrient that participates in enzyme activities, photosynthesis and the formation of healthy plant tissues.

Functions of copper in plants

1. Activates enzymes involved in plant metabolism.
2. Participates in photosynthesis.
3. Supports respiration.
4. Promotes proper development of reproductive structures.
5. Supports lignin formation, which strengthens plant tissues.
6. Contributes to the formation of healthy stems.
7. Supports the normal functioning of plant cells.

Symptoms of copper deficiency

1. Young leaves may become pale or yellow.
2. Leaf tips may become twisted or withered.
3. Growing points may die.
4. Plants develop weak stems.
5. Flowering and seed formation may be affected.
6. Some crops develop poorly formed grains.

Examples of copper fertilisers

- Copper sulphate.
- Copper chelates.

5. Boron (B)

Boron is an essential micronutrient that supports cell wall development, flowering, pollen formation and the movement of sugars within plants.

Functions of boron in plants

1. Supports the formation and development of cell walls.
2. Promotes the growth of root tips and shoot tips.
3. Supports pollen formation and pollen tube development.
4. Promotes successful fertilisation.
5. Supports flowering and fruit development.
6. Facilitates the movement of sugars within plants.
7. Supports seed development.
8. Helps maintain the normal growth of young plant tissues.

Symptoms of boron deficiency

1. Growing points may die.
2. Young leaves become distorted and brittle.
3. Stems may become hollow or cracked in some crops.
4. Flowering and fruit formation may be poor.
5. Fruits may become deformed.
6. Root development becomes abnormal.
7. Some root crops develop internal brown or hollow tissues.

Examples of boron fertilisers

- Borax.
- Boric acid.
- Solubor.

2.4 Summary of plant nutrients and their functions

Nitrogen	N	Promotes vegetative growth and protein formation
Phosphorus	P	Promotes root development and energy transfer
Potassium	K	Regulates water balance and improves crop quality
Calcium	Ca	Strengthens cell walls
Magnesium	Mg	Forms the central component of chlorophyll
Sulphur	S	Supports protein formation

Iron	Fe	Supports chlorophyll formation and photosynthesis
Manganese	Mn	Activates enzymes and supports photosynthesis
Zinc	Zn	Supports hormone production and enzyme activity
Copper	Cu	Supports enzyme activity and tissue strengthening
Boron	B	Supports flowering, cell wall development and pollen growth

Important distinction:

- Macronutrients are required in relatively large quantities.
- Micronutrients are required in very small quantities.
- Both categories are essential for healthy crop production.
- A nutrient can be deficient even where other nutrients are sufficiently available.

2.5 Factors affecting the availability of soil nutrients

Nutrient availability refers to the extent to which nutrients in the soil are present in forms that plant roots can absorb and utilise.

The following factors influence nutrient availability:

1. **Soil pH:** Very acidic or alkaline soils may reduce the availability of certain nutrients. For example, phosphorus may become less available in strongly acidic or alkaline soils.
2. **Soil moisture:** Water dissolves nutrients and helps transport them towards plant roots. Excessive water may cause nutrient leaching.
3. **Soil organic matter:** Organic matter releases nutrients during decomposition and improves nutrient retention.
4. **Soil texture:** Sandy soils generally have lower nutrient-holding capacity than clay soils.
5. **Soil microorganisms:** Microorganisms decompose organic matter and convert nutrients into forms that plants can use.
6. **Soil aeration:** Adequate oxygen supports root respiration and microbial activities involved in nutrient cycling.
7. **Temperature:** Soil temperature influences root activity and the rate at which microorganisms release nutrients.
8. **Nutrient interactions:** Excessive amounts of one nutrient may interfere with the uptake of another. For example, excessive phosphorus can contribute to zinc deficiency.

3.0 CATEGORIES OF INORGANIC FERTILISERS

Inorganic fertilisers can be classified according to the number of major plant nutrients they supply, their nutrient composition and the physical form in which they are manufactured.

One important classification is based on the primary nutrients: nitrogen, phosphorus and potassium.

3.1 Fertiliser classification using NPK

NPK refers to the three primary macronutrients required by plants.

- N – Nitrogen.
- P – Phosphorus (expressed as phosphate, P_2O_5, on commercial fertiliser labels).
- K – Potassium (expressed as potash, K_2O, on commercial fertiliser labels).

Fertiliser grades indicate the percentage by mass of nitrogen, available phosphate and soluble potash, respectively.

For example:

Example: NPK 17:17:17

17% **N** *Nitrogen*	**17%** **P_2O_5** *Phosphate*	**17%** **K_2O** *Potash*

The figures represent percentages by mass of the three declared nutrients, not necessarily the percentage of elemental phosphorus and potassium.

This means that 100 kg of NPK 17:17:17 contains:

- 17 kg of nitrogen.
- 17 kg of available phosphate expressed as P_2O_5.
- 17 kg of soluble potash expressed as K_2O.

The remaining mass consists of other components, including carriers and other ingredients.

3.2 Classification according to nutrient composition

Inorganic fertilisers are broadly classified into:

1. Straight fertilisers.
2. Compound fertilisers.

A. Straight fertilisers

Straight fertilisers are inorganic fertilisers that supply mainly one primary plant nutrient (nitrogen, phosphorus or potassium).

Some may also supply secondary nutrients or other elements.

Examples of straight fertilisers

Fertiliser	Main nutrient supplied
Urea	Nitrogen
Calcium ammonium nitrate (CAN)	Nitrogen
Ammonium sulphate	Nitrogen
Triple superphosphate (TSP)	Phosphorus
Single superphosphate (SSP)	Phosphorus
Muriate of potash (MOP)	Potassium
Sulphate of potash (SOP)	Potassium

1. Urea

- Urea is a concentrated nitrogen fertiliser.
- It normally contains approximately 46% nitrogen.
- It is usually manufactured in white granules or prills.
- It is converted into ammonium in the soil through microbial activity before much of its nitrogen is utilised by plants.
- It promotes vigorous vegetative growth.
- It is commonly used in maize, wheat and vegetable production.
- It should be incorporated into the soil or followed by suitable irrigation or rainfall to reduce ammonia losses from surface application.

2. Calcium ammonium nitrate (CAN)

- CAN is a nitrogen fertiliser.
- Common formulations contain approximately 26% nitrogen, although grades vary.
- It supplies nitrogen in ammonium and nitrate forms.
- It may also contain calcium and, depending on formulation, magnesium.
- It promotes healthy leaf and stem development.
- It is commonly used for top-dressing cereal crops and vegetables.
- It is suitable for supplying nitrogen during active crop growth.

3. Ammonium sulphate

- It contains approximately 21% nitrogen.
- It also supplies sulphur.
- It is suitable for crops requiring both nitrogen and sulphur.
- It promotes vegetative growth and protein formation.
- Its repeated use may contribute to soil acidification.

4. Triple superphosphate (TSP)

- TSP is a concentrated phosphorus fertiliser.
- It commonly contains approximately 46% available phosphate expressed as P_2O_5.
- It promotes root development and early crop establishment.
- It supports flowering and seed formation.
- It is commonly applied during planting.

5. Single superphosphate (SSP)

- SSP is a phosphorus fertiliser.

- It commonly contains approximately 16–20% available phosphate expressed as P_2O_5, depending on the grade.
- It also supplies calcium and sulphur.
- It promotes root growth.
- It is useful for crops requiring phosphorus and sulphur.

6. Muriate of potash (MOP)

- MOP is commonly known as potassium chloride.
- It commonly contains approximately 60% K_2O.
- It supplies potassium for water regulation and enzyme activation.
- It improves crop quality and stress tolerance.
- It is commonly used in crops such as maize and potatoes, subject to crop-specific recommendations.
- It should be used cautiously on chloride-sensitive crops.

7. Sulphate of potash (SOP)

- SOP is chemically known as potassium sulphate.
- It commonly contains approximately 50% K_2O.
- It also supplies sulphur.
- It improves crop quality and supports healthy plant growth.
- It is useful for chloride-sensitive crops because it does not contain chloride as its main accompanying ion.

Advantages of straight fertilisers

1. They allow farmers to supply a specific nutrient according to crop requirements.
2. They are useful when soil analysis identifies a particular nutrient deficiency.
3. They make it easier to adjust nutrient application rates.
4. They can be combined in appropriate fertiliser programmes to meet crop nutrient requirements.
5. They provide flexibility in fertiliser management.

Disadvantages of straight fertilisers

1. Several fertiliser products may be required to supply different nutrients.
2. Mixing different fertilisers may require technical knowledge.
3. Some fertilisers may cause soil acidity when repeatedly misused.
4. Incorrect combinations may cause chemical reactions that reduce nutrient availability.
5. Separate application may increase labour and operational costs.

B. Compound fertilisers

Compound fertilisers are fertilisers that contain two or more primary plant nutrients in a single product.

They are formulated to supply multiple nutrients in proportions suitable for particular crops or soil conditions.

Examples of compound fertilisers

1. NPK 17:17:17.
2. NPK 23:23:0.
3. NPK 20:20:0.
4. NPK 10:20:10.
5. NPK 15:15:15.

Characteristics of compound fertilisers

1. They contain two or more primary plant nutrients.
2. Their nutrient composition is expressed using fertiliser grades.
3. The nutrients are supplied in predetermined proportions.
4. They may contain secondary nutrients and micronutrients.
5. They are manufactured to meet different crop nutrient requirements.
6. They may be applied during planting or at other recommended growth stages, depending on their formulation.
7. They simplify fertiliser handling because several nutrients are supplied in one product.

Advantages of compound fertilisers

1. They supply several nutrients in one application.
2. They reduce the need to purchase and handle several separate fertilisers.
3. They simplify fertiliser application.
4. They save labour during field operations.
5. They provide balanced nutrient combinations where the formulation matches the soil and crop requirements.
6. They can promote uniform crop establishment when correctly applied.

Disadvantages of compound fertilisers

1. Their nutrient ratios may not match the actual nutrient requirements of a particular soil.
2. They may supply nutrients that are already sufficient in the soil.
3. They may be more expensive than some straight fertilisers.
4. They offer less flexibility when correcting a deficiency of one particular nutrient.
5. Incorrect application may lead to nutrient imbalance.

3.3 Differences between straight and compound fertilisers

Straight fertilisers	Compound fertilisers
Supply mainly one primary nutrient	Supply two or more primary nutrients
Examples include urea and TSP	Examples include NPK 17:17:17
Can target a particular nutrient deficiency	Supply several nutrients together
May require several products for balanced nutrition	One product may supply several nutrients
Nutrient composition is more specific to the main nutrient	Nutrients occur in predetermined proportions

Important: A fertiliser should not be selected merely because it is straight or compound. Selection should be based on soil analysis, crop requirements, nutrient recommendations and the stage of crop growth.

3.3 Other forms of inorganic fertilisers

Inorganic fertilisers may also be grouped according to their physical form.

1. Granular fertilisers

These are fertilisers manufactured in small solid particles or granules.

Examples:

- NPK.
- DAP.
- CAN.
- Urea granules.

Advantages:

- Easy to measure and handle.
- Suitable for broadcasting and placement.
- Can be applied using fertiliser spreaders.
- Generally convenient for field application.

2. Powdered fertilisers

These are fertilisers manufactured in fine powder form.

Examples:

- Some formulations of TSP.
- Certain micronutrient fertilisers.
- Powdered water-soluble fertiliser products.

Advantages:

- Can dissolve or disperse readily depending on the product.
- Useful in certain fertiliser application systems.
- Can be mixed with water where the product is designed for such use.

3. Liquid fertilisers

These are fertilisers supplied in liquid form or prepared as solutions for application.

Examples:

- Liquid nitrogen fertilisers.
- Water-soluble NPK fertilisers.
- Liquid micronutrient formulations.

Advantages:

- Can be applied through fertigation where suitable.
- Allow uniform application when correctly calibrated.
- Can be used for foliar feeding where the formulation is designed for leaf application.

4.0 SOIL SAMPLING

4.1 Meaning of soil sampling

Soil sampling is the process of collecting small portions of soil from different locations within a field and combining or preparing them to obtain a representative sample for laboratory analysis.

The purpose is to determine the physical and chemical properties of the soil, including:

1. Soil pH.
2. Nutrient levels.
3. Organic matter content.
4. Soil salinity.
5. Soil texture.
6. Nutrient deficiencies.
7. Other properties affecting crop production.

Soil sampling is important because fertiliser recommendations should be based on the actual nutrient status of the soil rather than guesswork.

4.2 Importance of soil sampling in crop production

1. **Determining soil fertility:** It helps establish the amount of nutrients available in the soil.
2. **Identifying nutrient deficiencies:** Laboratory analysis identifies nutrients that are deficient or present in inadequate quantities.
3. **Guiding fertiliser application:** Results help determine the correct type and quantity of fertiliser to apply.
4. **Determining soil pH:** It helps identify whether the soil is acidic, neutral or alkaline.
5. **Reducing fertiliser wastage:** Farmers avoid applying unnecessary fertilisers.
6. **Improving crop yields:** Appropriate soil management promotes healthy crop growth.
7. **Determining soil amendment requirements:** It helps establish whether lime or other amendments are necessary.
8. **Preventing environmental pollution:** Proper fertiliser recommendations reduce nutrient losses into water bodies.
9. **Monitoring soil fertility:** Repeated sampling helps farmers assess changes in soil fertility over time.
10. **Supporting profitable farming:** It helps farmers make informed decisions on fertiliser expenditure.

4.3 Requirements and equipment used in soil sampling

The following equipment and materials may be used:

1. Soil auger – used to collect soil from specific depths.
2. Spade or soil sampling shovel – used to dig and collect soil.
3. Clean plastic bucket – used for mixing collected soil.
4. Clean plastic bags – used to store samples.
5. Permanent marker – used to label samples.

6. Measuring tape or ruler – used to determine sampling depth.
7. Clean tray or sheet – used for mixing and drying samples.
8. Sample labels or forms – used to record field information.
9. Clean gloves – used to minimise contamination.

4.4 Factors to consider when selecting soil sampling sites

1. **Field size:** Large fields may require more sampling points than small fields.
2. **Soil type:** Areas with different soil types should be sampled separately.
3. **Topography:** Slopes, valleys and flat areas may have different soil characteristics.
4. **Crop history:** Areas that have received different fertiliser treatments should be sampled separately.
5. **Previous land use:** Land previously used for grazing, cultivation or other activities may have different fertility levels.
6. **Drainage conditions:** Waterlogged areas should be sampled separately from well-drained areas.
7. **Visible crop performance:** Areas with unusually poor or good crop growth may require separate investigation.
8. **Management history:** Areas receiving different irrigation, manure or fertiliser applications should not be combined indiscriminately.

4.5 Soil sampling sites

A sampling site refers to a specific location within a field from which soil is collected.

When selecting sampling sites:

1. Identify the field or area to be tested.
2. Divide the farm into management units with similar soil characteristics.
3. Identify representative locations within each unit.
4. Avoid unusual areas that may not represent the general field condition.
5. Collect samples from consistent depths.
6. Use separate samples for areas with different soil conditions.

Areas to avoid during routine representative sampling

- Near compost or manure heaps.
- Near fertiliser storage areas.
- Along field boundaries.
- Near roads and pathways.
- Near buildings and livestock pens.
- Waterlogged depressions.
- Recently fertilised spots.
- Areas where ash or other materials have been deposited.
- Places where burning has taken place.

Such areas may have unusually high or low nutrient concentrations and may produce misleading results.

4.6 Methods of soil sampling

There are several methods of collecting soil samples, depending on the size, shape and uniformity of the field.

1. Zigzag sampling method

In this method, soil samples are collected from different locations while moving across the field in a zigzag pattern.

Procedure

1. Identify the field to be sampled.
2. Walk across the field in a zigzag pattern.
3. Stop at regular intervals.
4. Collect a soil portion at each selected point.
5. Place the portions in a clean bucket.
6. Mix the portions thoroughly to obtain a composite sample.

Advantages

- Covers a large area of the field.
- Provides a representative sample of relatively uniform land.
- Reduces the effect of localised soil differences.
- Easy to carry out.

2. W-shaped sampling method

In this method, the farmer moves across the field following a W-shaped path and collects soil from several points along the path.

Procedure

1. Mark the boundaries of the field.
2. Follow a W-shaped route across the field.
3. Collect soil portions at selected points along the route.
4. Ensure that the sampling points are evenly distributed.
5. Combine the collected portions where the field is uniform.
6. Mix thoroughly to prepare a composite sample.

Advantages

- Provides good field coverage.
- Helps collect samples from different parts of the field.
- Suitable for relatively uniform fields.
- Reduces bias caused by collecting soil from only one location.

3. Grid sampling method

In grid sampling, the field is divided into small sections of equal size, and soil samples are collected from each grid or at designated points within each grid.

Procedure

1. Divide the field into equal-sized grids.

2. Identify the sampling point within each grid.
3. Collect soil from each sampling point.
4. Keep samples separate where individual grid analysis is required.
5. Label each sample according to its grid.
6. Submit the samples for laboratory analysis.

Advantages

- Provides detailed information about soil fertility variations.
- Identifies nutrient-deficient sections.
- Supports precision fertiliser application.
- Useful for large farms and fields with variable soil conditions.

Disadvantages

- Requires more labour and time.
- Laboratory analysis may be expensive.
- Requires proper field mapping and record keeping.

4. Random sampling method

In this method, soil portions are collected from randomly selected locations within a field.

Procedure

1. Identify the field to be sampled.
2. Select sampling points randomly.
3. Collect soil from each selected point.
4. Combine samples from the same uniform management unit.
5. Mix thoroughly.
6. Label and prepare the sample for analysis.

Advantages

- Simple to carry out.
- Reduces deliberate selection bias.
- Suitable for relatively uniform fields.

Limitation

- Some parts of the field may be poorly represented if the random points are unevenly distributed.

4.7 Soil sampling procedures

The following steps should be followed when collecting soil samples for laboratory analysis.

Step 1: Identify the field

- Identify the field where soil testing is required.
- Establish the boundaries.
- Divide the farm into uniform sampling units.
- Separate areas with different soil conditions.

Step 2: Select the sampling points

- Select representative points using zigzag, W-shaped, grid or random sampling.
- Avoid unusual or contaminated areas.
- Ensure that the sampling points cover the entire management unit.

Step 3: Clear the sampling area

- Remove grass, plant residues, stones and loose surface materials.
- Avoid removing the actual soil.
- Ensure that the area is suitable for sampling.

Step 4: Collect the soil

- Use a clean spade or soil auger.
- For routine topsoil testing, a depth of approximately 0–20 cm is commonly used for cultivated fields, unless a crop-specific recommendation requires another depth.
- Collect soil from the required depth.
- Ensure that each portion represents the same soil layer.

Step 5: Collect several soil portions

- Collect soil from approximately 15–20 representative points in a uniform field, depending on field size and sampling guidelines.
- Place all portions in a clean bucket.
- Avoid mixing soil from different management units.

Step 6: Mix the soil

- Break large soil clods gently.
- Remove stones, roots and other foreign materials.
- Mix the collected portions thoroughly to obtain a uniform composite sample.

Step 7: Reduce the sample

- Spread the mixed soil on a clean plastic sheet.
- Use the quartering method or another suitable sample reduction procedure.
- Obtain the required quantity for laboratory analysis, commonly around 500 g, subject to laboratory instructions.

Step 8: Package the sample

- Place the prepared soil in a clean sample bag or container.
- Seal the container properly.
- Ensure that the sample is not contaminated.

Step 9: Label the sample

Record:

1. Farmer's name.
2. Farm or field identification.
3. Location.

4. Date of collection.
5. Crop grown or intended for planting.
6. Sampling depth.
7. Previous fertiliser or manure application, where known.
8. Sampling method used.

Step 10: Submit the sample

- Deliver the sample to a recognised soil testing laboratory.
- Provide relevant field information.
- Request the appropriate soil analysis.
- Use the laboratory results to develop fertiliser and soil amendment recommendations.

4.8 Preparation of soil samples for laboratory analysis

Soil sample preparation refers to the activities carried out after collection to ensure that the sample is suitable for laboratory testing.

Procedures

1. Remove plant roots, stones and other foreign materials.
2. Break large soil clods gently.
3. Spread the soil thinly on a clean tray or plastic sheet.
4. Allow it to air-dry under suitable conditions.
5. Avoid drying the sample under excessive heat or direct strong sunlight, particularly when testing properties that may be affected by heating.
6. Crush soil clods gently without grinding individual mineral particles.
7. Pass the dried soil through an appropriate sieve, commonly a 2 mm sieve for routine analysis.
8. Mix the sieved soil thoroughly.
9. Place the prepared soil in a clean, labelled container.
10. Submit it to the laboratory for analysis.

Why should soil samples be properly prepared?

1. To remove materials that may interfere with laboratory tests.
2. To ensure uniformity of the sample.
3. To improve the reliability of analytical results.
4. To make the soil easier to handle during laboratory procedures.
5. To minimise contamination.

Important: Always follow the receiving laboratory's instructions. Some tests, particularly those involving mineral nitrogen, biological activity or particular contaminants, require special handling and should not automatically use the routine air-drying procedure.

4.9 The quartering method of reducing soil samples

The quartering method is a technique used to reduce the quantity of a mixed soil sample while maintaining a representative portion.

Procedure

1. Spread the mixed soil evenly on a clean surface.
2. Divide the soil into four approximately equal sections.

3. Remove two opposite quarters.
4. Combine the remaining two opposite quarters.
5. Mix the remaining soil thoroughly.
6. Repeat the process until the required quantity is obtained.
7. Place the final sample in a clean, labelled container.

Advantages

- Reduces the quantity of soil.
- Maintains a representative sample when properly carried out.
- Reduces laboratory handling costs.
- Makes transportation easier.

4.10 Precautions when carrying out soil sampling

1. Use clean sampling equipment.
2. Do not collect soil from recently fertilised spots.
3. Sample different soil types separately.
4. Maintain a consistent sampling depth.
5. Avoid sampling immediately after fertiliser or manure application.
6. Avoid sampling when the soil is excessively wet.
7. Do not use fertiliser-contaminated containers.
8. Label samples correctly.
9. Use suitable packaging materials.
10. Collect sufficient portions from different parts of the field.
11. Avoid mixing topsoil and subsoil.
12. Follow laboratory instructions for special tests.

5.0 SOIL pH

5.1 Meaning of soil pH

Soil pH is a measure of the degree of acidity or alkalinity of the soil.

It indicates the concentration of hydrogen ions in the soil solution and is measured using a pH scale ranging from 0 to 14.

Soil pH is an important soil property because it influences nutrient availability, microbial activities, root development and overall crop productivity.

5.2 Soil pH scale

The pH scale is divided into three main categories:

1. Acidic soils

- Have a pH below 7.
- Contain relatively high hydrogen ion activity.
- May have reduced availability of certain nutrients.
- Strongly acidic soils may contain toxic levels of aluminium and manganese.

Examples of pH values:

- pH 3 – strongly acidic.
- pH 4 – strongly acidic.
- pH 5 – moderately acidic.
- pH 6 – slightly acidic.

2. Neutral soils

- Have a pH of approximately 7.
- Have a balance between hydrogen and hydroxide ion activity.
- Many essential plant nutrients are relatively available.
- Most agricultural crops perform well within slightly acidic to neutral conditions, depending on the crop.

3. Alkaline soils

- Have a pH above 7.
- Have relatively low hydrogen ion activity.
- May have reduced availability of iron, zinc, manganese and phosphorus.
- Strongly alkaline soils may contain excessive sodium or salts.

Examples of pH values:

- pH 8 – slightly alkaline.
- pH 9 – moderately alkaline.
- pH 10 – strongly alkaline.
- pH 11–14 – very strongly alkaline to extremely alkaline.

5.3 Classification of soil pH

Soil pH	Classification
Below 4.5	Extremely acidic
4.5–5.0	Very strongly acidic
5.1–5.5	Strongly acidic
5.6–6.0	Moderately acidic
6.1–6.5	Slightly acidic
6.6–7.3	Near neutral
7.4–7.8	Slightly alkaline
7.9–8.4	Moderately alkaline
8.5–9.0	Strongly alkaline
Above 9.0	Very strongly alkaline

Classification ranges may differ slightly between soil science references.

5.4 Importance of soil pH in crop production

1. **Nutrient availability:** Soil pH determines the extent to which essential nutrients are available for plant absorption.
2. **Microbial activities:** Soil pH influences the growth and activities of beneficial microorganisms responsible for decomposition and nutrient cycling.

3. **Root development:** Suitable soil pH promotes healthy root growth and nutrient absorption.
4. **Nitrogen fixation:** Soil pH affects the activity of nitrogen-fixing bacteria associated with leguminous crops.
5. **Phosphorus availability:** Soil pH influences the chemical forms of phosphorus in the soil.
6. **Prevention of nutrient toxicity:** Appropriate soil pH helps reduce the risk of toxicity from elements such as aluminium and manganese.
7. **Crop establishment:** Suitable pH supports seed germination and early seedling development.
8. **Crop productivity:** Maintaining suitable pH promotes healthy crop growth and improved yields.
9. **Fertiliser efficiency:** Fertilisers are used more efficiently when soil pH is within a suitable range.
10. **Soil biological activity:** Appropriate pH supports earthworms and beneficial soil microorganisms.

5.5 Effects of soil acidity on crop production

Soil acidity occurs when soil pH falls below 7, although agricultural problems are particularly common in strongly acidic soils.

Negative effects of excessive soil acidity

1. Aluminium toxicity may occur, damaging plant roots.
2. Manganese may become excessively available and cause toxicity.
3. Phosphorus availability may decrease.
4. Calcium and magnesium may become deficient.
5. Beneficial microorganisms may become less active.
6. Nitrogen fixation by some leguminous crops may be reduced.
7. Root growth may be restricted.
8. Nutrient uptake becomes inefficient.
9. Crop growth becomes stunted.
10. Crop yields may decline.

5.6 Effects of soil alkalinity on crop production

Soil alkalinity occurs when soil pH is above 7.

Highly alkaline conditions can interfere with nutrient availability and crop growth.

Negative effects of excessive soil alkalinity

1. Iron deficiency may occur, causing yellowing of young leaves.
2. Zinc availability may decrease.
3. Manganese availability may decrease.
4. Phosphorus may become less available due to precipitation with calcium.
5. Copper availability may decrease.
6. Some crops may develop stunted growth.
7. Seed germination and crop establishment may be affected.
8. Excessive sodium may damage soil structure in sodic soils.
9. Poor soil structure may reduce water infiltration.
10. Crop productivity may decrease.

5.7 Factors affecting soil pH

1. **Parent material:** The minerals from which soil develops influence its chemical properties and pH.
2. **Rainfall:** High rainfall may wash away basic nutrients such as calcium, magnesium and potassium, contributing to soil acidification.
3. **Fertiliser application:** Repeated use of acidifying nitrogen fertilisers, such as ammonium sulphate, can lower soil pH over time.
4. **Organic matter decomposition:** Decomposition releases organic acids and other substances that may influence soil pH.
5. **Crop removal:** Harvesting removes nutrients from the soil, and continuous nutrient removal without replacement can contribute to soil acidification.
6. **Soil drainage:** Poor drainage may alter chemical reactions in the soil and influence pH.
7. **Irrigation water:** Water containing dissolved salts or bicarbonates may influence soil pH and alkalinity.
8. **Vegetation:** Different vegetation types influence the amount and nature of organic matter returned to the soil.
9. **Leaching:** Removal of basic cations through percolating water may contribute to soil acidity.
10. **Soil microorganisms:** Microbial processes such as nitrification influence the acidity of the soil.

5.8 Methods of determining soil pH

Soil pH can be determined through several methods.

1. Using a soil pH meter

A soil pH meter is an electronic instrument used to measure the acidity or alkalinity of a soil suspension or, with suitable equipment, soil directly.

Procedure

1. Collect a representative soil sample.
2. Prepare the sample according to laboratory instructions.
3. Place a measured quantity of soil in a clean container.
4. Add distilled or deionised water in the prescribed soil-to-water ratio.
5. Stir the mixture thoroughly.
6. Allow the suspension to settle for the recommended period.
7. Calibrate the pH meter using appropriate standard buffer solutions.
8. Rinse the electrode with distilled water.
9. Place the electrode in the soil suspension.
10. Wait for the reading to stabilise.
11. Record the pH value.
12. Clean the electrode after use.

Advantages

- Provides relatively accurate readings when properly calibrated.
- Gives quick results.

- Suitable for laboratory and field applications.
- Allows repeated measurements.

2. Using pH indicator paper

This method uses special indicator paper that changes colour depending on the pH of a solution.

Procedure

1. Collect a soil sample.
2. Mix the soil with distilled water.
3. Stir thoroughly.
4. Allow the soil particles to settle.
5. Dip the pH indicator paper into the clear liquid.
6. Remove the paper.
7. Compare the colour with the manufacturer's colour chart.
8. Record the approximate pH value.

Advantages

- Cheap and easy to use.
- Requires little equipment.
- Suitable for preliminary field assessment.

Disadvantages

- Less precise than a calibrated pH meter.
- Colour interpretation may be subjective.
- Soil colour and suspended particles may interfere with readings.

3. Using a laboratory soil analysis

Soil is collected and submitted to a recognised laboratory for chemical analysis.

Procedure

1. Collect a representative soil sample.
2. Label the sample correctly.
3. Prepare the sample according to laboratory requirements.
4. Submit it to the laboratory.
5. The laboratory determines soil pH using a standard method.
6. The results are recorded and interpreted.
7. Appropriate soil management recommendations are provided.

Advantages

- Provides reliable analytical results when standard procedures are followed.
- May include additional soil fertility information.
- Helps guide fertiliser and lime recommendations.

5.9 Suitable soil pH for different crops

Different crops have different pH requirements. Most common agricultural crops perform well in slightly acidic to near-neutral soils, although there are exceptions.

Crop	Approximate suitable soil pH
Maize	5.5–7.0
Wheat	6.0–7.5
Beans	5.5–7.0
Irish potatoes	5.0–6.0
Tomatoes	5.5–7.0
Cabbage	6.0–7.5
Rice	5.0–6.5
Carrots	5.5–7.0
Groundnuts	5.5–6.5
Tea	4.5–5.5

These are general agronomic ranges, not rigid limits. Variety, soil conditions and local recommendations should be considered.

6.0 SOIL AMENDMENT

6.1 Meaning of soil amendment

Soil amendment refers to the process of adding materials to the soil or carrying out appropriate soil management practices to improve its physical, chemical or biological properties for better crop production.

Soil amendments are used to correct problems such as:

1. Excessive soil acidity.
2. Excessive soil alkalinity.
3. Poor soil structure.
4. High soil salinity.
5. Nutrient imbalances.
6. Poor water infiltration.
7. Low organic matter content.

In this sub-strand, emphasis is placed on correcting soil acidity and alkalinity.

6.2 Importance of soil amendment

1. Improves soil conditions for crop growth.
2. Corrects unsuitable soil pH.
3. Improves nutrient availability.
4. Reduces the effects of nutrient toxicity.
5. Improves root development.

6. Promotes beneficial microbial activities.
7. Improves the efficiency of fertiliser application.
8. Supports healthy crop establishment.
9. Improves crop yields.
10. Promotes sustainable soil management.

6.3 Amendment of acidic soils

Acidic soils are soils with pH values below 7. Agricultural problems become more pronounced in strongly acidic soils.

The main practice used to correct excessive soil acidity is liming.

6.3.1 Meaning of liming

Liming is the application of suitable liming materials to acidic soils to reduce soil acidity and improve the availability of essential nutrients.

Liming materials contain calcium, magnesium or other alkaline components that neutralise soil acidity.

6.3.2 Liming materials

1. Agricultural limestone

Agricultural limestone is a natural material containing calcium carbonate ($CaCO_3$).

Functions

1. Neutralises soil acidity.
2. Supplies calcium to plants.
3. Reduces the harmful effects of aluminium toxicity.
4. Improves conditions for root development.
5. Improves nutrient availability.
6. Supports beneficial soil microorganisms.

2. Dolomitic limestone

Dolomitic limestone contains calcium magnesium carbonate.

Functions

1. Reduces soil acidity.
2. Supplies calcium.
3. Supplies magnesium.
4. Helps correct magnesium deficiency.
5. Improves nutrient availability in acidic soils.

3. Quicklime

Quicklime is calcium oxide (CaO).

Functions

1. Neutralises soil acidity.
2. Supplies calcium.
3. Reacts rapidly with soil moisture.

4. Can be used in soil amendment programmes under professional guidance.

Precaution: Quicklime is highly reactive and can cause burns. It must be handled carefully and applied according to technical recommendations.

4. Slaked lime

Slaked lime is calcium hydroxide [$Ca(OH)_2$].

Functions

1. Neutralises soil acidity.
2. Supplies calcium.
3. Raises soil pH.
4. Reduces aluminium toxicity under suitable conditions.

Precaution: It is more reactive than agricultural limestone and requires careful handling and correct application.

5. Industrial lime-based materials

Certain processed lime materials may be used to correct soil acidity where their chemical composition, quality and safety have been established.

They should only be used according to appropriate soil testing and agricultural recommendations.

6.3.3 Benefits of liming acidic soils

1. Raises soil pH towards a suitable level.
2. Reduces aluminium toxicity.
3. Reduces manganese toxicity in excessively acidic soils.
4. Supplies calcium and, in the case of dolomitic lime, magnesium.
5. Improves phosphorus availability in many acidic soils.
6. Encourages the activity of beneficial microorganisms.
7. Improves nitrogen fixation by suitable leguminous crops.
8. Promotes healthy root development.
9. Improves nutrient uptake.
10. Increases crop productivity where acidity is a limiting factor.

6.3.4 Factors determining the amount of lime required

The amount of lime required depends on:

1. Initial soil pH.
2. Soil texture.
3. Soil organic matter content.
4. Soil buffering capacity.
5. Type of crop to be grown.
6. Depth of soil to be treated.
7. Quality and purity of the liming material.
8. Neutralising value of the lime.
9. Degree of soil acidity.
10. Laboratory lime requirement recommendation.

Important: Soil pH alone is not enough to determine the lime requirement. A laboratory test or appropriate soil buffer test is needed because different soils resist changes in pH to different degrees.

6.3.5 Procedure for applying agricultural lime

1. Collect a representative soil sample.
2. Submit the sample for laboratory analysis.
3. Determine the soil pH and lime requirement.
4. Select an appropriate liming material.
5. Calculate the required amount using the laboratory recommendation.
6. Measure the correct quantity of lime.
7. Spread the lime uniformly over the field.
8. Incorporate the lime into the topsoil where appropriate.
9. Apply lime sufficiently early before planting to allow it to react with the soil.
10. Follow up with soil testing to assess the effectiveness of the amendment.

Precautions when applying lime

1. Avoid applying excessive amounts of lime.
2. Use the correct type of lime.
3. Ensure uniform distribution.
4. Avoid direct contact between concentrated lime and sensitive plant tissues.
5. Follow recommended application rates.
6. Do not mix lime indiscriminately with ammonium fertilisers because ammonia losses may occur.
7. Wear protective clothing when handling powdered lime.
8. Observe the recommended timing before planting and fertiliser application.

6.4 Amendment of alkaline soils

Alkaline soils have a pH above 7.

Strongly alkaline soils may restrict the availability of iron, zinc, manganese, copper and phosphorus.

Some alkaline soils also contain excessive sodium, resulting in poor soil structure and reduced water infiltration.

6.4.1 Methods of correcting alkaline soils

1. Application of elemental sulphur

Elemental sulphur is a soil amendment that can lower soil pH through microbial oxidation.

Soil microorganisms convert elemental sulphur into sulphuric acid under suitable conditions.

Functions

1. Reduces soil pH gradually.
2. Helps improve the availability of certain micronutrients.
3. Provides sulphur as an essential plant nutrient.
4. Helps manage alkaline soil conditions where its use is appropriate.

Precautions

- The rate should be determined through soil testing.
- Its effectiveness depends on soil moisture, temperature, aeration and microbial activity.
- Excessive application may cause over-acidification.

2. Application of acid-forming fertilisers

Some fertilisers contribute to soil acidification during their chemical transformation in the soil.

Examples include:

- Ammonium sulphate.
- Urea.
- Ammonium-based nitrogen fertilisers.

How they help

1. Their reactions in the soil may produce acidity.
2. They can gradually reduce soil pH in some conditions.
3. They supply essential nutrients to crops.
4. They may help manage moderately alkaline soil where the fertiliser is agronomically suitable.

Precautions

- Fertilisers should not be used solely as substitutes for a proper soil amendment programme.
- Their acidifying effects vary.
- Excessive use may lead to nutrient imbalance and other soil problems.

3. Application of organic matter

Organic matter includes decomposed plant and animal materials added to soil.

Examples:

- Well-decomposed farmyard manure.
- Compost.
- Green manure.
- Suitable plant residues.

How organic matter helps

1. Improves soil structure.
2. Increases the soil's capacity to retain nutrients.
3. Improves water-holding capacity.
4. Supports beneficial microorganisms.
5. Releases organic compounds that may influence nutrient availability.
6. Helps improve nutrient uptake.
7. Improves the overall biological condition of the soil.

Important: Organic matter does not reliably lower the pH of every alkaline soil. Its effect depends on the soil and the material used.

4. Application of iron sulphate

Iron sulphate is a mineral material that can provide iron and, under suitable conditions, contribute to acidification.

Functions

1. Supplies iron to plants.
2. Helps correct iron deficiency.
3. Can lower pH in the treated area under suitable conditions.
4. Improves plant nutrition where iron is deficient.

5. Application of gypsum in sodic soils

Gypsum is calcium sulphate dihydrate ($CaSO_4 \cdot 2H_2O$).

It is particularly useful in sodic soils, which contain excessive exchangeable sodium.

Functions

1. Supplies calcium.
2. Helps replace exchangeable sodium on soil particles.
3. Supports the removal of sodium through leaching where drainage is adequate.
4. Improves soil structure in suitable sodic soils.
5. Improves water infiltration.
6. Promotes better root development.

Important distinction: Gypsum is not a general soil acidifier. It is mainly used to correct sodicity and associated structural problems. It does not reliably reduce soil pH in ordinary alkaline soils.

6. Proper irrigation and drainage management

In alkaline or saline-alkaline soils, appropriate irrigation and drainage practices may help manage accumulated salts.

Practices include:

1. Using suitable irrigation water.
2. Avoiding excessive evaporation and salt accumulation.
3. Providing effective drainage.
4. Leaching soluble salts where conditions permit.
5. Monitoring soil salinity and sodicity.

This is especially important where excess sodium and soluble salts affect crop growth.

6.4.2 Comparison of soil amendments

Soil problem	Suitable amendment or practice	Main purpose
Acidic soil	Agricultural limestone	Neutralises acidity
Acidic soil with magnesium deficiency	Dolomitic limestone	Supplies calcium and magnesium and reduces acidity
Acidic soil	Quicklime or slaked lime	Neutralises acidity
Alkaline soil	Elemental sulphur	Gradually lowers pH
Alkaline soil	Suitable acid-forming fertilisers	May contribute to gradual acidification
Iron-deficient soil	Iron sulphate or iron chelate	Supplies iron
Sodic soil	Gypsum plus suitable drainage and leaching	Replaces exchangeable sodium and improves structure
Poor soil structure	Organic matter	Improves soil physical condition

7.0 CALCULATING AND APPLYING THE CORRECT AMOUNT OF INORGANIC FERTILISER

Correct fertiliser application involves determining the quantity of fertiliser required to meet the nutrient needs of a crop.

Farmers should avoid applying fertilisers based on guesswork because excessive or insufficient application can reduce crop productivity and increase production costs.

7.1 Importance of calculating fertiliser requirements

1. Ensures crops receive adequate nutrients.
2. Prevents excessive fertiliser application.
3. Reduces fertiliser wastage.
4. Minimises production costs.
5. Reduces environmental pollution.
6. Promotes uniform crop growth.
7. Improves fertiliser use efficiency.
8. Helps achieve recommended crop yields.
9. Prevents nutrient toxicity and imbalance.
10. Supports sustainable farming practices.

7.2 Information required when calculating fertiliser requirements

The following information is needed:

1. Size of the field.
2. Type of crop being grown.
3. Soil test results.
4. Recommended nutrient application rate.
5. Nutrient composition of the fertiliser.
6. Stage of crop growth.
7. Method of fertiliser application.

7.3 Formula for calculating the quantity of fertiliser required

The quantity of fertiliser required can be calculated using:

$$\text{Fertiliser required (kg)} = \frac{\text{Nutrient required (kg)}}{\text{Nutrient percentage}/100}$$

Alternatively:

$$F = \frac{R \times 100}{P}$$

Where:

- F = Quantity of fertiliser required (kg).
- R = Recommended nutrient requirement (kg).
- P = Percentage of the nutrient in the fertiliser.

Worked example 1: Calculating urea requirements

A farmer has a maize field requiring 60 kg of nitrogen per hectare. Calculate the amount of urea required if the urea contains 46% nitrogen.

Step 1: Identify the given information.

- Nitrogen requirement = 60 kg.
- Nitrogen content of urea = 46%.

Step 2: Write the formula.

$$F = \frac{R \times 100}{P}$$

Step 3: Substitute the values.

$$F = \frac{60 \times 100}{46}$$

$$F = \frac{6000}{46}$$

$$F = 130.43 \text{ kg}$$

Answer

The farmer requires approximately **130.4 kg of urea per hectare** to supply 60 kg of nitrogen.

Worked example 2: Calculating DAP requirements

A farmer requires 46 kg of available phosphate (P_2O_5) per hectare. Calculate the amount of DAP required if the fertiliser contains 46% P_2O_5.

Solution

Given:

- Required P_2O_5 = 46 kg.
- DAP nutrient content = 46%.

$$F = \frac{46 \times 100}{46}$$

$$F = 100 \text{ kg}$$

Answer

The farmer requires **100 kg of DAP per hectare**.

Worked example 3: Calculating MOP requirements

A farmer requires 90 kg of potassium oxide (K_2O) per hectare. Calculate the quantity of MOP required if MOP contains 60% K_2O.

Solution

$$F = \frac{90 \times 100}{60}$$

$$F = 150 \text{ kg}$$

Answer

The farmer requires **150 kg of MOP per hectare**.

7.4 Calculating fertiliser requirements for a field of a given size

The following formula is used:

$$\text{Fertiliser required} = \text{Rate per hectare} \times \text{Field area in hectares}$$

Worked example 4

A farmer is advised to apply 200 kg of NPK fertiliser per hectare. Calculate the quantity required for a field measuring 2.5 hectares.

Solution

Given:

- Application rate = 200 kg/ha.
- Field size = 2.5 ha.

$$F = 200 \times 2.5$$

$$F = 500 \text{ kg}$$

Answer

The farmer requires **500 kg of NPK fertiliser**.

7.5 Converting land area into hectares

One hectare is equivalent to 10,000 square metres.

$$1 \text{ ha} = 10{,}000 \text{ m}^2$$

Therefore:

$$\text{Area in hectares} = \frac{\text{Area in square metres}}{10{,}000}$$

Worked example 5

A farmer has a rectangular field measuring 200 metres long and 150 metres wide. Calculate the area in hectares.

Step 1: Calculate the area.

$$A = L \times W$$

$$A = 200 \times 150$$

$$A = 30{,}000 \text{ m}^2$$

Step 2: Convert to hectares.

$$\text{Area} = \frac{30{,}000}{10{,}000}$$

$$= 3 \text{ ha}$$

Answer

The field measures **3 hectares**.

Worked example 6: Fertiliser required for a small farm

A farmer has a 0.4-hectare field. The recommended application rate is 250 kg of fertiliser per hectare. Calculate the amount required.

Solution

$$F = 250 \times 0.4$$

$$F = 100 \text{ kg}$$

Answer

The farmer requires **100 kg of fertiliser**.

7.6 Calculating fertiliser application rates from nutrient recommendations

Sometimes farmers are given recommendations in terms of nutrients rather than the quantity of fertiliser.

For example, a farmer may be advised to apply:

- 60 kg nitrogen per hectare.
- 40 kg P_2O_5 per hectare.
- 30 kg K_2O per hectare.

The farmer must calculate the quantity of each fertiliser required.

Worked example 7

A farmer wants to supply 60 kg N, 40 kg P_2O_5 and 30 kg K_2O per hectare using:

- Urea containing 46% N.
- TSP containing 46% P_2O_5.
- MOP containing 60% K_2O.

Calculate the quantity of each fertiliser required.

Solution

A. Urea

$$F = \frac{60 \times 100}{46}$$

$$= 130.43 \text{ kg}$$

B. TSP

$$F = \frac{40 \times 100}{46}$$

$$= 86.96 \text{ kg}$$

C. MOP

$$F = \frac{30 \times 100}{60}$$

$$= 50 \text{ kg}$$

Final answers per hectare

Fertiliser	Quantity required
Urea	130.43 kg
TSP	86.96 kg
MOP	50 kg

7.7 Fertiliser application methods

Fertiliser application refers to the process of placing or distributing fertilisers in the soil or on plants to supply essential nutrients.

The choice of application method depends on:

- Type of fertiliser.
- Crop being grown.
- Stage of crop growth.
- Soil conditions.
- Field size.
- Available equipment.

1. Broadcasting

Broadcasting is the method of spreading fertiliser uniformly over the surface of the soil.

Procedure

1. Calculate the required quantity of fertiliser.
2. Divide the field into manageable sections.
3. Measure the required fertiliser.
4. Spread the fertiliser uniformly over the field.
5. Incorporate it into the soil where recommended.

Advantages

1. Easy to carry out.
2. Suitable for large fields.
3. Saves time and labour.
4. Can be carried out mechanically or manually.
5. Suitable for some basal and top-dressing applications.

Disadvantages

1. Fertiliser may be distributed unevenly.
2. Nutrients may be lost through surface runoff.
3. Some fertilisers may be lost through volatilisation.
4. Fertiliser may be applied to areas where there are no crops.

2. Row placement

This involves placing fertiliser in bands or rows near the crop rows during planting or crop establishment.

Procedure

1. Prepare the planting rows.
2. Measure the required fertiliser.
3. Place the fertiliser in bands near the planting rows.
4. Ensure that the fertiliser does not directly contact the seeds.

5. Cover with soil before or during planting.

Advantages

1. Places nutrients near developing roots.
2. Reduces fertiliser wastage in some situations.
3. Improves early nutrient availability.
4. Requires relatively small quantities for band placement.

Disadvantages

1. Requires careful measurement.
2. Poor placement may burn seeds or seedlings.
3. May require special planting equipment.
4. Can be labour-intensive when done manually.

3. Hole placement

In this method, fertiliser is placed in holes dug near individual plants.

Procedure

1. Identify the plants requiring fertiliser.
2. Measure the required quantity.
3. Dig small holes near the plants.
4. Place the fertiliser in the holes.
5. Cover the holes with soil.

Advantages

1. Allows accurate placement.
2. Reduces fertiliser wastage.
3. Suitable for individual plants.
4. Useful in small-scale crop production.

Disadvantages

1. Labour-intensive.
2. Time-consuming for large fields.
3. Incorrect placement may damage roots.
4. Requires careful measurement.

4. Ring application

Ring application involves placing fertiliser in a circular band around the base of a plant, usually at an appropriate distance from the stem.

Procedure

1. Identify the plant requiring fertiliser.
2. Determine the recommended distance from the stem.
3. Dig a shallow circular furrow around the plant.
4. Apply the required quantity of fertiliser.
5. Cover with soil.

Advantages

1. Places fertiliser within the root zone.
2. Reduces direct contact with the stem.
3. Suitable for fruit trees and other widely spaced crops.
4. Allows targeted nutrient application.

5. Top-dressing

Top-dressing involves applying fertiliser to the soil around established crops after planting, usually to supply nutrients needed during active growth.

Procedure

1. Identify the correct crop growth stage.
2. Measure the recommended fertiliser quantity.
3. Apply fertiliser around the plants or along crop rows.
4. Avoid direct contact with leaves and stems.
5. Incorporate or water in the fertiliser where appropriate.

Advantages

1. Supplies nutrients during active crop growth.
2. Supports vegetative development.
3. Allows additional nitrogen to be supplied when required.
4. Helps correct nutrient deficiencies during crop development.

6. Foliar application

Foliar application involves spraying a suitable fertiliser solution directly onto plant leaves for absorption through leaf surfaces.

Procedure

1. Select an appropriate foliar fertiliser.
2. Read the manufacturer's instructions.
3. Measure the recommended amount.
4. Mix the fertiliser with clean water.
5. Fill the sprayer.
6. Spray the leaves uniformly.
7. Apply under suitable weather conditions.

Advantages

1. Supplies nutrients directly through leaves.
2. Useful for correcting some micronutrient deficiencies.
3. Can provide a rapid response in suitable situations.
4. Requires relatively small amounts of nutrients.

Disadvantages

1. Cannot normally meet the full macronutrient requirements of major field crops.
2. Excessive concentration may scorch leaves.
3. Application may be affected by rainfall.

4. Requires appropriate spraying equipment.

7. Fertigation

Fertigation is the application of water-soluble fertilisers through an irrigation system.

Advantages

1. Supplies nutrients together with irrigation water.
2. Allows accurate nutrient application.
3. Saves labour.
4. Can improve nutrient-use efficiency.
5. Allows nutrients to be supplied at different crop growth stages.

Disadvantages

1. Requires suitable irrigation equipment.
2. Some fertilisers may block irrigation emitters.
3. Requires technical knowledge.
4. Initial installation costs may be high.

7.8 Precautions when applying inorganic fertilisers

1. Apply fertilisers at the recommended rate.
2. Use the correct fertiliser for the crop and soil.
3. Avoid direct contact between concentrated fertilisers and seeds.
4. Avoid applying fertilisers immediately before heavy rainfall.
5. Store fertilisers in dry, well-ventilated areas.
6. Keep fertilisers away from children and animals.
7. Use protective clothing when handling fertilisers.
8. Calibrate application equipment correctly.
9. Avoid applying fertiliser to waterways.
10. Observe recommended application timing.
11. Avoid mixing fertilisers without checking their compatibility.
12. Follow the manufacturer's instructions.

8.0 PRACTICAL APPLICATION OF SOIL SAMPLING AND FERTILISER MANAGEMENT

This section provides practical learning activities through which learners develop agricultural skills and competencies.

8.1 Practical activity: Collecting soil samples from a school farm

Learning objective: To enable learners to collect representative soil samples for laboratory analysis.

Requirements

- Soil auger or spade.
- Clean plastic bucket.
- Sample bags.
- Labels.
- Marker pen.

- Measuring ruler.
- Clean plastic sheet.

Procedure

1. Visit the school farm.
2. Identify a relatively uniform section of land.
3. Select 15–20 sampling points using a zigzag pattern.
4. Remove surface vegetation.
5. Collect soil from a consistent depth of approximately 0–20 cm.
6. Place all soil portions in a clean bucket.
7. Mix the collected soil thoroughly.
8. Remove stones and plant materials.
9. Spread the soil on a clean plastic sheet.
10. Reduce the sample using the quartering method.
11. Place the required quantity in a clean sample bag.
12. Label the sample.
13. Submit it for laboratory analysis.

Expected learning outcomes

By the end of the activity, learners should be able to:

- Select appropriate soil sampling points.
- Use soil sampling equipment correctly.
- Collect representative soil samples.
- Prepare composite soil samples.
- Label and package soil samples.
- Explain the importance of soil testing.

8.2 Practical activity: Identifying different inorganic fertilisers

Requirements

- Samples of urea.
- DAP.
- CAN.
- TSP.
- MOP.
- NPK compound fertiliser.
- Sample containers.
- Labels.
- Observation notebook.

Procedure

1. Obtain samples of different inorganic fertilisers.
2. Place each sample in a separate container.
3. Label the containers.
4. Observe the colour and physical appearance of each sample.
5. Examine the information on the fertiliser packaging.

6. Identify the nutrient composition.
7. Classify each fertiliser as straight or compound.
8. Record the findings in a table.

Sample observation table

Fertiliser	Main nutrient	Category
Urea	Nitrogen	Straight
DAP	N and P_2O_5	Compound
CAN	Nitrogen	Straight
TSP	P_2O_5	Straight
MOP	K_2O	Straight
NPK 17:17:17	N, P_2O_5 and K_2O	Compound

Note: DAP is a compound fertiliser because it supplies both nitrogen and phosphorus.

8.3 Practical activity: Testing soil pH

Requirements

- Soil samples.
- Distilled water.
- Soil pH meter.
- Measuring cylinder.
- Clean beakers.
- Stirring rod.
- pH indicator paper.

Procedure

1. Collect soil samples from different parts of the school farm.
2. Place equal quantities of soil in separate beakers.
3. Add the prescribed quantity of distilled water.
4. Stir the soil-water mixtures.
5. Allow the soil particles to settle.
6. Calibrate the pH meter.
7. Insert the electrode into each suspension.
8. Record the pH readings.
9. Classify each soil sample as acidic, neutral or alkaline.
10. Discuss the suitability of each soil for different crops.

Sample results table

Soil sample	pH reading	Classification
Sample A	4.8	Strongly acidic
Sample B	5.7	Moderately acidic
Sample C	6.8	Near neutral
Sample D	7.0	Neutral
Sample E	8.2	Moderately alkaline

The readings above are illustrative practical results.

8.4 Practical activity: Demonstrating the effect of soil pH on plant growth

Objective: To investigate how different soil pH conditions influence crop growth.

Requirements

- Similar soil samples with different pH values.
- Planting containers.
- Bean seeds.
- Water.
- Ruler.
- Labels.
- pH meter.

Procedure

1. Collect soil samples with different pH values.
2. Place equal quantities of soil in different containers.
3. Label each container according to its soil pH.
4. Plant an equal number of bean seeds in each container.
5. Provide similar watering and light conditions.
6. Observe germination.
7. Measure plant height at regular intervals.
8. Record leaf colour and general plant condition.
9. Compare plant growth in the different soil samples.
10. Discuss the relationship between soil pH and crop growth.

Expected observations

- Plants growing in suitable pH conditions may establish and grow better.
- Strongly acidic soil may restrict root growth.
- Highly alkaline soil may cause micronutrient deficiencies.
- Differences in plant growth may be observed.

Conclusion: Soil pH influences nutrient availability and plant growth. Maintaining suitable soil pH is important for successful crop production.

KEY AGRICULTURAL TERMS AND DEFINITIONS

Term	Meaning
Fertiliser	A material added to soil or plants to supply essential nutrients
Inorganic fertiliser	A manufactured or processed mineral fertiliser supplying plant nutrients
Macronutrients	Nutrients required by plants in relatively large quantities
Micronutrients	Nutrients required by plants in very small quantities
Nutrient deficiency	A condition resulting from insufficient availability of an essential plant nutrient
Chlorosis	Yellowing of normally green plant tissues due to reduced chlorophyll
Necrosis	Death of plant cells or tissues
Straight fertiliser	Fertiliser supplying mainly one primary plant nutrient
Compound fertiliser	Fertiliser containing two or more primary plant nutrients
Fertiliser grade	The percentage composition of declared nutrients in a fertiliser
Soil sampling	Collection of representative soil portions for analysis
Composite sample	A sample formed by mixing several soil portions collected from different points
Soil pH	A measure of soil acidity or alkalinity
Acidic soil	Soil with a pH below 7
Alkaline soil	Soil with a pH above 7
Neutral soil	Soil with a pH of approximately 7
Soil amendment	Material or practice used to improve soil properties
Liming	Application of suitable materials to reduce soil acidity
Leaching	Downward movement of soluble nutrients or salts through the soil with water
Fertigation	Application of fertilisers through irrigation water
Broadcasting	Uniform spreading of fertiliser over the soil surface
Top-dressing	Application of fertiliser to established crops after planting
Foliar feeding	Supplying plant nutrients through leaves
Soil fertility	The capacity of soil to supply essential nutrients for plant growth
Nutrient uptake	Absorption of nutrients by plant roots or other plant surfaces
Soil salinity	Accumulation of soluble salts in the soil
Soil sodicity	Excessive exchangeable sodium in soil

ASSESSMENT AND REVISION QUESTIONS

SUB-STRAND 1.1: INORGANIC FERTILISERS

Section A: Multiple-choice questions

Choose the correct answer in each question.

1. Which one of the following nutrients is classified as a primary macronutrient?

A. Zinc

B. Nitrogen

C. Boron

D. Copper

2. Which nutrient is responsible for promoting strong root development and energy transfer in plants?

A. Potassium

B. Calcium

C. Phosphorus

D. Iron

3. A farmer observes yellowing of the older leaves of maize plants. Which nutrient is most likely deficient?

A. Nitrogen

B. Boron

C. Copper

D. Iron

4. Which one of the following elements forms the central component of chlorophyll?

A. Calcium

B. Magnesium

C. Sulphur

D. Zinc

5. Which micronutrient is particularly important in pollen tube development and successful fertilisation?

A. Iron B. Copper

C. Boron D. Manganese

6. Which one of the following fertilisers is a straight nitrogen fertiliser?

A. NPK 17:17:17

B. Urea

C. NPK 23:23:0

D. DAP

7. A farmer purchases NPK 17:17:17 fertiliser. What does the first 17 represent?

A. Percentage of phosphorus.

B. Percentage of potassium.

C. Percentage of nitrogen.

D. Percentage of calcium.

8. Which one of the following fertilisers supplies both nitrogen and phosphorus?

A. Muriate of potash. B. Urea.

C. DAP. D. TSP.

9. Which method of soil sampling involves moving across the field in a zigzag pattern?

A. Random sampling.

B. Grid sampling.

C. Zigzag sampling.

D. Profile sampling.

10. Why should soil samples be collected from different parts of a field?

A. To increase soil weight.

B. To obtain a representative sample.

C. To increase soil acidity.

D. To remove soil microorganisms.

11. Which one of the following instruments is used to measure soil pH?

A. Thermometer. B. Rain gauge.

C. pH meter. D. Hygrometer.

12. A soil sample has a pH of 4.5. How should the soil be classified?

A. Neutral.

B. Alkaline.

C. Strongly acidic.

D. Slightly alkaline.

13. Which one of the following materials is commonly used to correct acidic soils?

A. Agricultural limestone.

B. Muriate of potash.

C. Urea.

D. Ammonium sulphate.

14. Which one of the following fertilisers supplies potassium?

A. TSP. B. Urea. C. MOP. D. CAN.

15. Which one of the following practices is most appropriate for reducing nutrient losses through fertiliser runoff?

A. Applying fertiliser immediately before heavy rainfall.

B. Applying fertiliser at the recommended rate and time.

C. Applying fertiliser near rivers.

D. Applying excessive fertiliser.

16. Which soil amendment is particularly useful in sodic soils?

A. Gypsum.

B. Urea.

C. DAP.

D. TSP.

17. Which nutrient deficiency is commonly associated with interveinal chlorosis of young leaves?

A. Iron.

B. Potassium.

C. Nitrogen.

D. Phosphorus.

18. A farmer applies fertiliser through an irrigation system. Which method is being used?

A. Broadcasting.

B. Ring application.

C. Fertigation.

D. Hole placement.

19. Which one of the following is the most appropriate reason for using a composite soil sample?

A. To represent the general soil condition of a uniform field.

B. To increase the acidity of the soil.

C. To eliminate all soil microorganisms.

D. To increase the quantity of fertiliser required.

20. Which one of the following is the main purpose of soil testing before fertiliser application?

A. To determine the colour of the soil.

B. To establish the nutrient status of the soil.

C. To increase the field size.

D. To determine the number of weeds.

Section B: Structured questions

21.

a) Define the term inorganic fertiliser. (2 marks)

b) Distinguish between macronutrients and micronutrients. (4 marks)

c) State four functions of nitrogen in crop growth. (4 marks)

d) Explain four symptoms of phosphorus deficiency in crops. (4 marks)

e) Describe four functions of potassium in crop production. (4 marks)

22.

a) Name the three primary macronutrients required by plants. (3 marks)

b) Distinguish between straight and compound fertilisers. (4 marks)

c) Give three examples of straight fertilisers and state the main nutrient supplied by each. (6 marks)

d) Explain four advantages of compound fertilisers in crop production. (4 marks)

23.

a) Define soil sampling. (2 marks)

b) State five reasons why farmers should carry out soil sampling before planting. (5 marks)

c) Describe the procedure for collecting a representative soil sample from a school farm. (8 marks)

d) State five precautions that should be observed when collecting soil samples. (5 marks)

24.

a) Define soil pH. (2 marks)

b) Distinguish between acidic, neutral and alkaline soils. (6 marks)

c) Explain five ways in which soil pH influences crop production. (5 marks)

d) State four factors that influence soil pH. (4 marks)

25.

a) Explain the meaning of soil amendment. (2 marks)

b) Identify four materials used in correcting acidic soils. (4 marks)

c) Explain five benefits of liming acidic soils. (5 marks)

d) Describe four methods of managing alkaline soils. (4 marks)

26.

a) A farmer requires 69 kg of nitrogen per hectare. Calculate the quantity of urea required if the fertiliser contains 46% nitrogen. (3 marks)

b) A farmer has a field measuring 2 hectares. The recommended fertiliser application rate is 150 kg per hectare. Calculate the total quantity of fertiliser required. (3 marks)

c) Explain four fertiliser application methods used in crop production. (8 marks)

d) State six precautions farmers should observe when applying inorganic fertilisers. (6 marks)

STRAND 1.0: CROP PRODUCTION

SUB-STRAND 1.2: WATER CONSERVATION – IRRIGATION

Main content areas

1. Meaning and principles of irrigation.
2. Methods of irrigation in crop production.
3. Importance of irrigation.
4. Efficient approaches to irrigation.
5. Water conservation during irrigation.
6. Selection and management of irrigation systems.
7. Practical application of irrigation in crop production.

1.0 INTRODUCTION TO IRRIGATION

Water is one of the most important requirements for successful crop production. Plants require water for germination, nutrient absorption, photosynthesis, transportation of manufactured food, cooling and other physiological processes.

In agricultural production, rainfall is a major natural source of water. However, rainfall is not always reliable because it may be insufficient, poorly distributed or seasonal.

In some areas, prolonged dry periods, drought and unpredictable rainfall interfere with crop growth and reduce agricultural productivity.

Farmers therefore use irrigation to supply water to crops when natural rainfall is inadequate.

Irrigation is particularly important in areas where rainfall is unreliable, such as arid and semi-arid regions of Kenya.



1.1 Meaning of irrigation

Irrigation is the artificial application of water to agricultural land to supplement rainfall and provide crops with sufficient moisture for proper growth and development.



It involves supplying water to the root zone of crops using different methods and equipment.

Water used for irrigation may be obtained from:

1. Rivers and streams.
2. Dams and reservoirs.
3. Lakes.
4. Boreholes.
5. Wells.
6. Springs.
7. Water pans.
8. Harvested rainwater.
9. Treated wastewater that meets agricultural safety requirements.

Examples of crops grown under irrigation in Kenya

- Tomatoes.
- Onions.
- Cabbages.
- Spinach.
- French beans.
- Maize.
- Watermelons.
- Capsicum.
- Rice.
- Potatoes.

1.2 Meaning of irrigation water conservation

Irrigation water conservation refers to the use of appropriate methods, equipment and management practices to reduce water wastage during irrigation while ensuring that crops receive sufficient water for healthy growth.

It involves applying the correct quantity of water at the correct time and in the correct place.

Examples of irrigation water conservation practices

1. Using drip irrigation.
2. Irrigating crops during cooler hours.
3. Mulching the soil.
4. Repairing leaking irrigation pipes.
5. Using rainwater harvesting systems.
6. Avoiding excessive irrigation.
7. Monitoring soil moisture.
8. Using efficient irrigation equipment.
9. Maintaining irrigation channels.
10. Selecting irrigation methods suitable for the soil and crop.

1.3 Difference between irrigation and rain-fed agriculture

Irrigation agriculture	**Rain-fed agriculture**
Water is artificially supplied to crops.	Crops mainly depend on rainfall.
Can support crop production during dry periods.	Crop production depends on rainfall availability.
Requires water sources and irrigation equipment.	May require fewer irrigation facilities.
Water application can be controlled.	Water supply is largely controlled by weather conditions.
Can support production throughout the year where water is available.	Production may be seasonal.
Requires investment in water supply and management.	May have lower initial water infrastructure costs.

2.0 IMPORTANCE OF IRRIGATION IN CROP PRODUCTION

Irrigation plays an important role in modern agriculture by ensuring that crops receive adequate water when rainfall is insufficient.

The following are the major benefits of irrigation.

2.1 Ensures adequate water supply to crops

- Irrigation supplies water when rainfall is insufficient.
- It prevents crops from suffering severe water stress.
- It maintains suitable soil moisture for plant growth.
- It supports normal physiological activities in plants.

For example, farmers growing tomatoes during dry seasons use irrigation to maintain adequate soil moisture.

2.2 Enables crop production throughout the year

- Irrigation allows farmers to grow crops during dry seasons.
- It reduces overdependence on seasonal rainfall.
- It supports continuous production of vegetables and other crops.
- It allows farmers to plan production according to market demand.

For example, farmers in parts of Makueni and Kajiado can produce vegetables during dry periods using water from dams and boreholes.

2.3 Increases crop yields

- Adequate water supports photosynthesis.
- It promotes cell enlargement and plant growth.
- It improves flowering and fruit development.
- It reduces losses caused by drought stress.
- It may increase the quantity of produce harvested per unit area.

For example, adequately irrigated onions may produce better-sized bulbs than onions grown under severe water stress.

2.4 Improves crop quality

- Adequate moisture promotes proper fruit development.
- It supports uniform growth.
- It improves the size and appearance of produce.
- It reduces some defects associated with irregular water supply.

For example, consistent irrigation helps maintain uniform fruit development in tomatoes.

2.5 Supports the production of high-value crops

- Irrigation allows farmers to grow high-value horticultural crops.
- It supports commercial vegetable farming.
- It enables farmers to meet market requirements.
- It can increase household income when properly managed.

Examples include:

- French beans.
- Tomatoes.
- Capsicum.
- Watermelons.
- Onions.
- Strawberries.

2.6 Reduces the risk of crop failure

- Irrigation provides supplementary water during dry spells.
- It reduces the likelihood of crop wilting.
- It supports crop establishment after planting.
- It helps farmers maintain production when rainfall is unreliable.

2.7 Promotes seed germination and seedling establishment

- Water softens the seed coat.
- It activates enzymes involved in germination.
- It supports the development of the radicle and plumule.
- It maintains moisture around newly planted seeds.
- It improves seedling establishment when appropriately managed.

2.8 Supports nutrient absorption

- Water dissolves mineral nutrients in the soil.
- It enables nutrients to move towards plant roots.
- It supports nutrient absorption by root hairs.
- It facilitates transportation of dissolved nutrients within plants.

2.9 Supports livestock feed production

- Irrigation enables farmers to grow fodder during dry periods.
- It supports the production of pasture grasses.
- It ensures a more reliable supply of animal feed.
- It can improve livestock productivity indirectly.

Examples include irrigated Napier grass, fodder sorghum and suitable forage crops.

2.10 Promotes employment creation

- Irrigated agriculture creates employment in crop production.
- It provides work in harvesting, packaging and transportation.
- It supports agro-processing activities.
- It creates business opportunities in irrigation equipment supply and maintenance.

2.11 Makes efficient use of agricultural land

- Irrigation enables cultivation in areas where rainfall is insufficient.
- It supports the productive use of suitable dryland areas.
- It can increase the intensity of crop production where soil, water and environmental conditions permit.

2.12 Supports national food security

- Irrigation increases the reliability of food production.
- It reduces dependence on rainfall.
- It supports production of cereals, vegetables and other food crops.
- It can help reduce food shortages during prolonged dry periods.

3.0 METHODS OF IRRIGATION IN CROP PRODUCTION

3.1 Meaning of irrigation methods

Irrigation methods refer to the different techniques used to deliver water from a source to agricultural land or directly to crops.

The choice of irrigation method depends on several factors, including:

1. Type of crop.
2. Soil texture.
3. Soil structure.
4. Land topography.
5. Availability of water.

6. Cost of installation.
7. Availability of labour.
8. Size of the farm.
9. Climate and weather conditions.
10. Availability of irrigation equipment.

The main irrigation methods covered in this sub-strand are:

1. Sprinkler irrigation.
2. Drip irrigation.
3. Basin irrigation.
4. Flood irrigation.
5. Furrow irrigation.

3.2 SPRINKLER IRRIGATION

3.2.1 Meaning of sprinkler irrigation

Sprinkler irrigation is a method of irrigation in which water is distributed over crops in the form of artificial rainfall using pipes, pumps and sprinkler nozzles.



Water is forced through pipes under pressure and released through sprinkler heads, which break the water into small droplets that fall onto the soil and crops.

The method imitates natural rainfall.

3.2.2 Components of a sprinkler irrigation system

A sprinkler irrigation system consists of the following components:

1. Water source

- This is where irrigation water is obtained.
- It may be a river, dam, reservoir, borehole or water tank.
- It provides the water required for irrigation.

2. Pumping unit

- A pump is used to move water from the source into the irrigation pipes.
- It provides the pressure needed to operate the sprinkler system.
- Pumps may be powered by electricity, diesel engines or solar energy.

3. Main pipe

- The main pipe transports water from the pump to the irrigation field.
- It supplies water to the distribution pipes.

4. Sub-main pipes

- These receive water from the main pipe.
- They distribute water to the lateral pipes.

5. Lateral pipes

- These are smaller pipes connected to the sub-main pipes.
- They carry water to the sprinkler heads.

6. Sprinkler heads

- They release water into the air in the form of droplets.
- Some sprinkler heads rotate to distribute water over a circular area.
- Others spray water over a fixed area.

7. Nozzles

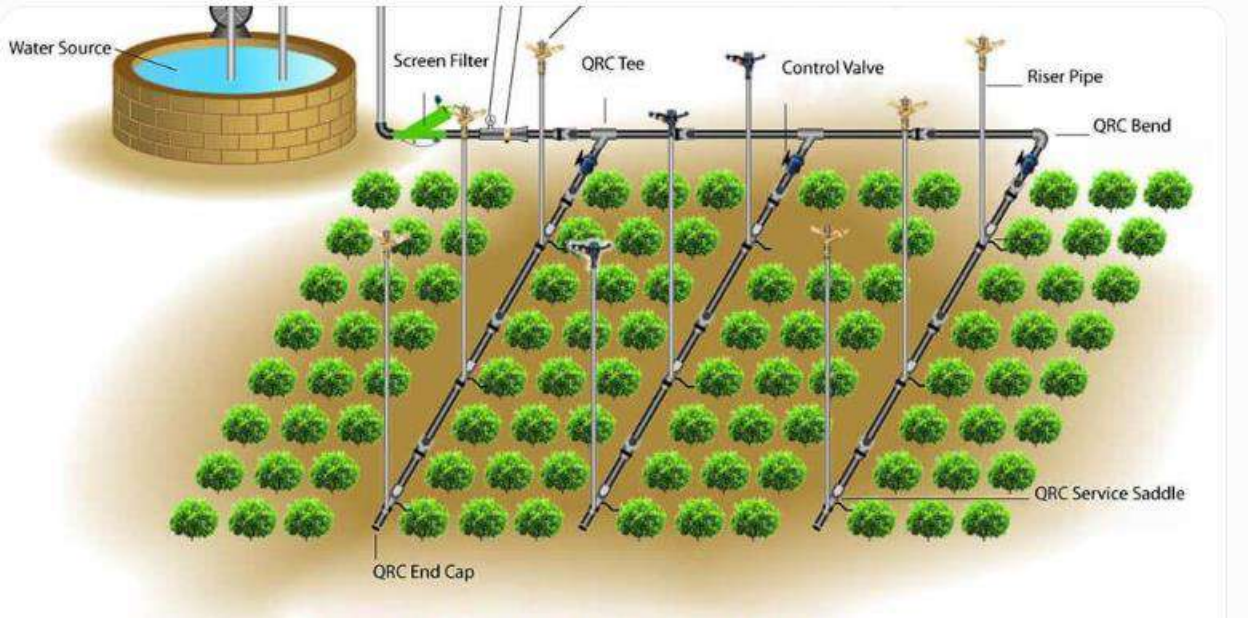
- Nozzles control the size and direction of water droplets.
- They influence the rate at which water is discharged.

8. Filters

- Filters remove dirt, sand and other particles from irrigation water.
- They prevent blockage of sprinkler nozzles.

9. Valves

- Valves control the movement and supply of water.
- They allow different sections of the irrigation system to be operated independently.



3.2.3 How sprinkler irrigation works

1. Water is obtained from a suitable source.
2. The pumping unit moves water into the main pipe.
3. Water flows through the main and sub-main pipes.
4. It reaches the lateral pipes.
5. Water is forced through sprinkler nozzles under pressure.
6. The sprinkler heads distribute water as droplets.
7. The droplets fall onto the crops and soil surface.
8. Water infiltrates the soil and becomes available to plant roots.

3.2.4 Types of sprinkler irrigation systems

A. Portable sprinkler system

- The pipes and sprinkler heads can be moved from one section of the farm to another.
- It is suitable for small and medium-sized farms.
- It allows farmers to irrigate different field sections using the same equipment.



B. Permanent sprinkler system

- The pipes are permanently installed in the field.
- Sprinkler heads are positioned at fixed locations.
- It reduces the need to move irrigation equipment.
- It is suitable for farms requiring regular irrigation.



C. Centre-pivot sprinkler irrigation

- It uses a long sprinkler-equipped pipeline supported by wheeled towers.
- The pipeline rotates around a central water supply point.
- It irrigates a large circular area.
- It is commonly used in large commercial farms.



D. Travelling sprinkler system

- A sprinkler unit moves across the field while applying water.
- It may be moved mechanically or by a suitable travelling mechanism.
- It is useful for irrigating relatively large areas.



3.2.5 Advantages of sprinkler irrigation

1. Suitable for different terrains: It can be used on gently sloping and uneven land where properly designed.

2. Uniform water distribution: It can distribute water relatively evenly when correctly designed and operated.

3. Reduced land preparation: It does not require the extensive levelling needed by some surface irrigation systems.

4. Efficient water control: The quantity of water applied can be controlled through operating time and system discharge.

5. Suitable for many crops: It can be used for vegetables, pastures, cereals and other crops.

6. Less soil erosion in suitable conditions: Properly designed sprinklers can apply water at rates that do not exceed the soil's infiltration capacity.

7. Can be automated: Timers and control devices can be used to regulate irrigation.

8. Useful for supplementary irrigation: It can provide water during dry spells.

9. No need for individual irrigation furrows: Water is distributed over the field through sprinkler heads.

10. Suitable for sandy soils: It can apply water in controlled amounts and intervals, reducing deep percolation when correctly managed.

3.2.6 Disadvantages of sprinkler irrigation

1. High installation costs: Pumps, pipes and sprinkler equipment may be expensive.

2. Energy requirements: Pressurised systems require energy to operate.

3. Wind interference: Strong winds may carry water droplets away from the intended area.

4. Evaporation losses: Some water may evaporate before reaching the soil.

5. Nozzle blockage: Dirt and suspended particles may block sprinkler nozzles.

6. Disease development: Wet foliage may encourage certain fungal and bacterial diseases in susceptible crops.

7. Maintenance requirements: Pipes, pumps and sprinkler heads require regular inspection.

8. Water pressure requirements: Inadequate pressure may lead to poor water distribution.

9. Water quality limitations: Saline water may leave salts on leaves, especially in hot conditions.

10. Not suitable in all weather conditions: High winds and very hot, dry conditions may reduce application efficiency.

3.2.7 Crops suitable for sprinkler irrigation

- Maize.
- Wheat.
- Vegetables.
- Pasture grasses.
- Potatoes.
- Beans.
- Onions.
- Seedlings in nurseries.

3.3 DRIP IRRIGATION

3.3.1 Meaning of drip irrigation







Drip irrigation is a method of irrigation in which water is supplied slowly and directly to the root zone of plants through a network of pipes, tubes and small outlets called emitters or drippers.

Water is delivered in small quantities at regular intervals, reducing unnecessary wetting of the soil surface between crop rows.

It is also known as trickle irrigation.

3.3.2 Components of a drip irrigation system

1. Water source

- Supplies water for irrigation.
- May include a tank, dam, river, borehole or reservoir.

2. Pump

- Moves water through the irrigation system.
- Provides the pressure required for water distribution.

3. Filter

- Removes sand, dirt and other particles.
- Prevents blockage of emitters.

4. Main pipe

- Transports water from the source to the irrigation field.

5. Sub-main pipe

- Distributes water from the main pipe to the lateral pipes.

6. Lateral pipes

- These are smaller pipes laid along crop rows.
- They carry water close to the plants.

7. Emitters or drippers

- Small outlets that release water slowly.
- They supply water directly to the root zone.

8. Pressure regulator

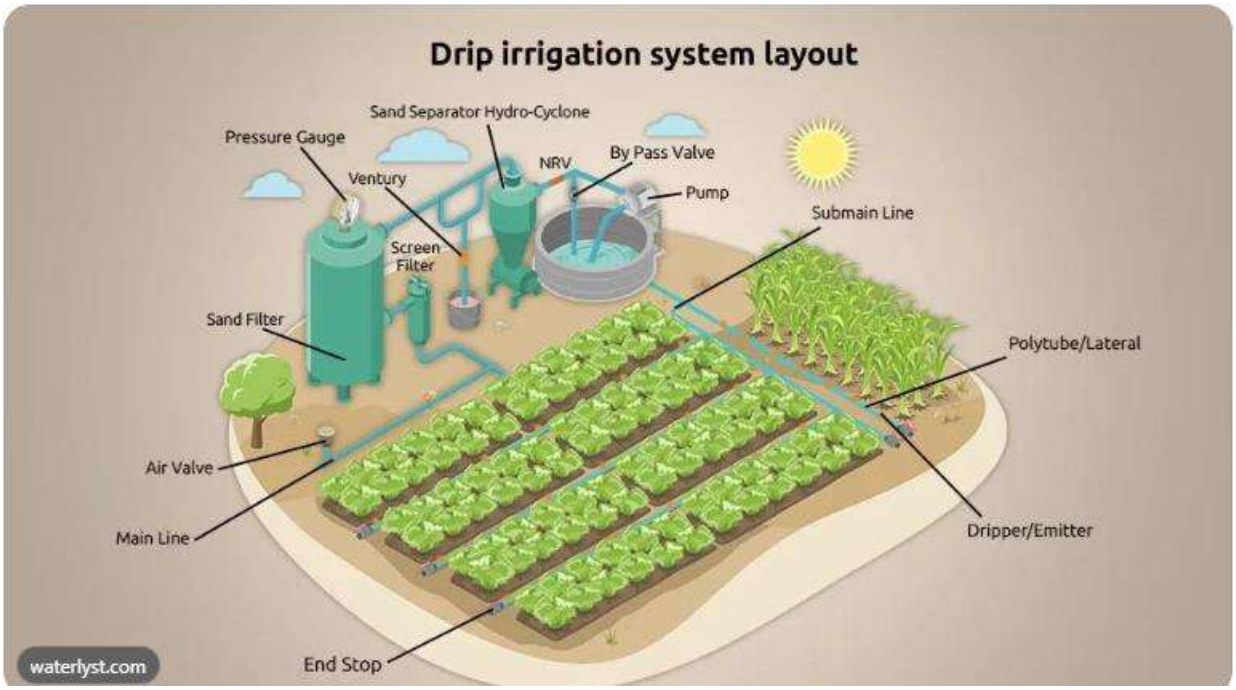
- Maintains suitable water pressure within the irrigation system.
- Prevents excessive pressure from damaging the pipes or affecting water distribution.

9. Control valves

- Regulate the supply of water to different sections of the farm.

10. Fertiliser injector

- Used to introduce suitable soluble fertilisers into irrigation water.
- Enables fertigation where appropriate.



3.3.3 How drip irrigation works

1. Water is collected from a suitable source.
2. It is pumped or allowed to flow through the system.
3. Water passes through filters to remove particles.
4. It flows through the main and sub-main pipes.
5. It enters the lateral pipes.
6. Emitters release water slowly near individual plants.
7. Water infiltrates the soil around the root zone.
8. Plant roots absorb the available moisture.

3.3.4 Types of drip irrigation

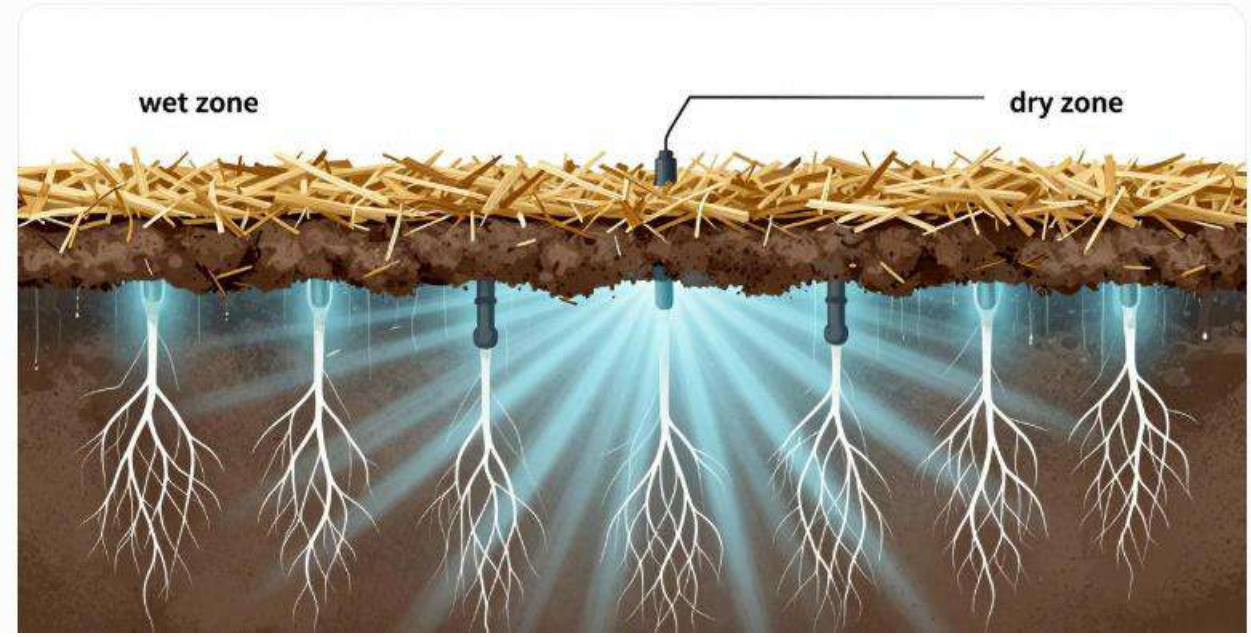
A. Surface drip irrigation

- Drip pipes are laid on the soil surface.
- Emitters release water near the base of plants.
- It is commonly used in vegetable production and orchards.



B. Subsurface drip irrigation

- Drip lines are installed below the soil surface.
- Water is supplied directly into the root zone.
- It reduces evaporation from the soil surface.
- It requires careful installation and maintenance.



3.3.5 Advantages of drip irrigation

1. Saves water: Water is delivered close to plant roots, reducing evaporation and unnecessary wetting.

2. Reduces weed growth: Only selected areas around the crop are wetted, reducing moisture availability to weeds between rows.

3. Improves water-use efficiency: Water is supplied in controlled quantities.

4. Reduces soil erosion: Water is released slowly, reducing surface runoff.

5. Supports fertigation: Suitable soluble fertilisers can be supplied through the irrigation system.

6. Reduces wetting of foliage: This may reduce the risk of some foliar diseases.

7. Suitable for uneven land: It can be designed to operate on sloping land using appropriate pressure regulation.

8. Saves labour: Automated systems can reduce manual watering.

9. Promotes uniform crop growth: Properly designed systems provide consistent water supply.

10. Suitable for water-scarce areas: It allows careful management of limited water resources.

3.3.6 Disadvantages of drip irrigation

1. High initial installation costs: Pipes, filters, emitters and control equipment may be expensive.

2. Emitter blockage: Small outlets may become blocked by dirt, algae or mineral deposits.

3. Requires clean water: Filtration is necessary to prevent clogging.

4. Regular maintenance: Filters and pipes require frequent inspection.

5. Damage to pipes: Rodents, farm tools and farm operations may damage drip lines.

6. Technical knowledge: Proper installation and operation require some technical skills.

7. Salt accumulation: Salts may accumulate around the edges of wetted areas, particularly where irrigation water is saline.

8. Limited wetting area: Water may not reach the entire root zone of widely spaced or deep-rooted crops unless the system is properly designed.

9. Dependence on equipment: Breakdown of pumps or blocked pipes may interrupt irrigation.

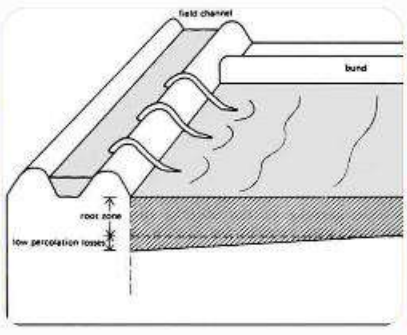
3.3.7 Crops suitable for drip irrigation

- Tomatoes.
- Capsicum.
- Onions.
- Cabbages.
- Watermelons.
- Strawberries.
- Fruit trees.
- Cucumbers.
- French beans.
- Avocados.

3.4 BASIN IRRIGATION

3.4.1 Meaning of basin irrigation







Basin irrigation is a surface irrigation method in which agricultural land is divided into small, relatively level plots surrounded by raised earth banks called bunds.

Water is directed into each enclosed basin and allowed to spread over the soil surface before infiltrating into the root zone.

The raised banks prevent water from flowing away from the designated area.

Basin irrigation is commonly used for crops grown in relatively level fields and for some widely spaced crops.

3.4.2 Components and features of basin irrigation

1. Basins: These are enclosed plots of land where irrigation water is applied.

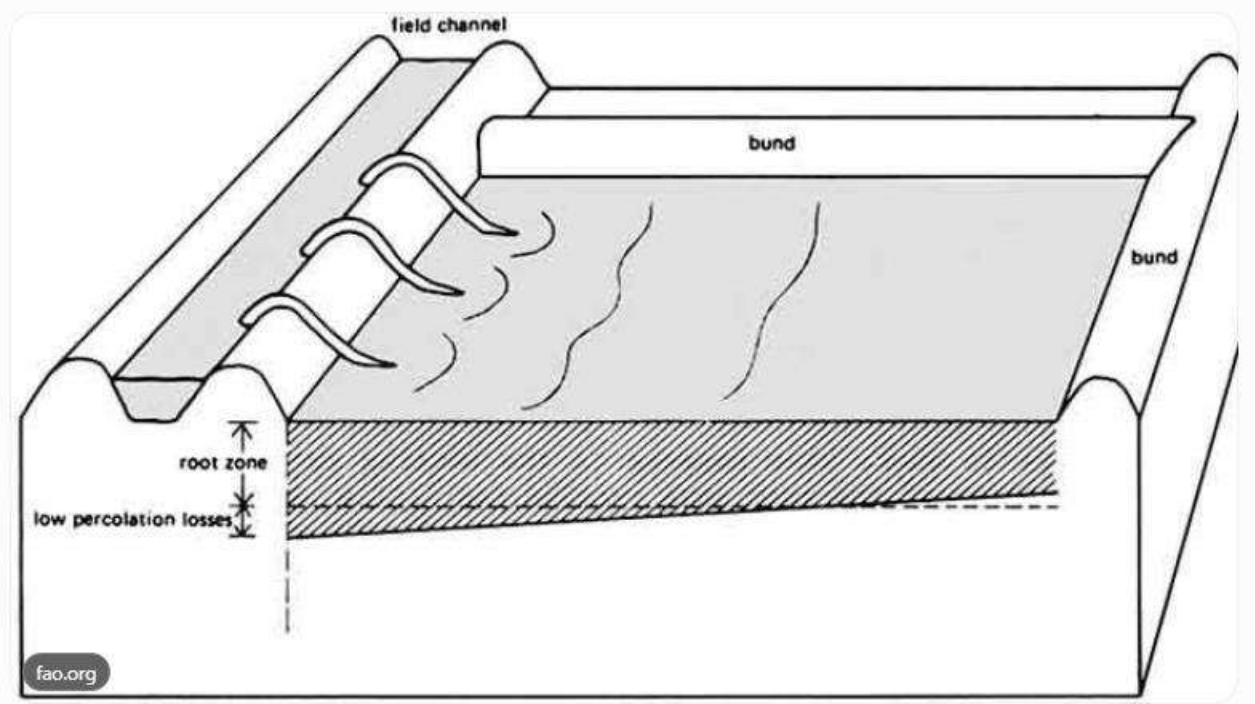
2. Bunds: Raised earth banks constructed around basins to retain water.

3. Water inlet: An opening through which water enters the basin.

4. Water supply channel: A channel that transports water from the source to the basins.

5. Outlet or drainage opening: Used to control or remove excess water where necessary.

6. Levelled soil surface: The basin should be relatively level to allow uniform distribution of water.



3.4.3 Types of basin irrigation

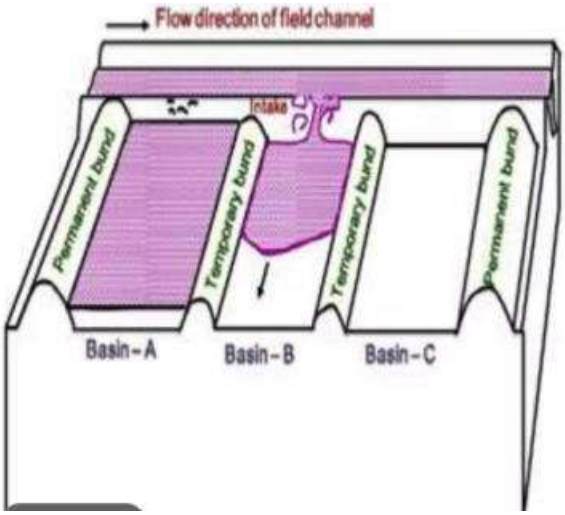
A. Check basin irrigation

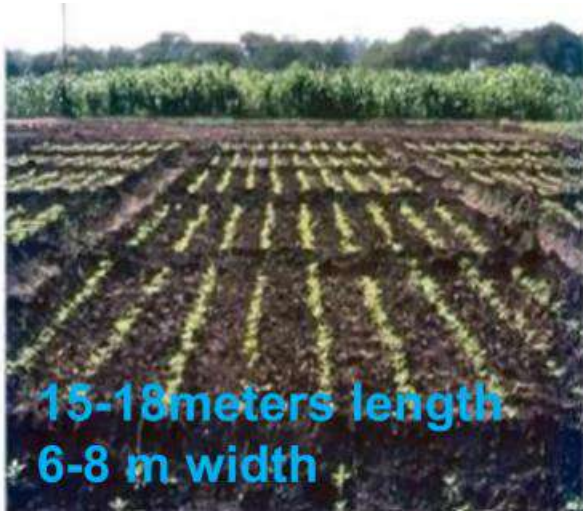
This involves dividing a field into small rectangular or square compartments surrounded by low earth embankments.

Characteristics

- The field is divided into individual basins.

- Water is introduced into each basin.
- The embankments prevent water from flowing between basins.
- Each basin is irrigated separately or through controlled inlets.



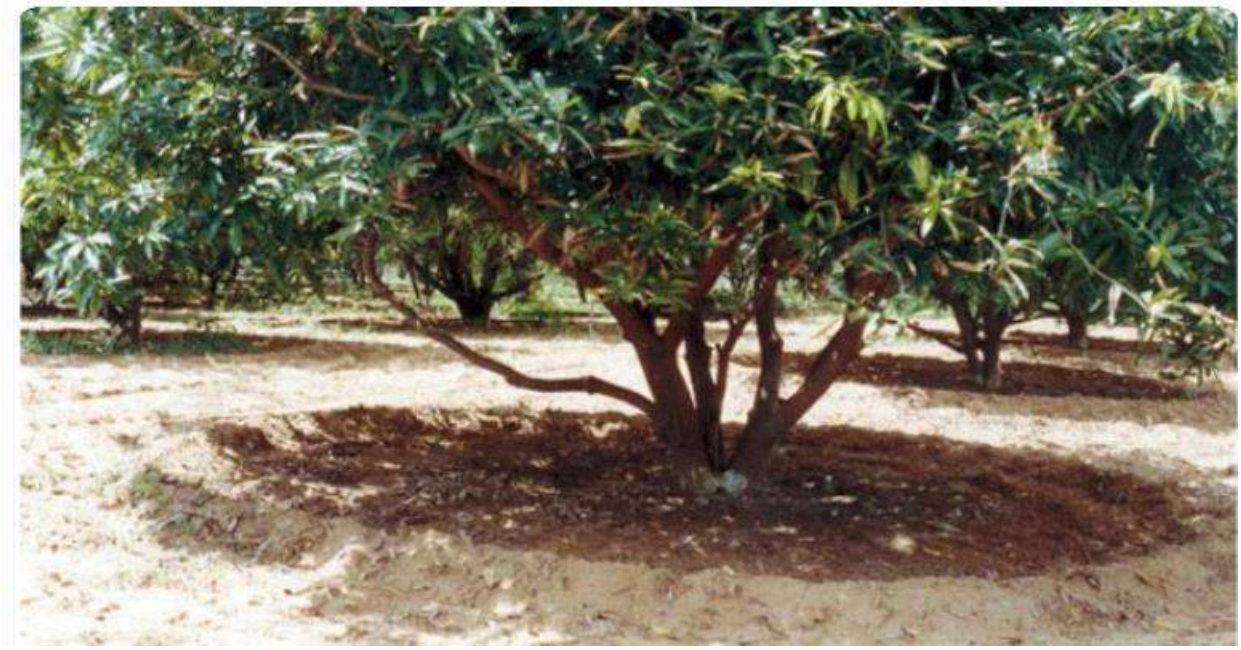


B. Ring basin irrigation

This involves constructing circular basins around individual trees to retain irrigation water near their root zones.

Characteristics

- Circular earth banks are made around trees.
- Water is applied inside the circular basin.
- The water infiltrates into the soil around the tree.
- The method is suitable for fruit trees and other widely spaced crops.



3.4.4 Procedure for carrying out basin irrigation

1. Select a suitable field with relatively level land.
2. Clear the field of weeds, stones and unwanted materials.
3. Prepare and level the soil surface.
4. Divide the field into suitable rectangular or square basins.
5. Construct earth bunds around each basin.
6. Prepare water supply channels.
7. Create inlets through which water can enter each basin.
8. Direct water into the basin.
9. Allow water to spread uniformly across the soil surface.
10. Stop water supply when the required amount has been applied.
11. Allow the water to infiltrate into the soil.
12. Inspect the bunds and repair any damaged sections.

3.4.5 Advantages of basin irrigation

1. Simple construction: Basins can be constructed using locally available materials and farm tools.

2. Low operating costs: The system may require little specialised equipment.

3. Suitable for relatively level land: Water can be distributed within individual basins.

4. Useful for rice production: It allows water to be retained in paddy fields.

5. Suitable for fruit trees: Ring basins help direct water around individual trees.

6. Controlled water application: Farmers can regulate the amount of water supplied to each basin.

7. Reduced water movement between plots: Bunds help retain water within designated sections.

8. Easy maintenance: Damaged bunds can be repaired using ordinary farm tools.

9. Suitable for small-scale farmers: It does not necessarily require expensive irrigation equipment.

10. Can support uniform crop establishment: When properly levelled and managed, basins provide relatively uniform moisture conditions.

3.4.6 Disadvantages of basin irrigation

1. Requires land levelling: Uneven land may result in unequal water distribution.

2. Waterlogging: Excessive water application may saturate the soil.

3. High water demand: Some basin systems require large quantities of water.

4. Labour requirements: Construction and maintenance of bunds require labour.

5. Limited suitability on steep slopes: Water may flow unevenly or cause erosion.

6. Soil crusting: Some soils may develop surface crusts after repeated irrigation.

7. Nutrient leaching: Excessive irrigation may wash soluble nutrients below the root zone.

8. Not suitable for all crops: Crops sensitive to prolonged waterlogging may perform poorly.

9. Weed growth: Wet soil surfaces may encourage weed germination.

3.4.7 Crops suitable for basin irrigation

- Rice.
- Some fruit trees.
- Citrus.
- Mangoes.
- Bananas, where appropriately designed.
- Certain forage crops.

Important: Rice is commonly grown using controlled basin irrigation in paddy fields. Other crops should only be irrigated in basins where soil drainage and crop water requirements permit.

3.5 FLOOD IRRIGATION

3.5.1 Meaning of flood irrigation

Flood irrigation is a surface irrigation method in which water is released and allowed to flow over a relatively large area of agricultural land, covering the soil surface before infiltrating into the ground.

The water moves across the field under the influence of gravity.

It is one of the oldest irrigation methods used in agriculture.



3.5.2 How flood irrigation works

1. Water is obtained from a river, canal, dam or other suitable source.
2. It is directed towards the agricultural field through supply channels.
3. Water is released onto the land.
4. It spreads across the soil surface under gravity.
5. Part of the water infiltrates into the soil.

6. Plant roots absorb the available moisture.
7. Excess water may flow into drainage channels or collect in low-lying areas.

3.5.3 Types of flood irrigation

A. Uncontrolled flooding

This is a method in which water is released onto agricultural land without carefully controlling its distribution across the field.

Characteristics

- Water flows freely over the land.
- There may be little or no formal field division.
- Water distribution depends largely on land slope and surface conditions.
- It may result in uneven wetting.



B. Controlled flooding

This involves regulating the amount and direction of water entering different sections of a field.

Characteristics

- Water flow is managed using channels and control structures.
- Land may be divided into sections.
- Water is directed to selected parts of the field.
- It reduces some of the wastage associated with uncontrolled flooding.



3.5.4 Advantages of flood irrigation

1. Low equipment requirements: It may operate using gravity without expensive pumping equipment where a suitable water source is available.

2. Simple operation: The method is relatively easy to understand and operate.

3. Suitable for rice production: It can maintain the water conditions required in paddy fields when properly controlled.

4. Low initial investment in simple systems: It may require fewer specialised components than pressurised irrigation.

5. Suitable for large areas: Water can be distributed across extensive fields where topography and water supply are appropriate.

6. Can recharge soil moisture: Water infiltrating into the soil increases moisture available to plants.

7. Useful where water is abundant: It can be practical where there is a reliable and sufficient water supply.

3.5.5 Disadvantages of flood irrigation

1. High water wastage: Large amounts of water may be lost through runoff and deep percolation.

2. Uneven water distribution: Higher parts of the field may receive less water than lower areas.

3. Soil erosion: Fast-moving water may remove fertile topsoil.

4. Waterlogging: Excessive water may fill soil pores and reduce oxygen availability to roots.

5. Nutrient leaching: Soluble nutrients may be carried below the root zone.

6. Salinity problems: In areas with poor drainage, salts may accumulate in the root zone.

7. Requires suitable land preparation: Uneven fields may result in poor water distribution.

8. Encourages weed growth: Water spreading over the soil surface may encourage weed germination.

9. May increase crop diseases: Prolonged wet soil conditions can favour some soil-borne diseases.

10. Difficult to control water application: It may be challenging to apply precise quantities of water.

3.5.6 Crops suitable for flood irrigation

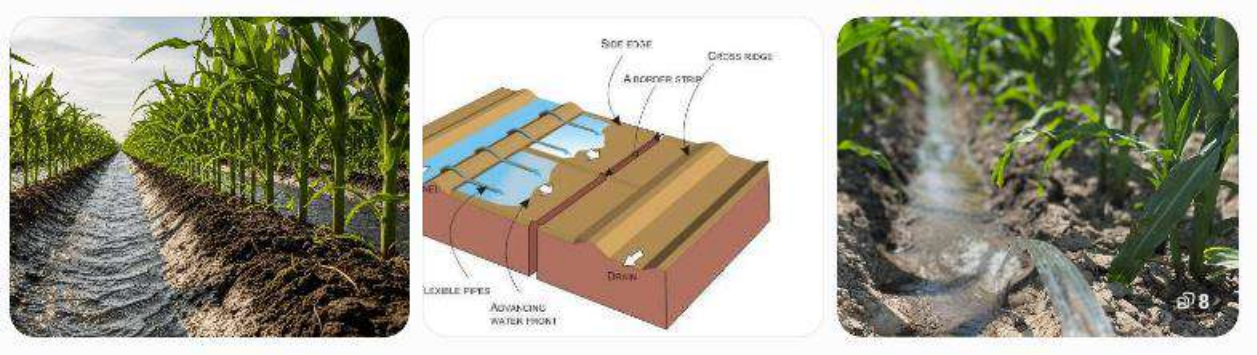
- Rice.
- Some pasture grasses.
- Certain fodder crops.
- Some crops grown on suitable level land.

Important: Flood irrigation should be properly managed to prevent water wastage, soil erosion and waterlogging.

3.6 FURROW IRRIGATION

3.6.1 Meaning of furrow irrigation

Furrow irrigation is a surface irrigation method in which water is directed through small channels called furrows constructed between crop rows.



Water flows along the furrows under gravity and infiltrates sideways and downwards into the soil, where it becomes available to plant roots.

The crops are planted on ridges or raised beds between the furrows.

3.6.2 Features of furrow irrigation

1. The field is prepared into ridges and furrows.
2. Crops are planted on the ridges or raised beds.
3. Water flows through the furrows.
4. Water infiltrates into the soil sideways and downwards.
5. Plant roots absorb water from the wetted soil.
6. Water movement is controlled by the length, slope and size of furrows.
7. Furrows may be supplied from irrigation channels or pipes.

3.6.3 Components of a furrow irrigation system

1. Water source: Supplies irrigation water.

2. Main supply channel: Transports water towards the field.

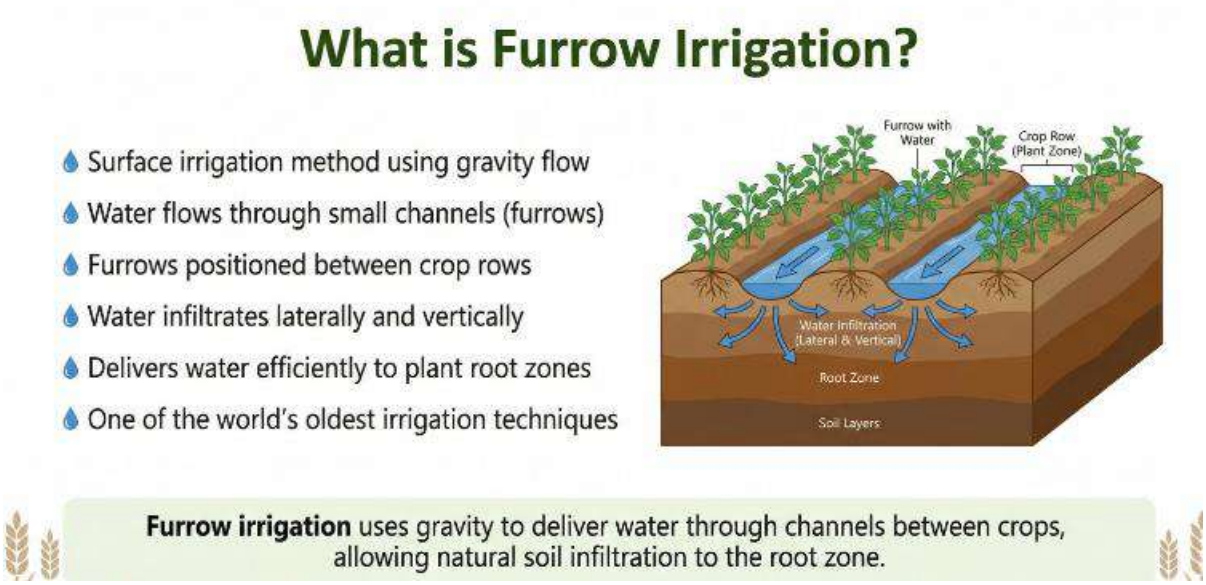
3. Field channels: Distribute water to individual furrows.

4. Furrows: Small channels through which water flows between crop rows.

5. Ridges: Raised sections of soil on which crops are planted.

6. Inlets: Openings through which water enters the furrows.

7. Drainage channels: Remove excess water where necessary.



3.6.4 Procedure for carrying out furrow irrigation

1. Select a suitable field with a gentle and uniform slope.
2. Clear the land and prepare it for cultivation.
3. Plough and harrow the soil.
4. Construct ridges and furrows using suitable farm equipment.
5. Plant crops on the ridges or raised beds.
6. Prepare a water supply channel.
7. Direct water into the furrows.
8. Allow water to flow along the furrows.
9. Monitor the movement of water to prevent excessive runoff.
10. Stop water application when sufficient water has infiltrated into the root zone.
11. Inspect the furrows for blockages and erosion.
12. Repair damaged channels when necessary.

3.6.5 Advantages of furrow irrigation

1. Economical water use: Water is directed through channels between crop rows rather than covering the entire soil surface.

2. Reduced foliage wetting: Water is supplied mainly through the soil, reducing direct wetting of leaves.

3. Simple construction: Furrows can be constructed using ordinary farm tools or ridging equipment.

4. Low equipment costs: Simple furrow systems may operate without expensive irrigation machinery.

5. Suitable for row crops: It is particularly useful for crops planted in rows.

6. Reduced soil disturbance: Crops grow on ridges while water moves through the furrows.

7. Suitable for gravity irrigation: It can operate without pumps where the water source is at a suitable elevation.

8. Allows intercultural operations: Weeding and other field operations can be carried out on the ridges.

9. Reduced direct contact between water and plant stems: This may reduce some diseases associated with prolonged stem wetting.

10. Can be adapted to different farm sizes: Furrows can be constructed for both small and relatively large fields.

3.6.6 Disadvantages of furrow irrigation

1. Soil erosion: Fast-moving water may erode furrow sides and bottoms.

2. Uneven water distribution: The upper and lower ends of a furrow may receive different amounts of water.

3. Requires proper land preparation: Incorrect furrow construction may result in water wastage.

4. Waterlogging: Excessive irrigation may saturate the soil.

5. Nutrient leaching: Excess water may move nutrients below the root zone.

6. Labour requirements: Construction and maintenance of furrows may require considerable labour.

7. Limited suitability on steep slopes: Water may flow too rapidly, causing erosion.

8. Not suitable for all crops: Crops requiring uniform surface wetting may be less suitable.

9. Maintenance costs: Furrows may need repeated repair after heavy rainfall or cultivation.

3.6.7 Crops suitable for furrow irrigation

- Maize.
- Potatoes.
- Tomatoes.
- Sugarcane.
- Cotton.
- Onions.
- Groundnuts.
- Some legumes.

4.0 COMPARISON OF THE FIVE METHODS OF IRRIGATION

The different irrigation methods vary in the way water is delivered, their water requirements, installation costs and suitability for different crops.

4.1 Comparison table

Feature	Sprinkler	Drip	Basin	Flood	Furrow
Water application	Artificial rainfall	Directly to root zone	Enclosed plots	Over field surface	Through channels
Pressure requirement	Usually high	Low to moderate	Usually gravity	Usually gravity	Usually gravity
Land levelling	Less extensive	Less extensive	Important	Important	Important
Water efficiency	Moderate to high	Generally very high	Variable	Generally low	Moderate
Installation cost	Moderate to high	Moderate to high	Low to moderate	Low in simple systems	Low to moderate
Main equipment	Pipes and sprinklers	Pipes and emitters	Bunds and channels	Supply and drainage channels	Ridges and furrows
Foliage wetting	Yes	Minimal	Usually no direct spraying	Usually no direct spraying	Usually no direct spraying
Suitable examples	Vegetables and pasture	Tomatoes and fruits	Rice and fruit trees	Rice and suitable pasture	Maize and potatoes

Water-use efficiency and costs depend on design, maintenance, soil, climate and water supply.

4.2 Differences between sprinkler and drip irrigation

Sprinkler irrigation	Drip irrigation
Water is sprayed into the air.	Water is released slowly through emitters.
Wets a relatively large soil area.	Wets selected areas around the roots.
May wet plant leaves.	Normally avoids wetting most foliage.
More affected by wind.	Less affected by wind.
Evaporation may occur during spraying.	Evaporation losses are generally lower.
Suitable for many field crops.	Particularly suitable for horticultural crops and orchards.

4.3 Differences between basin and furrow irrigation

Basin irrigation	Furrow irrigation
Water is retained within enclosed plots.	Water flows through channels between crop rows.
Requires bund construction.	Requires ridge and furrow construction.
Water covers most of the basin surface.	Water mainly covers the furrow.
Suitable for rice and some fruit trees.	Suitable for maize, potatoes and other row crops.
Requires relatively level basins.	Requires suitable furrow slope and alignment.

4.4 Selecting the most appropriate irrigation method

A farmer should consider the following factors before choosing an irrigation system.

1. Availability of water

- Drip irrigation is useful where water is limited.
- Flood irrigation may be practical where water is abundant and land conditions are suitable.
- Sprinkler systems require a reliable water supply.

2. Type of crop

- Drip irrigation is suitable for tomatoes and capsicum.
- Furrow irrigation is suitable for maize and potatoes.
- Basin irrigation is suitable for rice and certain fruit trees.
- Sprinkler irrigation is suitable for vegetables and pasture.

3. Soil texture

- Sandy soils have high infiltration rates and low water-holding capacity; frequent, controlled irrigation may be necessary.
- Clay soils have lower infiltration rates and may require slower water application.
- Loamy soils generally have balanced water-holding and drainage properties.

4. Land topography

- Drip and sprinkler irrigation can be designed for gently sloping land.
- Basin irrigation requires relatively level land.
- Furrow irrigation requires suitable slope and field alignment.
- Flood irrigation is most practical on appropriately levelled land.

5. Installation costs

- Simple surface irrigation systems may require relatively low initial investment.

- Drip and sprinkler systems require pipes and other specialised equipment.
- The farmer should compare installation costs with expected production benefits.

6. Availability of labour

- Some surface irrigation methods require considerable manual labour.
- Automated drip and sprinkler systems may reduce routine labour requirements.
- Maintenance skills should also be considered.

7. Quality of irrigation water

- Water containing suspended particles requires filtration in drip and sprinkler systems.
- Saline water may cause soil and crop problems.
- Water quality should be tested before use.

5.0 EFFICIENT APPROACHES TO IRRIGATION IN CROP PRODUCTION

5.1 Meaning of efficient irrigation

Efficient irrigation refers to the application and management of water in a way that meets crop water requirements while minimising water losses, energy use and environmental damage.

It involves ensuring that the correct quantity of water reaches the crop root zone at the appropriate time.

Efficient irrigation is important because water is a limited natural resource, and poor irrigation practices may result in wastage, soil degradation and reduced crop productivity.

5.2 Characteristics of an efficient irrigation system

An efficient irrigation system should:

1. Supply adequate water to the crop root zone.
2. Minimise water losses through evaporation.
3. Reduce water losses through surface runoff.
4. Minimise deep percolation below the root zone.
5. Distribute water uniformly.
6. Allow farmers to control the amount of water applied.
7. Reduce unnecessary wetting of non-cropped areas.
8. Be affordable to operate and maintain.
9. Prevent waterlogging and soil erosion.
10. Support sustainable crop production.

5.3 Approaches to improving irrigation efficiency

1. Using drip irrigation



- Drip irrigation supplies water directly to the crop root zone.
- It reduces evaporation from exposed soil surfaces.
- It minimises unnecessary wetting between crop rows.
- It reduces water losses through runoff.
- It enables farmers to apply small quantities of water regularly.
- It is particularly useful in water-scarce areas.

2. Irrigating at the correct time

- Irrigation should be carried out when crops need water.
- Early morning and late afternoon are generally suitable periods.
- Irrigating during very hot and windy conditions may increase water losses.
- Farmers should avoid unnecessary irrigation when rainfall has adequately supplied soil moisture.

Example: A tomato farmer should monitor soil moisture and irrigate when the root zone requires additional water rather than following an unnecessary daily watering routine.

3. Applying the correct quantity of water

- Crops require different amounts of water depending on their species and growth stages.
- Excessive irrigation causes water wastage.
- Insufficient irrigation leads to water stress.

- Farmers should determine suitable irrigation amounts based on crop water requirements and soil conditions.

4. Mulching

Mulching is the practice of covering the soil surface around crops with suitable materials to reduce moisture loss and improve soil conditions.





Materials used for mulching

- Dry grass.
- Straw.
- Crop residues.
- Dry leaves.
- Wood chips.
- Plastic mulch sheets.

How mulching conserves irrigation water

1. Reduces direct exposure of soil to sunlight.
2. Reduces evaporation from the soil surface.
3. Maintains soil moisture for longer periods.
4. Reduces weed growth and competition for water.
5. Improves soil structure when organic materials decompose.
6. Reduces the frequency of irrigation.
7. Protects the soil against erosion.

5. Repairing leaking irrigation pipes

- Farmers should inspect irrigation pipes regularly.
- Damaged pipes should be repaired immediately.
- Loose joints should be tightened.
- Faulty valves should be replaced.

- Leaking connections should be sealed properly.

Importance: This prevents unnecessary water losses before water reaches the crops.

6. Using soil moisture monitoring equipment

Soil moisture monitoring involves determining the amount of water present in the soil to guide irrigation decisions.





Examples of soil moisture monitoring equipment

- Soil moisture meters.
- Tensiometers.
- Capacitance sensors.
- Time-domain reflectometry (TDR) sensors.

Importance

1. Helps determine when crops require irrigation.
2. Prevents unnecessary watering.
3. Reduces water wastage.
4. Helps prevent waterlogging.
5. Improves irrigation scheduling.
6. Supports better crop water management.

7. Rainwater harvesting

Rainwater harvesting is the collection and storage of rainwater for future agricultural use.





Methods of harvesting rainwater

1. Roof catchment systems.
2. Water pans.
3. Farm ponds.
4. Storage tanks.
5. Earth dams.
6. Collection from suitable runoff channels.

How rainwater harvesting improves irrigation efficiency

- Provides additional water during dry periods.
- Reduces dependence on rivers and boreholes.
- Makes use of rainfall that would otherwise be lost as runoff.
- Supports irrigation during critical crop growth stages.
- Improves the reliability of agricultural water supply.

8. Proper land levelling

- Land should be levelled appropriately before surface irrigation.
- It helps water move uniformly across the field.
- It reduces the formation of dry and excessively wet patches.
- It minimises water accumulation in low-lying sections.
- It improves water distribution.

9. Constructing terraces and contour structures



- Terraces reduce the speed of surface runoff.
- Contour structures help retain water within agricultural land.
- They reduce soil erosion.
- They improve water infiltration.
- They help conserve soil moisture in sloping areas.

10. Using suitable irrigation equipment

- Farmers should select equipment appropriate for the crop and field.
- Efficient pumps reduce unnecessary energy consumption.
- Suitable emitters improve water distribution.
- Properly designed pipes minimise leakage.
- Filters prevent blockage of irrigation outlets.

11. Applying water according to crop growth stages

Different crop growth stages have different water requirements.

For example, maize requires adequate moisture during:

1. Germination and emergence.
2. Early vegetative growth.
3. Rapid stem and leaf development.
4. Tasselling and silking.
5. Grain filling.

Water shortage during flowering and grain formation may cause significant yield losses.

12. Using suitable irrigation schedules

An irrigation schedule is a plan showing when and how much water should be applied to crops.

Farmers should consider:

- Crop type.
- Crop growth stage.
- Soil moisture.
- Rainfall received.
- Weather conditions.
- Soil texture.
- Irrigation system capacity.

A suitable irrigation schedule prevents both over-irrigation and under-irrigation.

6.0 CROP WATER REQUIREMENTS

6.1 Meaning of crop water requirement

Crop water requirement refers to the amount of water needed by a crop to support its normal growth and development during a particular growing period.

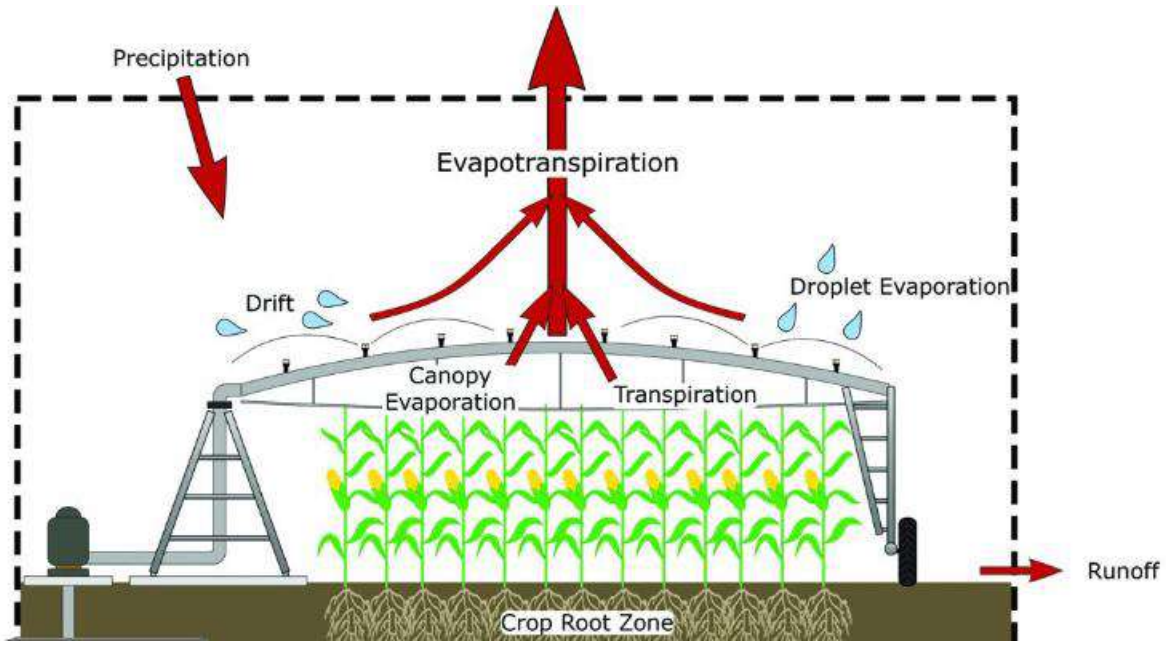
It includes water lost through transpiration and evaporation from the soil surface, collectively referred to as evapotranspiration.

The amount of water required varies according to:

1. Crop species.
2. Crop variety.
3. Stage of crop growth.
4. Temperature.
5. Relative humidity.
6. Wind speed.
7. Solar radiation.
8. Soil type.
9. Rainfall received.
10. Plant population.

6.2 Meaning of evapotranspiration

Evapotranspiration is the combined process of water loss through evaporation from soil and other wet surfaces and transpiration from plants.



A. Evaporation

Evaporation is the process through which liquid water changes into water vapour and escapes from the soil, water bodies or wet plant surfaces into the atmosphere.

Examples:

- Water evaporating from a wet soil surface.
- Water evaporating from an irrigation channel.
- Water evaporating from wet crop leaves.

B. Transpiration

Transpiration is the process through which plants lose water vapour into the atmosphere, mainly through stomata in their leaves.

Importance of transpiration

1. Helps regulate plant temperature.
2. Supports the movement of water through plants.
3. Facilitates the transport of dissolved mineral nutrients.
4. Maintains water movement from roots to leaves.
5. Supports normal plant physiological activities.

6.3 Factors affecting crop water requirements

1. Crop type

Different crops require different quantities of water.

For example:

- Rice requires relatively high water supply under paddy cultivation.
- Cactus requires relatively little water.
- Tomatoes require adequate moisture throughout active growth.

2. Stage of growth

Water requirements change as crops develop.

- Germinating seeds require adequate moisture.
- Young seedlings require regular moisture.
- Flowering crops may be sensitive to water shortages.
- Developing fruits and grains require adequate water.

3. Temperature

- High temperatures increase evaporation and transpiration.
- Crops may therefore require more frequent irrigation during hot periods.

- Low temperatures generally reduce atmospheric water demand.

4. Wind speed

- Strong winds increase the movement of water vapour away from plant surfaces.
- This may increase transpiration.
- Wind can also increase evaporation losses from sprinkler irrigation.

5. Relative humidity

- Low relative humidity increases the rate of water loss from plants.
- High relative humidity generally reduces transpiration.

6. Soil texture

- Sandy soils drain quickly and retain relatively little water.
- Clay soils retain more water but may have poor drainage.
- Loamy soils generally have balanced water retention and drainage.

7. Rainfall

- Adequate rainfall reduces the amount of supplementary irrigation required.
- Insufficient rainfall increases dependence on irrigation.

8. Plant population

- High plant populations may increase the total water demand of a field.
- The amount of water required depends on crop density and growth characteristics.

6.4 Signs of water deficiency in crops





1. Wilting of leaves and stems.
2. Leaf rolling in crops such as maize.
3. Yellowing of leaves.
4. Premature leaf shedding.
5. Stunted plant growth.
6. Poor flowering.

7. Flower and fruit abortion.
8. Poor fruit development.
9. Reduced grain filling.
10. Premature crop maturity.
11. Reduced crop yields.
12. In severe cases, death of plants.

6.5 Effects of excessive irrigation





1. Causes waterlogging.
2. Reduces oxygen availability in the root zone.
3. Interferes with root respiration.
4. Promotes some root diseases.
5. Causes nutrient leaching.
6. May result in soil erosion.
7. May encourage weed growth.
8. Can cause nutrient imbalance.
9. May lead to salt accumulation under certain conditions.
10. Increases production costs through unnecessary water use.

7.0 IRRIGATION WATER CONSERVATION PRACTICES

Water conservation involves protecting water resources and using available water responsibly to ensure continued agricultural production and environmental sustainability.

7.1 Practices used to conserve water during irrigation

1. Drip irrigation

- Directs water to plant roots.
- Reduces evaporation.
- Minimises runoff.
- Allows controlled application.

2. Mulching

- Covers the soil surface.
- Reduces evaporation.
- Maintains soil moisture.
- Reduces weed competition.

3. Irrigation scheduling

- Prevents unnecessary irrigation.
- Matches water application with crop requirements.
- Reduces excessive water use.

4. Rainwater harvesting

- Collects water during rainy periods.
- Stores water for use during dry seasons.
- Reduces dependence on other water sources.

5. Proper maintenance of irrigation systems

- Prevents leakage.
- Improves water distribution.
- Reduces equipment breakdown.
- Prevents unnecessary water losses.

6. Conservation tillage

Conservation tillage involves reducing soil disturbance during land preparation and cultivation.

How it conserves water

1. Reduces excessive soil exposure.
2. Helps maintain crop residues on the soil surface.
3. Reduces evaporation.
4. Improves soil structure over time.
5. Reduces surface runoff.
6. Promotes water infiltration.

7. Planting cover crops

Cover crops are plants grown mainly to protect and improve the soil rather than for direct harvesting.

Examples

- Mucuna.
- Sunn hemp.
- Suitable clover species.
- Cowpeas.
- Other locally adapted cover crops.

Importance

1. Protect the soil surface.
2. Reduce direct evaporation.
3. Reduce soil erosion.
4. Improve soil structure.
5. Add organic matter when incorporated or left as residues.

8. Constructing water storage facilities

- Farm ponds store water for future irrigation.
- Water pans collect surface runoff.
- Tanks store harvested rainwater.
- Small reservoirs improve water availability during dry periods.

9. Avoiding irrigation during strong winds

- Strong winds may increase evaporation.
- They may cause uneven sprinkler distribution.
- Irrigating under calmer conditions improves application efficiency.

10. Controlling weeds

- Weeds compete with crops for available soil moisture.
- Timely weeding reduces unnecessary water consumption.
- Maintaining appropriate weed control improves crop water availability.

11. Using appropriate irrigation quantities

- Avoid excessive watering.
- Consider soil moisture before irrigating.

- Apply water according to crop needs.
- Avoid repeated irrigation when the soil already contains sufficient moisture.

12. Recycling suitable irrigation drainage water

- Drainage water may sometimes be collected and reused.
- Its suitability should be assessed before reuse.
- Salinity, pathogens and chemical contaminants must be considered.
- Appropriate treatment and management may be required.

8.0 IRRIGATION WATER MANAGEMENT

8.1 Meaning of irrigation water management

Irrigation water management refers to the planning, control and monitoring of water application to ensure that crops receive adequate moisture while minimising wastage and environmental damage.

It involves managing the water source, irrigation equipment, application time and quantity of water supplied.

8.2 Principles of good irrigation water management

1. Understand the water requirements of crops.
2. Determine the water-holding capacity of the soil.
3. Monitor soil moisture regularly.
4. Apply water at the appropriate crop growth stages.
5. Use suitable irrigation equipment.
6. Avoid excessive irrigation.
7. Maintain irrigation channels and pipes.
8. Prevent soil erosion.
9. Monitor water quality.
10. Keep irrigation records.
11. Protect water sources from contamination.
12. Maintain proper field drainage.

8.3 Irrigation scheduling

Irrigation scheduling is the process of deciding when to irrigate crops and the amount of water to apply.

It helps farmers avoid applying water either too early or too late.

Methods of determining when to irrigate

A. Soil observation

- Farmers examine the soil to determine its moisture condition.

- Dry and loose soil may indicate the need for irrigation.
- Moist soil may not require immediate watering.

B. Feel-and-appearance method

- A small quantity of soil is collected from the root zone.
- The soil is squeezed between the fingers.
- Its moisture condition is assessed through texture and appearance.
- Different soil textures require different interpretations.

C. Soil moisture meters

- These instruments measure soil moisture.
- They provide information for irrigation decisions.
- They reduce reliance on guesswork.

D. Weather-based scheduling

- Farmers consider rainfall, temperature, humidity and wind.
- High temperatures and low humidity may increase crop water demand.
- Recent rainfall may reduce irrigation requirements.

E. Crop observation

- Farmers observe signs of water stress.
- Leaf rolling and wilting may indicate insufficient water.
- However, waiting until severe wilting occurs may already expose crops to harmful water stress.

8.4 Steps in preparing an irrigation schedule

1. Identify the crop being grown.
2. Determine the crop growth stage.
3. Establish the soil type.
4. Assess soil moisture.
5. Consider recent rainfall.
6. Examine weather conditions.
7. Estimate crop water requirements.
8. Determine the appropriate irrigation method.
9. Calculate the amount of water to apply.
10. Decide the irrigation frequency.
11. Apply water.

12. Monitor the crop response and adjust the schedule.

8.5 Importance of irrigation scheduling

1. Prevents unnecessary water application.
2. Reduces irrigation costs.
3. Improves crop water availability.
4. Reduces waterlogging.
5. Prevents excessive nutrient leaching.
6. Improves crop growth.
7. Promotes uniform crop development.
8. Improves water-use efficiency.
9. Supports sustainable water management.
10. Helps farmers plan irrigation activities.

9.0 IRRIGATION WATER QUALITY

9.1 Meaning of irrigation water quality

Irrigation water quality refers to the suitability of water for agricultural use based on its physical, chemical and biological properties.

Water quality is important because unsuitable irrigation water may affect soil fertility, crop growth and human health.

9.2 Characteristics of good-quality irrigation water

Suitable irrigation water should generally:

1. Have acceptable salinity levels.
2. Contain low concentrations of harmful substances.
3. Have suitable pH.
4. Have acceptable sodium levels.
5. Be free from harmful pathogens where food safety is concerned.
6. Contain minimal suspended particles that may block irrigation equipment.
7. Be suitable for the crops and soil where it is applied.

9.3 Problems associated with poor-quality irrigation water

A. Salinity

Salinity refers to the accumulation of soluble salts in soil or irrigation water.

Effects

1. Makes water absorption difficult for plants.
2. Causes physiological drought.
3. Reduces seed germination.
4. Causes leaf scorching in sensitive crops.
5. Reduces crop yields.
6. May result in poor soil conditions.

B. Sodicity

Sodicity refers to excessive exchangeable sodium in the soil.

Effects

1. Causes soil particles to disperse.
2. Reduces soil aggregation.
3. Causes poor water infiltration.
4. Reduces soil aeration.
5. Restricts root development.
6. May cause surface crusting.

C. Chemical contamination

- Some water sources may contain harmful industrial chemicals.
- Contaminated water may affect crops.
- Some contaminants may accumulate in soils or harvested produce.
- Appropriate water testing and treatment are necessary.

D. Biological contamination

- Untreated wastewater may contain disease-causing organisms.
- Contaminated irrigation water may pose risks to farm workers and consumers.
- Water used on food crops must meet relevant safety requirements.

9.4 Ways of maintaining irrigation water quality

1. Protect rivers and dams from pollution.
2. Prevent direct disposal of chemicals into water sources.
3. Test water before using it for irrigation.
4. Use suitable filters.
5. Maintain storage tanks.
6. Prevent livestock contamination of water sources.
7. Use treated wastewater that meets applicable standards.
8. Monitor soil salinity.
9. Maintain suitable drainage.
10. Follow relevant environmental and public health guidelines.

10.0 PRACTICAL LEARNING ACTIVITIES

These activities enable learners to acquire practical irrigation skills through observation, experimentation, demonstration and collaboration.

10.1 Practical activity: Demonstrating drip irrigation



Learning objective: To demonstrate how water can be supplied directly to the root zone of crops while minimising wastage.

Materials required

1. Plastic water bottles.
2. Small containers.

3. Water.
4. Nails or suitable hole-making equipment.
5. Scissors.
6. Small garden plants.
7. Soil.
8. Measuring container.

Procedure

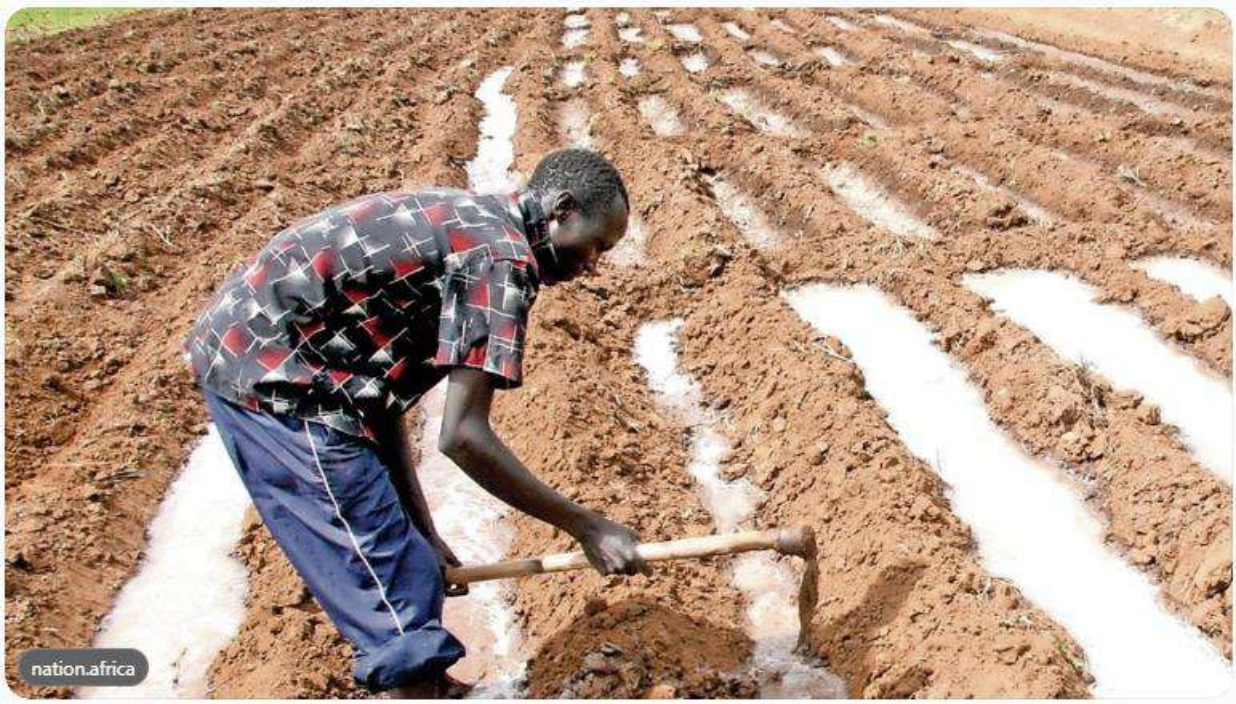
1. Obtain clean plastic bottles.
2. Make small holes in the bottle cap or use a suitable drip outlet.
3. Fill the bottle with water.
4. Position the bottle close to the plant root zone.
5. Allow water to drip slowly into the soil.
6. Observe the area wetted by the water.
7. Compare the amount of water used with ordinary surface watering.
8. Record the observations.

Expected learning outcomes

Learners should be able to:

- Explain how drip irrigation operates.
- Demonstrate water application near plant roots.
- Identify ways of reducing irrigation water wastage.
- Explain the importance of controlled water application.

10.2 Practical activity: Constructing a simple furrow irrigation system



Materials required

- Garden space.
- Jembe.
- Watering can.
- Measuring tape.
- Seeds or seedlings.
- String.

Procedure

1. Select a suitable garden site.
2. Clear the land.
3. Measure and mark the garden.
4. Prepare ridges and furrows.
5. Plant suitable crops on the ridges.
6. Pour water into the furrows.
7. Observe how water moves along the furrows.
8. Examine the soil moisture around the crop roots.
9. Record the observations.

Expected learning outcomes

Learners should be able to:

- Construct simple irrigation furrows.
- Explain how water moves through furrows.
- Identify crops suitable for furrow irrigation.
- Demonstrate controlled water application.

10.3 Practical activity: Comparing different irrigation methods

Objective: To investigate the differences in water application among sprinkler, drip, basin and furrow irrigation.

Requirements

- Four small garden plots or containers.
- Watering can.
- Plastic bottles.
- Small sprinkler.
- Measuring container.
- Soil.
- Suitable crop seedlings.

Procedure

1. Prepare four similar plots.
2. Label each plot according to the irrigation method.
3. Set up drip irrigation in the first plot.
4. Demonstrate sprinkler irrigation in the second plot.
5. Construct a basin in the third plot.
6. Construct furrows in the fourth plot.
7. Apply measured quantities of water.
8. Observe water distribution and soil wetting.
9. Compare water runoff and water losses.
10. Discuss the most appropriate method for conserving water under the conditions observed.

Sample observation table

Irrigation method	Water distribution	Main observation
Drip	Near plant roots	Localised wetting
Sprinkler	Over the soil and foliage	Artificial rainfall
Basin	Within enclosed plots	Water retained by bunds
Furrow	Along channels	Sideways infiltration

10.4 Practical activity: Investigating the effect of mulching on soil moisture

Objective: To establish how mulching helps conserve irrigation water.

Requirements

- Two similar planting containers.
- Similar quantities of soil.
- Dry grass or straw.
- Water.
- Measuring cylinder.
- Small seedlings.

Procedure

1. Fill two containers with equal quantities of similar soil.
2. Plant similar seedlings in both containers.
3. Cover the soil surface of one container with dry grass.
4. Leave the other container uncovered.
5. Apply equal quantities of water.
6. Place the containers under similar environmental conditions.
7. Observe soil moisture after a given period.
8. Compare the moisture conditions.
9. Record the observations.
10. Explain the importance of mulching in water conservation.

Expected conclusion: Mulching reduces direct evaporation from the soil surface and can help maintain soil moisture for longer periods.

10.5 Practical activity: Designing an irrigation system for a school farm

Learning objective: To enable learners to select an appropriate irrigation method for a given agricultural situation.

Procedure

1. Visit the school farm.
2. Identify the crops grown or intended for planting.
3. Examine the soil type.
4. Assess the slope of the land.
5. Identify available water sources.
6. Discuss the cost of different irrigation systems.
7. Select an appropriate irrigation method.
8. Draw a simple diagram of the proposed irrigation system.
9. Present the proposed design to the class.
10. Explain how the system will conserve water.

Expected learning outcomes

Learners should demonstrate:

- Decision-making skills.
- Problem-solving skills.
- Creativity.
- Collaboration.
- Environmental responsibility.

KEY AGRICULTURAL TERMS AND DEFINITIONS

Term	Meaning
Irrigation	Artificial application of water to agricultural land
Irrigation efficiency	Effectiveness of an irrigation system in delivering and using water
Drip irrigation	Supplying water slowly to plant root zones through emitters
Sprinkler irrigation	Applying water as artificial rainfall using sprinkler heads
Basin irrigation	Applying water to enclosed plots surrounded by bunds
Flood irrigation	Allowing water to flow over a relatively large soil surface
Furrow irrigation	Supplying water through channels between crop rows
Irrigation scheduling	Planning when and how much water to apply
Evaporation	Conversion of liquid water into water vapour
Transpiration	Loss of water vapour from plants, mainly through stomata
Evapotranspiration	Combined water loss through evaporation and transpiration
Waterlogging	Condition in which soil becomes excessively saturated with water
Mulching	Covering the soil surface with suitable materials to conserve moisture
Emitter	An outlet through which water is released in a drip irrigation system
Sprinkler head	A device that distributes water in the form of droplets
Fertigation	Application of fertiliser through irrigation water
Soil moisture	Water present in the soil
Water infiltration	Entry of water into the soil surface
Percolation	Downward movement of water through soil layers
Runoff	Water flowing over the soil surface
Salinity	Accumulation of soluble salts in soil or water
Sodicity	Excessive exchangeable sodium in soil
Water conservation	Responsible management and protection of water resources
Water-use efficiency	The effectiveness with which water is used to support crop production

ASSESSMENT AND REVISION

STRAND 1.0: CROP PRODUCTION

SUB-STRAND 1.2: WATER CONSERVATION – IRRIGATION

SECTION A: MULTIPLE-CHOICE QUESTIONS

Choose the correct answer in each question.

1. Which one of the following best describes irrigation in crop production?

A. Application of artificial fertilisers to crops.

B. Artificial application of water to agricultural land.

C. Removal of excess vegetation from a farm.

D. Application of pesticides to crops.

2. A farmer wants to supply water directly to the root zone of tomato plants while minimising evaporation. Which irrigation method would be most appropriate?

A. Flood irrigation.

B. Basin irrigation.

C. Drip irrigation.

D. Uncontrolled flooding.

3. Which component of a sprinkler irrigation system breaks water into small droplets?

A. Main pipe.

B. Sprinkler nozzle.

C. Water tank.

D. Control valve.

4. A farmer divides a field into small rectangular sections surrounded by raised earth banks. Which irrigation method is being prepared?

A. Sprinkler irrigation.

B. Drip irrigation.

C. Basin irrigation.

D. Furrow irrigation.

5. Which one of the following is a major advantage of sprinkler irrigation?

A. It requires no water pressure.

B. It distributes water in the form of artificial rainfall.

C. It prevents all evaporation losses.

D. It only wets the roots of individual plants.

6. Which component of a drip irrigation system removes suspended particles from water?

A. Emitter.

B. Filter.

C. Lateral pipe.

D. Pressure regulator.

7. A farmer constructs small channels between crop rows and directs water along them. Which irrigation method is being used?

A. Basin irrigation.

B. Furrow irrigation.

C. Sprinkler irrigation.

D. Drip irrigation.

8. Which one of the following crops is commonly grown under controlled basin irrigation?

A. Rice.

B. Cactus.

C. Sisal.

D. Aloe vera.

9. Which irrigation method is most likely to experience uneven water distribution due to strong winds?

A. Drip irrigation.

B. Basin irrigation.

C. Sprinkler irrigation.

D. Furrow irrigation.

10. Why is filtration important in drip irrigation?

A. It increases soil acidity.

B. It prevents emitters from becoming blocked.

C. It increases water evaporation.

D. It prevents plant transpiration.

11. Which one of the following practices helps reduce evaporation from the soil surface?

A. Mulching.

B. Excessive tillage.

C. Uncontrolled flooding.

D. Burning crop residues.

12. A farmer applies fertiliser through a drip irrigation system. Which practice is being carried out?

A. Broadcasting.

B. Fertigation.

C. Flooding.

D. Top-dressing.

13. Which one of the following is a disadvantage of flood irrigation?

A. It requires specialised emitters.

B. It may result in excessive water wastage.

C. It cannot supply water to the soil.

D. It requires artificial rainfall.

14. Which factor should be considered when selecting an irrigation method?

A. Colour of farm buildings.

B. Type of crop grown.

C. Number of farm visitors.

D. Size of the farmer's house.

15. What is the main function of a bund in basin irrigation?

A. To increase water evaporation.

B. To prevent water from flowing out of the basin.

C. To spray water over crops.

D. To filter irrigation water.

16. Which one of the following practices is most suitable for determining when crops require irrigation?

A. Guessing according to the calendar.

B. Monitoring soil moisture.

C. Applying water every hour.

D. Waiting until all leaves dry.

17. The combined loss of water through evaporation and transpiration is referred to as:

A. Infiltration.

B. Percolation.

C. Evapotranspiration.

D. Runoff.

18. Which one of the following is a major effect of excessive irrigation?

A. Improved soil aeration in all cases.

B. Waterlogging.

C. Elimination of all soil diseases.

D. Complete prevention of nutrient leaching.

19. A farmer installs a water storage tank to collect rainwater from the roof of a farm building. Which conservation practice is being used?

A. Waterlogging.

B. Rainwater harvesting.

C. Uncontrolled flooding.

D. Excessive irrigation.

20. Which irrigation method is generally most appropriate where water is scarce and targeted delivery to crop roots is required?

A. Uncontrolled flood irrigation.

B. Drip irrigation.

C. Uncontrolled basin irrigation.

D. Surface flooding.

SECTION B: STRUCTURED QUESTIONS

21.

a) Define irrigation. (2 marks)

b) State five sources of water used for irrigation in crop production. (5 marks)

c) Explain six benefits of irrigation in crop production. (6 marks)

d) State four factors that influence the selection of an irrigation method. (4 marks)

22.

a) Define sprinkler irrigation. (2 marks)

b) Identify five components of a sprinkler irrigation system. (5 marks)

c) Explain five advantages of sprinkler irrigation. (5 marks)

d) Explain four disadvantages of sprinkler irrigation. (4 marks)

23.

a) Define drip irrigation. (2 marks)

b) Identify six components of a drip irrigation system. (6 marks)

c) Explain five ways in which drip irrigation helps conserve water. (5 marks)

d) State three limitations of drip irrigation. (3 marks)

24.

a) Differentiate between basin irrigation and furrow irrigation. (4 marks)

b) Describe the procedure for carrying out basin irrigation. (6 marks)

c) Explain five advantages of furrow irrigation. (5 marks)

d) State five disadvantages of flood irrigation. (5 marks)

25.

a) Define the term irrigation water conservation. (2 marks)

b) Explain six practices farmers can use to conserve water during irrigation. (6 marks)

c) Describe five factors that influence crop water requirements. (5 marks)

d) Explain four effects of excessive irrigation on crop production. (4 marks)

e) State three methods used by farmers to determine when crops require irrigation. (3 marks)

26.

A farmer intends to establish a commercial tomato farm in an area that experiences unreliable rainfall and prolonged dry seasons.

a) Recommend the most appropriate irrigation method for the farmer and give two reasons for your choice. (3 marks)

b) Identify five components required for installing the recommended irrigation system. (5 marks)

c) Explain five practices the farmer should adopt to conserve irrigation water. (5 marks)

d) Explain four factors the farmer should consider when determining the irrigation schedule. (4 marks)

e) State three maintenance practices required to keep the irrigation system operating efficiently. (3 marks)

17.0 SUGGESTED LEARNER PROJECT: Project: Establishing a water-efficient school garden

Project objective

To enable learners to design, establish and manage a small irrigated vegetable garden using water conservation practices.

Project activities

1. Identify a suitable site within the school compound.
2. Examine the soil and drainage conditions.
3. Identify an appropriate water source.
4. Select suitable vegetables for cultivation.
5. Design a simple irrigation system.
6. Construct the irrigation system using available resources.
7. Prepare the planting beds.
8. Plant suitable vegetable seedlings.
9. Apply mulch to reduce moisture loss.
10. Develop an irrigation schedule.
11. Monitor soil moisture and crop growth.
12. Maintain the irrigation equipment.
13. Record water use and crop performance.
14. Harvest the vegetables.
15. Present the project findings to the class.

Expected project outcomes

By completing the project, learners should be able to:

- Select appropriate irrigation methods.
- Construct simple irrigation systems.
- Apply water efficiently.
- Demonstrate water conservation practices.
- Work collaboratively.
- Maintain agricultural equipment.
- Appreciate sustainable crop production.

Suggested project assessment indicators

Assessment area	**Evidence of achievement**
Planning	Appropriate garden and irrigation design
Practical skills	Correct construction and installation
Water conservation	Proper use of mulch and controlled watering
Crop management	Healthy crop establishment and maintenance
Record keeping	Accurate irrigation and crop growth records
Collaboration	Effective participation in group activities
Presentation	Clear explanation of project findings

18.0 SUMMARY OF SUB-STRAND 1.2

Irrigation is an important crop production practice that supplements natural rainfall by supplying water to crops when required.

The five main irrigation methods studied are:

1. Sprinkler irrigation – distributes water as artificial rainfall.
2. Drip irrigation – supplies water slowly to the root zone.
3. Basin irrigation – retains water in enclosed plots.
4. Flood irrigation – allows water to spread over the soil surface.
5. Furrow irrigation – supplies water through channels between crop rows.

Efficient irrigation requires proper water management, suitable irrigation equipment, appropriate scheduling, soil moisture monitoring and water conservation practices.

Farmers should select irrigation systems based on crop requirements, soil characteristics, water availability, land topography and installation costs.

Key inquiry question: How does efficient irrigation of crops conserve water?

Efficient irrigation conserves water by:

- Delivering water where crops need it.
- Reducing evaporation.
- Preventing unnecessary runoff.
- Minimising deep percolation.
- Reducing leakage.
- Preventing excessive watering.
- Maintaining soil moisture through mulching.
- Using appropriate irrigation schedules.
- Harvesting and storing rainwater.
- Maintaining irrigation equipment.

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STRAND 1.0: CROP PRODUCTION

SUB-STRAND 1.3: VEGETATIVE PROPAGATION

1.3.1 Introduction to vegetative propagation

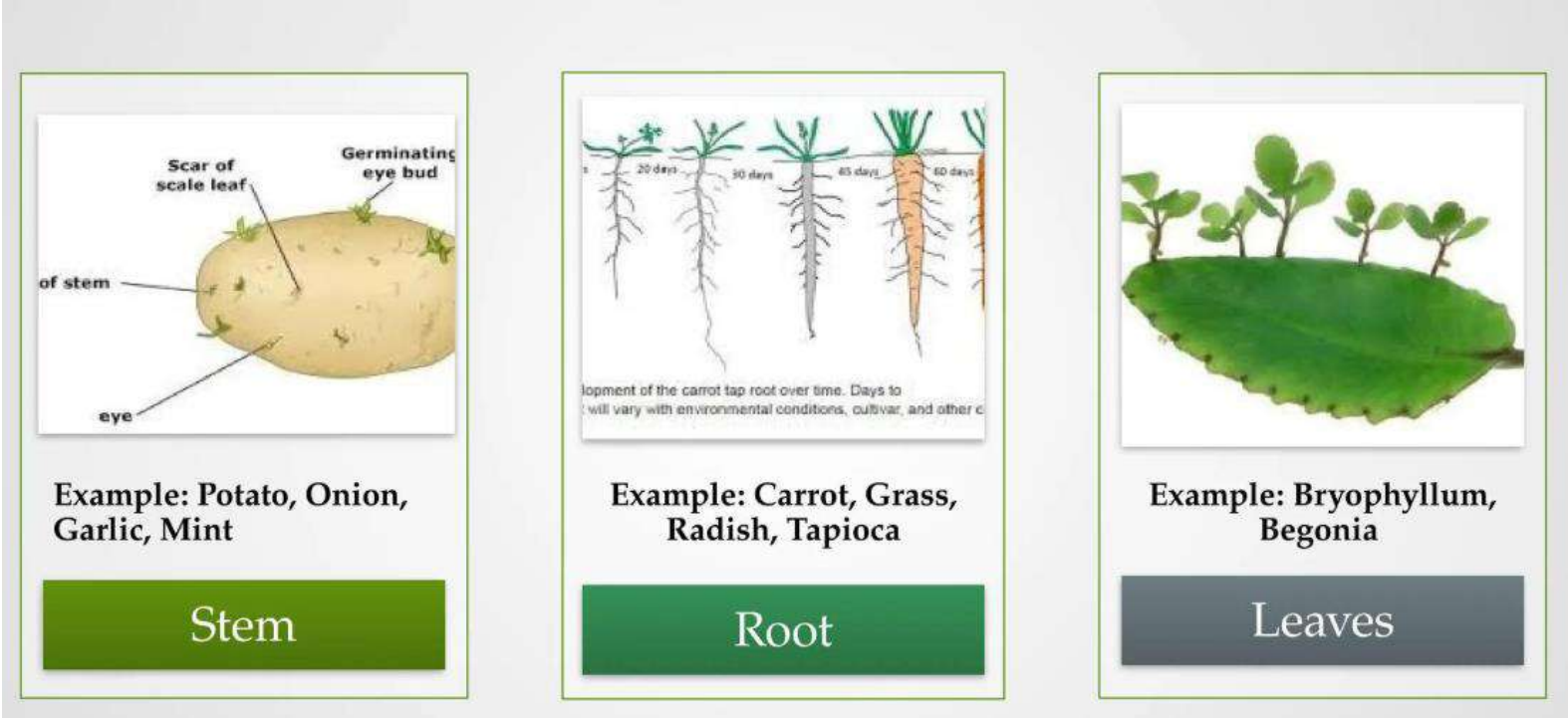
Vegetative propagation is a method of plant reproduction in which new plants are produced from vegetative parts of an existing parent plant rather than from seeds.



The vegetative parts used include stems, roots and leaves. These plant parts can develop into new plants under suitable conditions because they contain living cells capable of growing and forming new shoots and roots.

Vegetative propagation is also referred to as asexual propagation because it does not involve the fusion of male and female gametes or fertilisation.

Examples of crops propagated vegetatively include:



- Sugarcane – using stem cuttings.
- Cassava – using stem cuttings.
- Banana – using suckers.
- Irish potatoes – using tubers.
- Sweet potatoes – using vines.
- Onions – using bulbs.
- Ginger – using rhizomes.
- Pineapples – using crowns, slips and suckers.
- Tea – using stem cuttings.
- Avocado – commonly using grafting or budding.
- Roses – using stem cuttings and budding.

1.3.2 Meaning of important terms

1. Propagation: The process of multiplying plants to produce new individuals.
2. Vegetative propagation: Production of new plants from vegetative parts such as stems, roots and leaves.
3. Parent plant: The original plant from which planting materials are obtained.
4. Propagule: Any plant part used to produce a new plant.
5. Cutting: A detached part of a plant, usually a stem, root or leaf, planted to develop into a new plant.
6. Scion: A shoot or twig selected from a desirable plant and joined to another plant during grafting.
7. Rootstock: The rooted lower part of a plant onto which a scion is grafted or a bud is inserted.
8. Grafting: Joining a scion from one plant to a rooted rootstock of another compatible plant so that they grow as one plant.
9. Budding: A method of propagation in which a single bud from a desirable plant is inserted into the bark of a rootstock.
10. Layering: A method in which roots are encouraged to develop on a stem while it is still attached to the parent plant.
11. Sucker: A shoot arising from the base or underground part of a parent plant.
12. Rhizome: A horizontal underground stem that produces roots and shoots at its nodes.
13. Tuber: A swollen underground stem or storage organ containing buds capable of developing into new plants.
14. Bulb: A short underground stem surrounded by fleshy, food-storing leaf bases.
15. Corm: A short, swollen underground stem that stores food and produces new shoots.
16. Slip: A young shoot arising from the base or fruiting region of a plant, commonly used in pineapple propagation.
17. Crown: The leafy top portion of a pineapple fruit, which can be planted to produce a new pineapple plant.
18. Bulbil: A small bulb-like structure formed above or below the ground that can grow into a new plant.
19. Splitting or division: Separating a plant clump or underground growing structure into smaller sections, each capable of developing into an independent plant.
20. Callus: A mass of cells that develops around a wounded plant surface and may contribute to the formation of new roots or shoots.

1.3.3 Types of vegetative propagation

Vegetative propagation can be grouped into two major categories:

A. Natural vegetative propagation

This occurs naturally when plants produce structures that develop into new independent plants without deliberate human intervention.

Examples include:

- Suckers.
- Slips.
- Crowns.
- Splits or divisions.
- Rhizomes.
- Tubers.
- Bulbs.
- Corms.
- Bulbils.

B. Artificial vegetative propagation

This involves deliberate human intervention to produce new plants using selected plant parts and propagation techniques.

The main methods include:

- Grafting.
- Budding.
- Layering.
- Use of cuttings.

1.3.4 METHODS OF VEGETATIVE PROPAGATION

A. GRAFTING

Meaning of grafting

Grafting is an artificial method of vegetative propagation in which a shoot or twig from a desirable plant (scion) is joined to the rooted lower part of another compatible plant (rootstock).

The two parts are carefully joined so that their tissues unite and grow as one plant.

The scion contributes the desired shoot characteristics, such as fruit quality, while the rootstock provides the root system and may contribute characteristics such as resistance to soil-borne diseases, tolerance to certain soil conditions and plant vigour.

Examples of crops propagated through grafting:

- Mango.
- Avocado.
- Citrus fruits such as oranges and lemons.
- Apples.
- Pears.
- Some ornamental plants.



Requirements for successful grafting

The following materials and conditions are required:

1. Healthy rootstock

- The rootstock should be healthy, vigorous and free from pests and diseases.
- It should be compatible with the scion.
- It should have a well-developed root system.

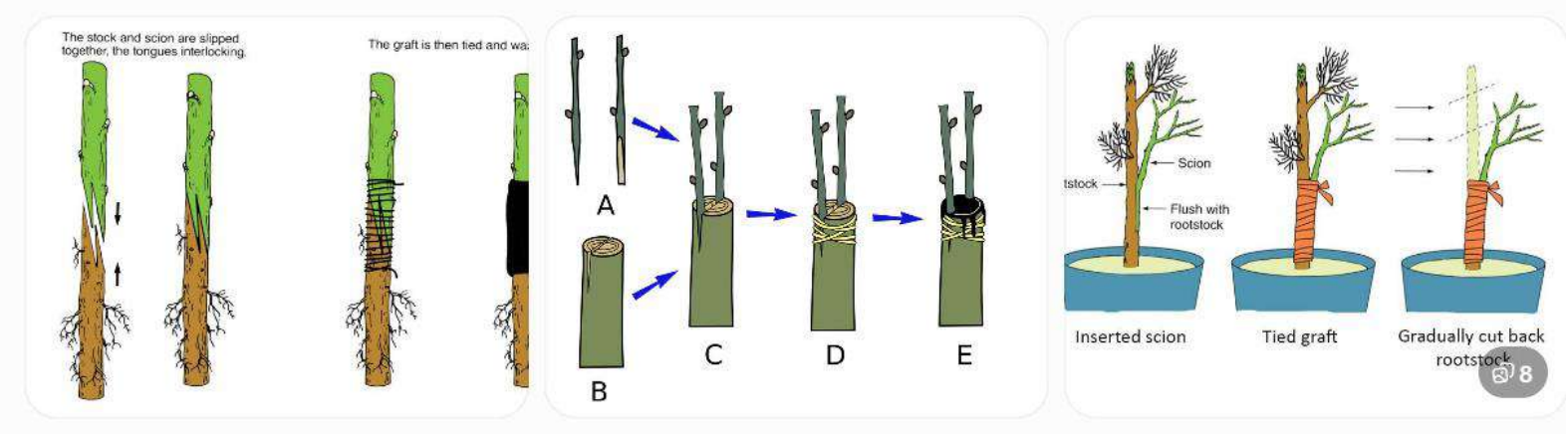
2. Desirable scion

- The scion should be obtained from a healthy, high-yielding parent plant.
- It should have desirable characteristics such as good fruit quality and high productivity.

- It should be free from pests and diseases.

3. Sharp grafting knife
   - Used to make smooth and clean cuts on the rootstock and scion.
   - A sharp knife reduces damage to plant tissues.
4. Grafting tape or polythene strips
   - Used to hold the scion firmly in position.
   - They prevent movement at the graft union.
   - They reduce moisture loss from the cut surfaces.
5. Pruning shears
   - Used to collect scions and remove unwanted branches.
6. Disinfectant
   - Used to clean tools and reduce the spread of diseases.
7. Suitable environmental conditions
   - Adequate moisture and moderate temperatures encourage successful union formation.
   - Excessive heat and drying winds may cause the scion to dry before joining successfully.

Procedure for carrying out grafting



The general procedure is as follows:

1. Select a healthy and compatible rootstock.
2. Identify a healthy parent plant with desirable characteristics.
3. Collect a suitable scion from the selected parent plant.
4. Prepare the rootstock by making a clean cut at the appropriate position.
5. Prepare the scion by making a suitable slanting or wedge-shaped cut, depending on the grafting technique.
6. Join the scion to the rootstock.

7. Ensure that the cambium layers of the scion and rootstock are in close contact, preferably along at least one side.
8. Tie the graft union firmly using grafting tape or polythene strips.
9. Protect the grafted section from excessive moisture loss and physical damage.
10. Keep the plant under suitable nursery conditions.
11. Monitor the graft union for signs of successful growth.
12. Remove shoots arising from the rootstock below the graft union because they may compete with the scion.
13. Remove or loosen binding material when appropriate to prevent girdling.

Why is cambium contact important during grafting?

The cambium is a thin layer of actively dividing cells found between the bark and the woody tissues. When the cambium layers of the scion and rootstock are properly aligned, they can form new tissues that establish a connection between the two parts. This enables water and nutrients to move through the joined plant.

Common methods of grafting

1. Whip and tongue grafting

- Used where the rootstock and scion have approximately similar thickness.
- Slanting cuts are made on both parts.
- A small tongue-shaped slit is made on each cut surface.
- The two parts are fitted together.
- The union is tied firmly.

2. Cleft grafting

- Used where the rootstock is thicker than the scion.
- The rootstock is cut across and split vertically.
- The scion is shaped into a wedge.
- The scion is inserted into the split.
- The cambium layers are aligned and the union is tied.

3. Side veneer grafting

- A slanting cut is made on the side of the rootstock.
- A matching cut is made on the scion.
- The two surfaces are fitted together.
- The union is tied and protected.
- Commonly used in nursery propagation of some fruit trees.

4. Approach grafting

- Two independently rooted plants or branches are brought close together.
- Matching portions of bark are removed.
- The exposed surfaces are joined and tied.
- Once the union is established, the scion may be separated from its original parent plant.

Advantages of grafting

1. Maintains desirable characteristics

- Grafting enables farmers to reproduce plants with desirable fruit quality, productivity and other characteristics.

2. Earlier fruit production

- Grafted fruit trees may begin bearing fruits earlier than plants raised from seeds, depending on the crop and rootstock.

3. Combines desirable characteristics

- A desirable scion can be combined with a rootstock that has suitable root characteristics.

4. Improves disease tolerance

- Some rootstocks are selected because they tolerate or resist particular soil-borne diseases.

5. Produces uniform crops

- Plants produced from the same scion variety are generally more uniform in important characteristics.

6. Repairs damaged trees

- Grafting can be used to replace damaged branches or restore parts of valuable fruit trees.

7. Useful for seedless or poor-seeding varieties

- Some desirable varieties do not produce viable seeds or do not reproduce true to type through seeds.

8. Can improve adaptation

- Appropriate rootstocks may help plants tolerate certain soil or environmental conditions.

Disadvantages of grafting

1. Requires skilled labour

- Correct preparation and joining of the scion and rootstock require practical skills.

2. May be expensive

- Grafting materials, tools and skilled labour may increase production costs.

3. Not all plants are compatible

- Grafting is most successful between closely related and compatible plants.

4. Risk of disease transmission

- Infected scions, rootstocks or tools can spread diseases.

5. Requires careful aftercare

- Grafted plants need monitoring and protection until the union is established.

6. Graft failure may occur

- Poor cambium alignment, unsuitable conditions or incorrect technique may cause the scion to dry or fail.

7. May require special equipment

- Commercial nurseries may need grafting knives, tapes, labels and protective materials.

Precautions when carrying out grafting

- Use clean and sharp tools.
- Select healthy scions and rootstocks.
- Ensure compatibility between the two plant parts.
- Avoid touching the cut surfaces unnecessarily.
- Align the cambium layers correctly.
- Tie the graft union firmly without excessive pressure.
- Protect the graft from drying.
- Label grafted plants correctly.
- Monitor the graft union regularly.

B. BUDDING

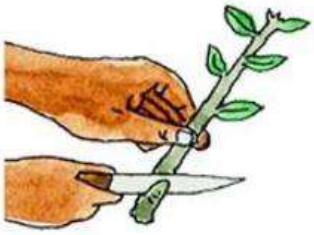
Meaning of budding

Budding is an artificial vegetative propagation method in which a single bud from a desirable parent plant is inserted beneath the bark of a compatible rootstock.

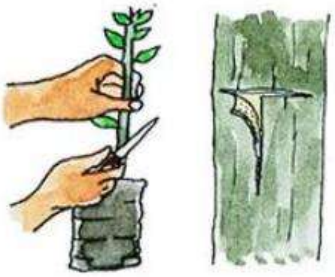
1. Select healthy trees from which to obtain bud graft branches



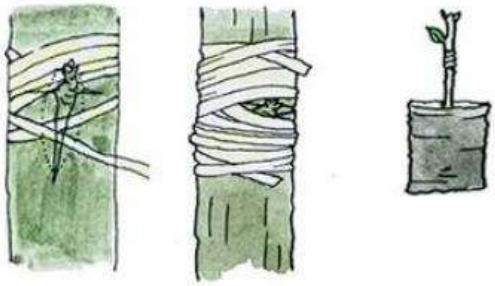
2. Gently slice the bud together with the bark form the bud stick



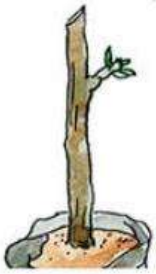
3. Make a 1½-inch cut in the shape of a "T" into the bark



4. Insert the bud under the "T" slice and wrap with a budding tape



5. Remove the budding tape when the buds start sprouting





The inserted bud develops into a shoot, while the rootstock provides the established root system.

Budding is closely related to grafting, but the main difference is that budding uses a single bud instead of a shoot or twig containing several buds.

Examples of crops propagated through budding:

- Roses.
- Citrus fruits.
- Peaches.
- Plums.
- Some ornamental plants.

Requirements for successful budding

1. Healthy rootstock.
2. A healthy bud stick from a desirable parent plant.
3. Sharp budding knife.
4. Budding tape or polythene strips.
5. Clean pruning shears.
6. Disinfectant for cleaning tools.
7. Suitable nursery conditions.
8. Water for maintaining moisture.

Common methods of budding

1. T-budding or shield budding

This is one of the common methods used in fruit-tree propagation.

Procedure:

1. Select a healthy and actively growing rootstock.
2. Select a healthy bud from the desired parent plant.
3. Make a T-shaped incision on the bark of the rootstock.
4. Carefully loosen the bark flaps.
5. Remove a shield-shaped piece of bark containing a healthy bud from the bud stick.
6. Insert the bud beneath the loosened bark flaps.
7. Ensure that the bud fits properly against the rootstock.
8. Tie the inserted bud using budding tape, leaving the bud itself exposed where appropriate.
9. Monitor the bud for signs of successful union.
10. Once the bud has successfully united, cut back the rootstock above the bud at the appropriate stage to encourage the bud to grow into a shoot.

2. Patch budding

- A rectangular patch of bark is removed from the rootstock.
- A similarly sized patch containing a healthy bud is removed from the bud stick.
- The bud patch is fitted into the opening on the rootstock.
- It is tied firmly with budding tape.
- The bud is monitored until successful union occurs.

3. Chip budding

- A small chip of bark and wood is removed from the rootstock.
- A matching chip containing a bud is cut from the selected bud stick.
- The bud chip is fitted into the opening.
- The area is tied securely.
- It can be used where the bark does not separate easily from the wood.

Advantages of budding

1. Produces plants with desirable characteristics
   - Buds are selected from parent plants with desirable features.
2. Requires little propagation material
   - Only one bud is needed for each propagated plant.
3. Can be economical
   - A single bud stick can provide buds for several rootstocks.
4. Combines desirable characteristics
   - The bud contributes the desired variety while the rootstock provides the root system.
5. Produces uniform plants
   - Plants produced from selected buds are generally similar in their variety characteristics.
6. May result in early maturity
   - Budded fruit trees may bear earlier than seed-grown trees.
7. Useful in nursery production
   - Many fruit-tree seedlings can be budded to produce improved planting materials.

Disadvantages of budding

1. It requires practical skills and careful handling.
2. It may fail if the bud does not unite with the rootstock.
3. It requires healthy and compatible rootstocks.
4. Diseases may be transmitted through infected buds.
5. Some budding methods require suitable bark conditions.
6. Budding requires aftercare and regular monitoring.
7. It may be affected by unsuitable weather conditions.

Precautions during budding

- Use healthy bud sticks.

- Select compatible rootstocks.
- Make clean and accurate cuts.
- Avoid damaging the bud.
- Keep the bud moist before use.
- Tie the bud securely.
- Avoid covering the bud unnecessarily.
- Disinfect tools to prevent disease transmission.

C. LAYERING

Meaning of layering

Layering is an artificial method of vegetative propagation in which roots are encouraged to develop on a stem or branch while it is still attached to the parent plant.

After roots have developed sufficiently, the rooted portion is cut off from the parent plant and planted separately to grow into an independent plant.

Layering is useful for plants whose stems can develop roots when placed in contact with moist soil or a suitable rooting medium.

Examples of crops propagated through layering:

- Bougainvillea.
- Jasmine.
- Black pepper.
- Guava.
- Litchi.
- Some ornamental shrubs.
- Some fruit trees.

Types of layering

1. Simple layering

Simple layering involves bending a low-growing flexible branch towards the ground and covering part of it with soil while leaving the tip exposed.

Procedure:

1. Select a healthy, flexible branch growing close to the ground.
2. Prepare the soil near the parent plant by loosening it.
3. Remove leaves from the section of the branch that will be buried.
4. Make a small cut or wound on the underside of the branch where roots are expected to develop, if appropriate for the species.

5. Bend the branch gently towards the ground.
6. Bury the wounded section in moist soil.
7. Hold the buried section in position using a peg or forked stick.
8. Leave the terminal end of the branch above the soil.
9. Water regularly to maintain moisture.
10. Allow roots to develop from the buried section.
11. Once a healthy root system has developed, cut the rooted section from the parent plant.
12. Transplant it carefully into a pot, nursery bed or suitable planting site.

2. Air layering (marcotting)

Air layering is a method in which roots are encouraged to develop on an aerial branch without bending it down to the ground.

A section of bark is removed or wounded, and the exposed area is covered with moist rooting material and wrapped to retain moisture.

It is commonly used in the propagation of some fruit trees and ornamental plants.

Procedure:

1. Select a healthy, mature branch from a desirable parent plant.
2. Choose a suitable position on the branch.
3. Remove a ring of bark around the selected section, taking care not to damage the branch excessively.
4. Scrape off the cambium layer where necessary to reduce bark regeneration across the wound.
5. Apply moist sphagnum moss, coco peat or another suitable rooting medium around the wounded section.
6. Wrap the rooting medium using transparent polythene or another suitable material.
7. Tie the wrapping securely at both ends to retain moisture.
8. Monitor the wrapped section and maintain adequate moisture.
9. Observe the development of roots through the wrapping.
10. Once a sufficient root system has developed, cut the branch below the rooted section.
11. Remove the wrapping carefully without damaging the roots.
12. Plant the rooted branch in a suitable container or nursery bed.
13. Keep the new plant under partial shade as it establishes.

3. Compound or serpentine layering

- A long, flexible branch is bent repeatedly so that several sections touch the soil.
- Alternate sections of the branch are covered with soil while other sections remain exposed.
- Each buried section may develop roots.
- The rooted sections are separated after sufficient root development.
- This method can produce several new plants from one branch.

4. Tip layering

- The tip of a flexible shoot is bent towards the ground.
- The tip is buried in moist soil.
- Roots and a new shoot develop from the buried tip.
- The rooted section is later separated from the parent plant.

Advantages of layering

1. Produces plants similar to the parent plant

- Layering produces offspring that generally retain the desirable characteristics of the parent plant.

2. High chances of successful establishment

- The branch remains attached to the parent plant while roots develop.
- It continues receiving water and nutrients from the parent plant.

3. Useful for difficult-to-root plants

- Some plants that do not root easily from detached cuttings can be propagated through layering.

4. Requires relatively simple equipment

- Simple layering mainly requires soil, water and materials for holding the branch in position.

5. Produces relatively mature planting materials

- Layered plants may establish and mature faster than plants raised from seeds, depending on the crop.

6. Maintains desirable fruit or flower characteristics

- The new plants retain the characteristics of the selected parent plant.

7. Can be carried out on established plants

- Farmers can propagate suitable branches without removing the entire parent plant.

Disadvantages of layering

1. Produces relatively few plants

- Compared with methods such as seed propagation or mass production of cuttings, layering may produce fewer planting materials.

2. Requires more time and labour

- Bending, wounding, wrapping and monitoring branches require careful attention.

3. Not suitable for all crops

- Plants with stiff, brittle or unsuitable stems may not be easily layered.

4. May damage the parent plant

- Poor handling or excessive removal of branches may weaken the parent plant.

5. Root development may be slow

- Some branches take a long time to develop sufficient roots.

6. Requires regular moisture management

- The rooting medium may dry out or become waterlogged, affecting root development.

Precautions when carrying out layering

- Select healthy branches.
- Avoid breaking or splitting branches when bending them.
- Use clean tools when making wounds.
- Keep the rooting medium moist but not waterlogged.
- Protect layered sections from physical damage.
- Separate the rooted section only after adequate root development.
- Reduce water loss from newly separated plants by providing suitable shade and care.

D. USE OF CUTTINGS

Meaning of cuttings

A cutting is a section of a plant that is detached from the parent plant and planted under suitable conditions to develop roots and shoots, forming a new independent plant.

Cuttings may be obtained from stems, roots or leaves.

The new plant generally has the same genetic characteristics as the parent plant because it is produced through asexual reproduction.

Examples of crops propagated using cuttings:

- Cassava – stem cuttings.
- Sugarcane – stem cuttings.
- Sweet potato – vine cuttings.
- Tea – stem cuttings.
- Roses – stem cuttings.
- Bougainvillea – stem cuttings.

- Black pepper – stem cuttings.
- Some ornamental plants – leaf or stem cuttings.

Types of cuttings

1. Stem cuttings

Stem cuttings are sections of stems containing one or more nodes and buds. They are planted to develop roots and shoots.

Examples:

- Cassava.
- Sugarcane.
- Tea.
- Roses.
- Bougainvillea.
- Black pepper.

Types of stem cuttings according to maturity

a) Hardwood cuttings

- Obtained from mature, woody stems.
- The stems are firm and have completed most of their growth.
- They are commonly used in the propagation of certain fruit trees and shrubs.
- They are generally collected during suitable dormant or less active growth periods, depending on the crop.

b) Semi-hardwood cuttings

- Obtained from partially mature stems.
- The stems are neither very soft nor completely woody.
- They are used in propagating several ornamental plants and shrubs.
- They are usually taken from healthy current-season growth that has begun to mature.

c) Softwood cuttings

- Obtained from young, soft and actively growing shoots.
- They are generally easier to prepare but may lose water quickly.
- They require careful moisture management.
- Examples include suitable shoots of some ornamental shrubs.

d) Herbaceous cuttings

- Obtained from soft, non-woody plants.

- They are commonly used to propagate plants with soft stems.
- Examples include some garden and ornamental plants.

2. Root cuttings

Root cuttings are sections of roots taken from a parent plant and planted under suitable conditions to develop new shoots and roots.

Procedure:

1. Select a healthy parent plant known to propagate successfully through root cuttings.
2. Carefully expose part of the root system.
3. Select healthy roots of suitable thickness.
4. Cut the roots into sections of appropriate length.
5. Maintain the correct orientation of the root sections where necessary.
6. Plant the sections in a suitable rooting medium.
7. Cover them lightly with soil or rooting medium.
8. Water gently to maintain moisture.
9. Provide suitable shade and protection.
10. Allow new shoots and roots to develop.
11. Transplant the established plants when they are sufficiently strong.

Examples include some ornamental plants, raspberries and other suitable species.

3. Leaf cuttings

Leaf cuttings involve using a whole leaf or part of a leaf to produce a new plant.

Some leaves can develop roots and shoots when placed in a suitable rooting medium.

Examples:

- Bryophyllum.
- Begonia.
- African violet.
- Some succulent ornamental plants.

Procedure:

1. Select a healthy, disease-free leaf.
2. Detach the leaf carefully using a clean tool.
3. Prepare a suitable rooting medium, such as a mixture of clean soil and sand.
4. Place the leaf or leaf section in the rooting medium using the appropriate technique for the plant species.

5. Maintain suitable moisture without waterlogging.
6. Provide adequate light and protection from excessive direct sunlight.
7. Allow roots and shoots to develop.
8. Separate and transplant the new plantlets when sufficiently established.

Procedure for carrying out stem cutting propagation

The following procedure can be used when propagating suitable crops such as cassava, tea and ornamental plants. The exact cutting length and preparation depend on the crop.

1. Select a healthy parent plant

- Choose a vigorous plant that has desirable characteristics.
- Avoid plants showing signs of pest attack or disease.

2. Select suitable stems

- Choose stems of the correct age and maturity for the crop.
- The stems should have healthy nodes and buds.

3. Prepare the tools

- Use a sharp knife or secateurs.
- Clean and disinfect the tools to minimise disease transmission.

4. Prepare the cuttings

- Cut the stems into suitable sections.
- Ensure that each cutting has viable buds or nodes.
- Make clean cuts to reduce tissue damage.

5. Prepare the planting medium

- Use fertile, well-drained soil or an appropriate rooting medium.
- Remove stones, weeds and other unwanted materials.

6. Plant the cuttings

- Insert the cuttings into the rooting medium using the correct orientation.
- Ensure that the required number of nodes are buried while some buds remain above the soil where necessary.

7. Water the cuttings

- Apply sufficient water to maintain moisture.
- Avoid excessive watering that may cause rotting.

8. Provide suitable conditions

- Protect cuttings from excessive heat, strong winds and direct sunlight where necessary.

- Maintain adequate moisture and ventilation.

9. Monitor growth

- Observe the development of roots and shoots.
- Remove diseased or rotting cuttings.

10. Harden the young plants

- Gradually expose rooted plants to normal environmental conditions before transplanting.

11. Transplant

- Transfer well-established plants to the field or final planting containers.

Advantages of using cuttings

1. Maintains desirable characteristics

- Cuttings produce plants that are generally genetically similar to the parent plant.

2. Relatively simple method

- Many crops can be propagated using simple tools and locally available materials.

3. Faster establishment

- Cuttings can develop into established plants more quickly than seed-grown plants in suitable crops.

4. Useful for crops with poor seed production

- It is suitable for crops that produce few viable seeds or do not reproduce reliably from seeds.

5. Uniformity

- Plants produced from selected parent plants tend to have similar growth and production characteristics.

6. Economical

- Farmers can obtain planting materials from existing healthy plants, reducing the need to purchase seeds.

7. Large numbers can be produced

- A suitable parent plant can provide several cuttings, depending on its size and the crop.

8. Preserves desirable varieties

- Farmers can maintain crop varieties with preferred quality and production characteristics.

Disadvantages of using cuttings

1. Disease transmission

- Diseases and pests present in the parent plant may be transferred to the cuttings.

2. Limited genetic variation

- Plants produced are generally genetically similar, reducing genetic diversity.

3. Some cuttings fail to root

- Success depends on the plant species, cutting condition and environmental factors.

4. Requires moisture management

- Detached cuttings can lose water before roots develop.

5. May have weak root systems

- Some cutting-propagated plants may develop root systems that are less suitable for particular field conditions.

6. Requires suitable parent plants

- Healthy, vigorous parent plants must be available to provide planting material.

7. Not suitable for every crop

- Some plants do not readily produce roots from detached sections.

Factors affecting successful rooting of cuttings

- Age of cutting: The maturity of the stem influences its ability to form roots.
- Health of parent plant: Healthy parent plants provide stronger planting materials.
- Moisture: Adequate moisture prevents cuttings from drying.
- Temperature: Suitable temperatures encourage root formation.
- Rooting medium: A clean, well-drained medium supports root development.
- Light intensity: Excessive direct sunlight may cause water loss.
- Cutting size: Appropriate length and thickness provide sufficient stored food and viable buds.
- Plant growth hormones: Suitable rooting hormones, such as auxins, may improve rooting in some species.
- Sanitation: Clean tools and planting materials reduce rotting and disease spread.

1.3.5 NATURAL VEGETATIVE PROPAGATION

Natural vegetative propagation occurs when a plant produces specialised vegetative structures that can grow into new independent plants.

These structures may develop above or below the ground. They contain buds or growing points that produce new shoots and roots under favourable conditions.

The main natural vegetative propagation structures include suckers, slips, crowns, splits, rhizomes, tubers, bulbs, corms and bulbils.

A. SUCKERS

Meaning of suckers

Suckers are shoots that develop from the base of a parent plant or from underground stems and roots. They can be separated from the parent plant and planted to produce new plants.

Suckers usually have their own growing points and may develop roots before separation.

Examples of crops propagated using suckers:

- Bananas.
- Plantains.
- Pineapples.
- Some fruit trees and ornamental plants.

Types of banana suckers

1. Sword suckers

- Have narrow, pointed leaves resembling a sword.
- Possess a relatively thick base.
- Usually have a well-developed underground stem.
- Are generally preferred for banana planting because they tend to establish well.
- Are selected from healthy, productive parent plants.

2. Water suckers

- Have broad leaves at an early stage.
- Usually have a relatively weak or poorly developed base compared with sword suckers.
- May establish less successfully than well-developed sword suckers.
- Are generally less preferred as banana planting materials.

Procedure for propagating bananas using suckers

1. Identify a healthy, high-yielding banana plantation.
2. Select a vigorous sword sucker from a disease-free parent plant.
3. Remove soil around the base of the sucker to expose its attachment to the parent plant.
4. Separate the sucker carefully using a sharp, clean tool.
5. Ensure that the sucker has a healthy base and, where possible, some roots.
6. Trim damaged roots and remove excessively large or damaged leaves to reduce water loss.
7. Prepare a suitable planting hole.
8. Plant the sucker upright at the correct depth.

9. Firm the soil around its base.
10. Water immediately after planting.
11. Apply mulch around the plant while leaving a small space around the stem.
12. Protect the young plant from livestock, weeds and physical damage.

Advantages of using suckers

- They are readily available in crops that naturally produce suckers.
- They retain desirable characteristics of the parent plant.
- They are relatively easy to obtain and plant.
- They can establish quickly when well selected and handled.
- They may produce earlier than plants raised from seeds.
- They do not require complicated propagation equipment.

Disadvantages of using suckers

- They may transmit pests and diseases from the parent plant.
- Some crops produce few suckers, limiting the supply of planting materials.
- Poorly selected suckers may have weak growth.
- Removing too many suckers can weaken the parent plant.
- Suckers may be bulky and difficult to transport in large quantities.
- They may compete with the parent plant for nutrients and water if not properly managed.

B. SLIPS

Meaning of slips

Slips are young shoots that develop from the base of a plant or from the fruiting structure and can be detached and planted to produce new plants.

Slips are commonly associated with pineapple propagation.

Example: Pineapple.

Procedure for propagating pineapples using slips

1. Select healthy pineapple plants with desirable fruit characteristics.
2. Identify well-developed slips on the parent plant.
3. Allow the slips to attain suitable size before removal.
4. Detach the slips carefully using a sharp, clean knife.
5. Remove dry or damaged leaves.
6. Allow the cut base to dry briefly in a shaded, well-ventilated place where appropriate.

7. Prepare a well-drained planting site.
8. Plant the slip firmly in the soil, ensuring that its base is properly covered.
9. Avoid burying the growing point.
10. Water appropriately to encourage establishment.
11. Weed and maintain the plants regularly.

Advantages of using slips

- They produce plants with characteristics similar to those of the parent plant.
- They are relatively easy to obtain from mature pineapple plants.
- They can establish faster than seed-grown plants.
- They help farmers maintain desirable pineapple varieties.
- They are useful for establishing commercial pineapple plantations.

Disadvantages of using slips

- Their availability depends on the number and condition of the parent plants.
- They may carry pests and diseases.
- They require careful handling to prevent damage.
- They may take time to develop to suitable planting size.
- Transporting large quantities may be difficult.

C. CROWNS

Meaning of crowns

A crown is the leafy shoot at the top of a pineapple fruit. It can be detached and planted to produce a new pineapple plant.

The crown contains a growing point that develops into leaves and a new plant when provided with suitable growing conditions.

Example: Pineapple.

Procedure for propagating pineapples using crowns

1. Select a healthy pineapple fruit from a desirable variety.
2. Hold the fruit firmly and remove the leafy crown by twisting or cutting it off.
3. Remove some of the lower leaves to expose the base.
4. Remove any fruit flesh remaining at the base to reduce the risk of rotting.
5. Allow the cut surface to dry briefly in a shaded, well-ventilated place.
6. Prepare a suitable planting site or container containing well-drained growing medium.
7. Insert the base of the crown into the soil.

8. Firm the soil around the base.
9. Water lightly and maintain suitable moisture.
10. Keep the crown under suitable conditions as it develops roots.
11. Remove weeds and protect the young plant from damage.

Advantages of using crowns

- They are easily obtained from pineapple fruits.
- They do not require specialised propagation equipment.
- They produce plants similar to the parent variety.
- They can be used by small-scale farmers to establish a few plants.
- They are useful where other pineapple planting materials are unavailable.

Disadvantages of using crowns

- They may take longer to establish and mature than some other pineapple planting materials.
- They are often available only when pineapple fruits are harvested.
- They may carry pests and diseases.
- Some crowns may fail to establish if the base is damaged or begins to rot.
- They may not be economical for large-scale commercial production where faster-maturing planting materials are preferred.

D. SPLITS OR DIVISIONS

Meaning of splits

Splitting or division is a method of vegetative propagation in which a mature plant clump or underground growing structure is separated into smaller sections. Each section should have a viable growing point and, where possible, roots.

The separated sections are planted individually to develop into independent plants.

This method is commonly used for perennial crops and ornamental plants that grow in clumps.

Examples include:

- Ginger clumps.
- Some ornamental grasses.
- Certain perennial herbs.
- Some flower plants such as daylilies.
- Suitable clump-forming plants.

Procedure for carrying out propagation by splitting

1. Select a healthy and mature parent plant.
2. Water the plant before lifting it where necessary to reduce root damage.
3. Loosen the soil around the plant.
4. Lift the plant carefully using a fork or spade.
5. Remove excess soil to expose the roots and growing points.
6. Identify natural divisions or suitable sections.
7. Divide the clump using a clean, sharp knife or spade.
8. Ensure that each section has a healthy growing point and sufficient roots.
9. Remove dead, diseased or damaged parts.
10. Plant each division in a prepared hole or container.
11. Firm the soil around the roots.
12. Water immediately after planting.
13. Provide suitable shade and aftercare as the divisions establish.

Advantages of splitting

- It is relatively simple to carry out.
- It produces plants similar to the parent plant.
- It can rejuvenate overcrowded perennial plants.
- It produces planting materials without requiring seeds.
- It can provide relatively large planting materials that establish quickly.

Disadvantages of splitting

- It may produce only a limited number of new plants.
- It can damage the parent plant if poorly done.
- It may spread pests and diseases through infected plant sections.
- It requires careful lifting and handling.
- It is unsuitable for plants that do not naturally form separable clumps.

E. RHIZOMES

Meaning of rhizomes

A rhizome is a horizontal underground stem that grows below or sometimes along the soil surface. It has nodes, internodes and buds.

The buds on a rhizome can develop into new shoots, while roots grow from its nodes. Therefore, rhizomes can be cut into sections and planted to produce new plants.

Examples of crops propagated using rhizomes:

- Ginger.
- Turmeric.
- Bamboo.
- Some ornamental plants.

Characteristics of rhizomes

1. They are modified stems that commonly grow horizontally underground.
2. They have nodes and internodes.
3. They possess buds that can develop into new shoots.
4. They may store food for the developing plant.
5. They produce adventitious roots from their nodes.
6. They can branch and spread underground.
7. They can be divided into sections for planting.

Procedure for propagating ginger using rhizomes

1. Select healthy, mature ginger rhizomes from disease-free parent plants.
2. Choose rhizomes with visible, healthy buds.
3. Clean off excess soil and inspect for rotting or pest damage.
4. Cut the rhizomes into suitable sections using a clean, sharp knife.
5. Ensure that each section has at least one healthy viable bud; more buds may improve the chances of establishment.
6. Allow cut surfaces to dry or heal briefly under suitable clean conditions where recommended.
7. Prepare a fertile, well-drained planting bed.
8. Make planting holes or shallow furrows.
9. Place the rhizome pieces with the buds facing upwards.
10. Cover them with soil at the appropriate depth.

11. Water gently to maintain adequate moisture.
12. Mulch the bed to conserve moisture and suppress weeds.
13. Weed and monitor the crop as shoots emerge.

Advantages of using rhizomes

- They contain stored food that supports early growth.
- They produce plants similar to the parent plant.
- They are useful for crops that produce few or no viable seeds.
- They can be divided into several planting sections.
- They may establish faster than seed-grown plants.
- They help farmers maintain desirable crop varieties.

Disadvantages of using rhizomes

- They may carry soil-borne pests and diseases.
- They may rot in poorly drained soils.
- Large quantities may be required for planting.
- Preparing planting sections requires labour.
- Poorly selected rhizomes may produce weak plants.
- Storage may be difficult because rhizomes can dry out or rot.

F. TUBERS

Meaning of tubers

Tubers are enlarged underground storage organs that contain stored food and buds capable of developing into new plants.

In Irish potatoes, the tuber is a modified underground stem. Its buds are commonly called eyes.

When a suitable potato tuber or a properly prepared tuber section is planted, the buds can sprout and develop into shoots and roots.

Examples of crops propagated using tubers:

- Irish potatoes.
- Yams.
- Some other tuber-producing crops.

Characteristics of Irish potato tubers

1. They are swollen underground stems.
2. They store food mainly in the form of starch.
3. They have buds known as eyes.

4. The eyes are arranged at different positions on the tuber.
5. Each viable eye can develop into a new shoot.
6. They are used as planting materials.
7. They can be planted whole or divided into suitable sections, depending on size and recommended practice.

Procedure for propagating Irish potatoes using tubers

1. Select healthy, disease-free seed potato tubers from a reliable source.
2. Choose tubers of suitable size with well-developed eyes.
3. Reject tubers that are rotten, damaged or infected.
4. Where large tubers are cut, use a clean, sharp knife and ensure each section has at least one viable eye, preferably more where practical.
5. Allow cut surfaces to heal under suitable clean conditions before planting, where this practice is recommended.
6. Prepare a well-drained seedbed or ridges.
7. Make planting holes or furrows at the recommended spacing.
8. Place the tubers or sections in the soil with the eyes facing upwards where practical.
9. Cover with soil.
10. Water according to soil moisture conditions.
11. Earth up the crop as it grows to cover developing tubers and protect them from exposure to sunlight.
12. Weed and manage pests and diseases appropriately.

Importance of using certified seed potatoes

Certified seed potatoes are planting tubers that have been inspected and meet specified quality and health standards.

They are important because they:

- Reduce the risk of planting diseased tubers.
- Improve crop establishment.
- Promote uniform growth.
- Help maintain varietal purity.
- Can improve productivity when combined with good crop management.

Advantages of using tubers

- Tubers contain stored food for early shoot development.
- They produce plants similar to the parent variety.
- They are easy to plant and manage.

- They are suitable for crops that do not produce reliable planting seeds.
- They can establish quickly under suitable conditions.
- They help maintain desirable crop varieties.

Disadvantages of using tubers

- They may be bulky and expensive to transport.
- They may transmit diseases from one season to another.
- Large quantities are needed for planting.
- They may rot in wet or poorly drained soil.
- Storage requires suitable conditions.
- Cutting tubers incorrectly may result in poor establishment.

G. BULBS

Meaning of bulbs

A bulb is a modified underground storage structure consisting of a short stem surrounded by fleshy, food-storing leaf bases.

The bulb contains a growing point that can develop into a new shoot. Some bulbs also produce smaller daughter bulbs that can be separated and planted.

Examples of crops propagated using bulbs:

- Onions.
- Garlic.
- Shallots.
- Some ornamental lilies and tulips.

Characteristics of bulbs

1. They have a short, compressed stem known as the basal plate.
2. They contain fleshy leaves or leaf bases that store food.
3. They have a growing point that develops into a shoot.
4. They may produce roots from the basal plate.
5. Some bulbs produce smaller bulbs called daughter bulbs or offsets.
6. They enable plants to survive unfavourable conditions by storing food.
7. They can be used as planting materials.

Procedure for propagating garlic using cloves

Garlic is commonly propagated using individual cloves, which are parts of the compound bulb.

1. Select healthy, mature garlic bulbs from desirable varieties.
2. Separate the bulbs into individual cloves shortly before planting.
3. Select large, healthy cloves that are free from damage and disease.
4. Prepare a fertile, well-drained planting bed.
5. Make planting holes or shallow furrows.
6. Plant each clove with the pointed end facing upwards and the basal end downwards.
7. Cover with soil at the recommended depth.
8. Water appropriately.
9. Mulch where necessary to conserve moisture and suppress weeds.
10. Weed and monitor the crop regularly.

Advantages of using bulbs

- They contain stored food for early growth.
- They produce plants similar to the parent variety.
- They are easy to handle and plant.
- They can survive periods of unfavourable conditions.
- They are suitable for crops that are not normally propagated using true seeds.
- They can produce new daughter bulbs for further multiplication.

Disadvantages of using bulbs

- Bulbs may be expensive to obtain in large quantities.
- They can be affected by rotting in wet conditions.
- They may carry pests and diseases.
- They may require careful storage before planting.
- They may produce fewer planting materials than some other propagation methods.

H. CORM

Meaning of a corm

A corm is a short, swollen, solid underground stem that stores food and produces buds from which new shoots can develop.

Unlike a bulb, which has fleshy leaf bases surrounding a short stem, a corm consists mainly of solid stem tissue.

Examples of crops propagated using corms:

- Cocoyam.
- Taro.
- Gladiolus.
- Some ornamental plants.

Characteristics of corms

1. They are modified underground stems.
2. They are short, swollen and solid internally.
3. They store food for future growth.
4. They have buds that develop into shoots.
5. They produce roots from the basal region.
6. They may produce smaller corms or cormels.
7. They can be divided into suitable sections where each section has a viable bud.

Procedure for propagating cocoyam using corms or cormels

1. Select healthy corms or cormels from productive plants.
2. Remove soil and inspect for rotting or pest damage.
3. Select suitable planting pieces with viable buds.
4. Prepare a moist but well-drained planting site suitable for the crop.
5. Dig planting holes at the recommended spacing.
6. Place the planting material in the hole with the growing point correctly positioned.
7. Cover with soil.
8. Water as required.
9. Weed and maintain the crop.
10. Monitor for pest and disease attack.

Difference between bulbs and corms

Bulbs	Corms
Mainly consist of fleshy, food-storing leaf bases.	Mainly consist of solid, swollen stem tissue.
Have a short basal stem.	The whole swollen structure is a stem.
Examples include onion and garlic.	Examples include cocoyam and gladiolus.
Garlic cloves are individual parts of a compound bulb.	Cormels may develop around the parent corm.

I. BULBILS

Meaning of bulbils

Bulbils are small bulb-like structures that develop on the aerial or underground parts of certain plants. They can detach from the parent plant and grow into new independent plants under suitable conditions.

They function as vegetative reproductive structures.

Examples of plants that produce bulbils:

- Air potato.
- Some species of lilies.
- Some garlic varieties.
- Certain ornamental plants.

Characteristics of bulbils

1. They are small, bulb-like structures.
2. They contain stored food.
3. They possess buds or growing points.
4. They can develop into new plants.
5. They may develop on aerial stems, leaf axils or flower structures.
6. They can detach naturally from the parent plant.
7. They provide an alternative means of vegetative reproduction.

Procedure for propagating plants using bulbils

1. Identify a healthy parent plant that produces bulbils.
2. Select mature, well-developed bulbils.
3. Detach the bulbils carefully where they do not fall naturally.

4. Reject damaged or diseased bulbils.
5. Prepare suitable soil or a nursery container.
6. Plant the bulbils at the appropriate depth for the species.
7. Cover lightly with soil where necessary.
8. Water appropriately.
9. Maintain suitable growing conditions.
10. Allow the bulbils to sprout and develop into young plants.
11. Transplant them when sufficiently established, if required.

Advantages of using bulbils

- They provide an additional means of multiplying plants.
- They contain stored food that supports early growth.
- They are usually easy to collect from suitable parent plants.
- They produce plants similar to the parent plant.
- They can help maintain desirable varieties.

Disadvantages of using bulbils

- Not all crops produce bulbils.
- Some plants produce only a limited number.
- Bulbils may take time to reach suitable planting size.
- They may transmit diseases from the parent plant.
- They may be easily lost or damaged during harvesting and handling.

1.3.6 SUMMARY OF NATURAL VEGETATIVE PROPAGATION STRUCTURES

Vegetative structure	Description	Examples of crops
Suckers	Shoots arising from the base or underground parts of a parent plant.	Banana, plantain, pineapple
Slips	Young shoots commonly arising around the base or fruiting region of pineapple plants.	Pineapple
Crowns	Leafy shoots at the top of pineapple fruits.	Pineapple
Splits/divisions	Sections of a mature plant clump separated for propagation.	Ornamental plants, some perennial herbs
Rhizomes	Horizontal underground stems with nodes, buds and internodes.	Ginger, turmeric, bamboo
Tubers	Swollen storage organs with buds capable of producing new plants.	Irish potato, yam
Bulbs	Short stems surrounded by fleshy food-storing leaf bases.	Onion, garlic, shallot
Corms	Short, swollen, solid underground stems.	Cocoyam, taro, gladiolus
Bulbils	Small bulb-like structures that develop on certain plant parts.	Air potato, some lilies

Important examination point: A potato tuber is a modified underground stem, while a sweet potato is a modified storage root. Irish potato eyes are buds, whereas the nodes of rhizomes also contain buds.

1.3.7 DIFFERENCES BETWEEN THE METHODS OF VEGETATIVE PROPAGATION

A. Differences between grafting and budding

Grafting	Budding
Uses a scion containing a shoot or twig with several buds.	Uses a single bud from a desirable parent plant.
The scion is joined to a compatible rootstock.	A single bud is inserted into the bark or prepared section of a rootstock.
Usually requires a larger amount of propagation material.	Requires relatively little propagation material.
Includes techniques such as cleft and whip-and-tongue grafting.	Includes T-budding, patch budding and chip budding.
Commonly used in mango and avocado propagation.	Commonly used in roses and citrus propagation.

B. Differences between layering and cuttings

Layering	Cuttings
Roots develop while the stem is still attached to the parent plant.	A plant part is detached before roots develop.
The developing layer receives water and nutrients from the parent plant.	The cutting depends on its stored food and the conditions provided after detachment.
Usually produces fewer plants from one parent plant.	Can produce many plants from a suitable parent plant.
Examples include air layering of suitable fruit trees.	Examples include cassava, tea and sugarcane.
Often has a relatively high chance of establishment for suitable species.	Rooting success depends on the crop, cutting type and environmental conditions.

C. Differences between natural and artificial vegetative propagation

Natural vegetative propagation	Artificial vegetative propagation
Occurs through naturally produced plant structures.	Involves deliberate human intervention.
Does not normally require specialised propagation procedures.	Often requires tools, materials and technical skills.
Examples include suckers, rhizomes, bulbs and tubers.	Examples include grafting, budding, layering and cuttings.
Plant multiplication depends on the structures produced naturally by the crop.	Farmers can select and manage propagation materials to meet production needs.
May be limited by the number of natural propagules produced.	Some methods allow controlled multiplication of desirable varieties.

1.3.8 USES AND IMPORTANCE OF VEGETATIVE PROPAGATION IN CROP PRODUCTION

Vegetative propagation plays an important role in agriculture, horticulture, commercial farming and the conservation of desirable crop varieties.

The following are the major uses and importance of vegetative propagation.

1. Maintaining desirable crop characteristics

- Vegetative propagation produces plants that are generally genetically similar to the parent plant.
- This enables farmers to maintain desirable characteristics such as fruit size, taste, colour, quality and productivity.
- For example, a farmer can propagate a mango variety with desirable fruit characteristics through grafting.

2. Rapid multiplication of planting materials

- Vegetative propagation enables farmers to produce new plants from existing plants.
- Some methods allow several planting materials to be obtained from one parent plant.
- For example, cassava stems can be divided into several cuttings for planting.

3. Early maturity and production

- Plants produced vegetatively may reach the flowering and fruiting stages earlier than plants raised from seeds.
- This is because some vegetatively propagated materials are obtained from physiologically mature parent plants.
- For example, grafted mango trees may bear fruits earlier than mango trees raised from seeds.

4. Propagation of crops that produce few or no viable seeds

- Some crops produce few viable seeds or have difficulty reproducing reliably through seeds.
- Vegetative propagation provides an alternative method of producing planting materials.
- Examples include sugarcane, banana and some seedless fruit varieties.

5. Production of uniform crops

- Plants produced from selected parent plants tend to have similar genetic characteristics.
- This promotes uniformity in growth, maturity, fruit quality and other crop characteristics.
- Uniform crops are important in commercial farming and marketing.

6. Combining desirable characteristics of different plants

- Grafting and budding enable farmers to combine a desirable scion variety with a suitable rootstock.
- The scion may provide desirable fruit characteristics, while the rootstock may provide tolerance to certain soil conditions or diseases.
- This can improve the suitability of fruit trees for particular production environments.

7. Production of disease-tolerant plants

- Farmers can use rootstocks that tolerate or resist particular soil-borne diseases.
- Such rootstocks may improve the survival and performance of grafted plants.
- For example, selected citrus rootstocks can be used to improve tolerance to certain soil-related problems.

8. Conservation of valuable crop varieties

- Vegetative propagation helps preserve valuable local and commercial crop varieties.
- It enables farmers and agricultural institutions to maintain plants with desirable characteristics.
- It is particularly useful where seeds do not reproduce the desired variety consistently.

9. Rejuvenation and multiplication of perennial plants

- Methods such as division and layering can be used to produce new plants from established perennial plants.
- Division may also help manage overcrowded clumps of suitable ornamental and perennial crops.

10. Production of planting materials for commercial agriculture

- Commercial nurseries use vegetative propagation to produce planting materials for farmers.
- Grafted fruit seedlings, tea cuttings and ornamental plants are examples of commercially produced planting materials.

11. Supports food security

- Vegetative propagation enables farmers to establish crops using readily available planting materials.
- It supports the production of food crops such as cassava, bananas, potatoes and yams.
- It can contribute to reliable food production when suitable planting materials and good management practices are used.

12. Production of ornamental plants

- Vegetative propagation is used to multiply flowers, shrubs and decorative plants.
- Examples include roses, bougainvillea and some lilies.
- It helps maintain desirable flower colour, shape and other ornamental characteristics.

13. Useful in establishing plantations

- Vegetative propagation provides planting materials for crops grown in large quantities.
- Examples include sugarcane, tea and bananas.
- It helps farmers establish fields with selected crop varieties.

14. Enables production of seedless varieties

- Some seedless or poorly seeded varieties can be maintained through vegetative propagation.
- This is important for maintaining desirable fruit varieties that cannot be reliably propagated using seeds.

15. Supports agricultural entrepreneurship

- Farmers can establish nurseries and sell quality planting materials.
- Grafted fruit seedlings, tea cuttings, ornamental plants and other vegetatively propagated crops can provide income-generating opportunities.
- It creates employment in nursery management, crop production and agricultural marketing.

1.3.9 ADVANTAGES OF VEGETATIVE PROPAGATION

The following are general advantages of vegetative propagation:

1. Preservation of desirable characteristics: New plants generally retain the genetic characteristics of the parent plant.

2. Early production: Many vegetatively propagated crops mature and produce earlier than seed-grown crops.

3. Uniformity: Plants are generally uniform in growth, maturity and product quality.

4. Useful for seedless crops: It enables multiplication of crops that produce no viable seeds or few viable seeds.

5. Rapid establishment: Some vegetative planting materials establish quickly because they contain stored food or developed growing structures.

6. Reliable multiplication of selected varieties: Farmers can maintain preferred crop varieties.

7. Commercial production: It supports large-scale production of selected planting materials.

8. Reduced dependence on seeds: Farmers can obtain planting materials from established parent plants.

9. Specialised rootstock benefits: Grafting and budding can combine desirable shoot and root characteristics.

10. Conservation of valuable plants: It helps maintain rare or valuable varieties that may be difficult to reproduce from seeds.

11. Simple methods are available: Methods such as suckers, cuttings and division can be carried out using relatively simple equipment.

12. Income generation: Farmers can establish nurseries and sell planting materials.

1.3.10 DISADVANTAGES OF VEGETATIVE PROPAGATION

1. Limited genetic variation

- Plants produced are generally genetically similar to their parent plants.
- This may reduce the ability of a crop population to adapt to changing environmental conditions.

2. Transmission of diseases

- Viruses, bacteria, fungi and pests may be carried in infected planting materials.
- This can spread diseases from one field or farm to another.

3. High initial costs for some methods

- Methods such as grafting and budding may require skilled labour and specialised equipment.

4. Limited availability of planting materials

- Some crops produce few suckers, bulbs, rhizomes or other propagules.

5. Bulky planting materials

- Tubers, corms, suckers and other vegetative structures may be difficult and expensive to transport.

6. Storage difficulties

- Some planting materials may dry out, sprout prematurely or rot during storage.

7. Need for technical skills

- Grafting, budding and some layering techniques require practical knowledge.

8. Possibility of poor establishment

- Cuttings and other propagules may fail to develop roots or shoots if handled poorly.

9. Shortage of suitable parent plants

- Large-scale propagation requires healthy parent plants that can supply quality planting materials.

10. Accumulation of pests and diseases

- Repeated use of infected vegetative materials may increase disease problems over successive planting seasons.

11. Damage to parent plants

- Excessive removal of suckers, stems or branches may weaken the parent plant.

12. Not suitable for all crops

- Some plants cannot be easily propagated through vegetative methods.

1.3.11 FACTORS TO CONSIDER WHEN SELECTING A METHOD OF VEGETATIVE PROPAGATION

A farmer should consider several factors before deciding on the most suitable method.

1. Type of crop

- Different crops respond differently to vegetative propagation methods.
- For example, cassava is commonly propagated through stem cuttings, while bananas are commonly propagated using suckers.

2. Availability of planting materials

- The farmer should select a method for which healthy planting materials are readily available.
- For example, a farmer with mature banana plants can obtain suitable suckers.

3. Cost of propagation

- The method should be affordable.
- Grafting and budding may require additional tools, materials and skilled labour.

4. Skills and knowledge required

- Some methods require specialised skills.
- A farmer should consider whether the necessary skills are available or whether a trained resource person is needed.

5. Purpose of production

- The farmer should consider whether the aim is to produce fruit trees, food crops, ornamental plants or commercial planting materials.
- For example, grafting is useful when establishing fruit trees with selected varieties.

6. Time required

- Some methods produce established planting materials more quickly than others.
- The farmer should consider the time available before the next planting season.

7. Environmental conditions

- Soil moisture, temperature, rainfall and humidity influence the success of propagation.
- Cuttings, for example, require suitable moisture conditions to prevent drying before roots develop.

8. Disease and pest status

- Planting materials should be obtained from healthy parent plants.
- The farmer should avoid propagating plants that show signs of disease or pest infestation.

9. Quantity of planting materials required

- Some methods are more suitable for producing large quantities of plants.
- Cuttings can provide many planting materials from suitable parent plants, while layering may produce fewer.

10. Rooting and establishment ability

- The farmer should select methods that the crop can successfully undergo.
- Some crops root readily from cuttings, while others are more successfully propagated through grafting, budding or natural propagules.

11. Availability of land and nursery facilities

- Some propagation methods require nursery beds, containers, shade structures or suitable growing media.
- Farmers should consider the facilities available.

12. Market demand

- Commercial farmers should consider the demand for particular crop varieties.
- They should propagate varieties that meet the needs of consumers and markets.

1.3.12 GENERAL PRECAUTIONS WHEN CARRYING OUT VEGETATIVE PROPAGATION

For successful propagation, farmers should observe the following precautions:

1. Select healthy parent plants with desirable characteristics.
2. Use disease-free planting materials.
3. Select the correct propagation method for the crop.
4. Use sharp and clean tools.
5. Disinfect tools before and after use where necessary.
6. Avoid damaging buds, growing points and roots.
7. Use suitable soil or rooting media.
8. Maintain appropriate moisture levels.
9. Avoid waterlogging of planting materials.
10. Provide suitable shade where required.
11. Protect newly propagated plants from strong winds and excessive heat.
12. Label different varieties correctly.
13. Remove diseased or rotting planting materials.
14. Control weeds around nursery plants.
15. Monitor plant growth and replace failed planting materials.
16. Harden nursery plants before transplanting where necessary.
17. Follow recommended spacing and planting depth for each crop.
18. Observe hygiene to prevent the spread of pests and diseases.

1.3.13 PRACTICAL AGRICULTURE: CARRYING OUT VEGETATIVE PROPAGATION

Vegetative propagation is a practical agricultural skill. Learners should be able to select planting materials, prepare them, plant them and manage them until they establish.

Practical activity 1: Propagating cassava using stem cuttings

Materials required

- Healthy mature cassava stems.
- Sharp knife or secateurs.
- Measuring stick.
- Watering can.
- Prepared planting site.
- Labels or markers.
- Protective gloves.

Procedure

1. Visit a cassava field and identify healthy parent plants.
2. Select mature stems that are free from pests and diseases.
3. Cut the stems into suitable sections according to recommended local practice.
4. Ensure that each cutting has several healthy nodes.
5. Prepare the planting site by clearing weeds and loosening the soil.
6. Plant the cuttings using the recommended orientation and depth.
7. Firm the soil around each cutting.
8. Water where necessary, especially when soil moisture is inadequate.
9. Label the planted materials.
10. Observe the development of shoots and roots.
11. Record the number of cuttings that establish successfully.

Expected learning outcomes

By the end of the activity, learners should be able to:

- Identify suitable cassava stems for propagation.
- Prepare stem cuttings correctly.
- Plant cuttings using the correct orientation.
- Explain the importance of selecting healthy planting materials.

- Monitor and record the establishment of cuttings.

Practical activity 2: Propagating bananas using suckers

Materials required

- Healthy banana parent plant.
- Suitable sword sucker.
- Spade or digging fork.
- Sharp knife or machete.
- Watering can.
- Manure or compost.
- Prepared planting hole.

Procedure

1. Identify a healthy and productive banana parent plant.
2. Select a vigorous sword sucker.
3. Clear the soil around the base of the sucker.
4. Separate the sucker carefully from the parent plant.
5. Inspect the base and roots for damage or disease.
6. Prepare a planting hole with suitable soil and well-decomposed organic manure.
7. Place the sucker upright in the hole.
8. Cover the roots and base with soil.
9. Firm the soil gently.
10. Water the plant.
11. Apply mulch appropriately.
12. Monitor the plant for establishment and growth.

Expected learning outcomes

- Ability to identify sword and water suckers.
- Ability to select suitable banana planting materials.
- Ability to separate and plant suckers.
- Understanding of the importance of proper planting-material selection.

Practical activity 3: Propagating an ornamental plant using stem cuttings

Materials required

- Healthy parent plant.
- Sharp knife or secateurs.
- Nursery containers or seed trays.
- Clean rooting medium.
- Watering can.
- Labels.

Procedure

1. Select a healthy ornamental parent plant.
2. Identify suitable young or semi-mature stems.
3. Cut sections with viable nodes.
4. Remove lower leaves that would otherwise be buried.
5. Prepare containers with a suitable rooting medium.
6. Insert the cuttings into the medium.
7. Firm the medium gently around each cutting.
8. Water lightly.
9. Place the containers in a suitable shaded nursery area.
10. Maintain moisture without waterlogging.
11. Observe root and shoot development.
12. Transplant established plants into larger containers or suitable planting sites.

1.3.14 COMPETENCE-BASED EDUCATION (CBE) INTEGRATION

A. Core competencies developed

Core competence	How it is developed during the sub-strand
Digital literacy	Learners search digital media for illustrations and information about grafting, budding, layering, cuttings and natural propagules.
Communication and collaboration	Learners work in groups, discuss propagation methods and present their findings.
Critical thinking and problem solving	Learners select suitable propagation methods for different crops and explain why certain methods may succeed or fail.
Creativity and imagination	Learners design simple nursery arrangements and improvise suitable propagation materials using locally available resources.
Learning to learn	Learners conduct investigations, seek guidance from resource persons and reflect on practical experiences.
Self-efficacy	Learners develop confidence by preparing and planting vegetative materials independently.

B. Values to be developed

1. Respect

- Learners listen to and appreciate resource persons, teachers and fellow learners during practical activities.

2. Responsibility

- Learners handle tools carefully and take responsibility for maintaining nursery plants.

3. Cooperation

- Learners share tasks and work together during group propagation activities.

4. Integrity

- Learners honestly record observations and report the success or failure of their propagation experiments.

5. Care for the environment

- Learners avoid unnecessary destruction of parent plants and use resources responsibly.

6. Patriotism

- Learners appreciate the contribution of crop production to food security and national development.

C. Pertinent and Contemporary Issues (PCIs)

1. Environment and technology

- Learners use appropriate propagation technologies to improve crop production.
- They appreciate the role of improved planting materials in sustainable agriculture.

- They practise responsible use of natural resources during nursery activities.

2. Food security

- Learners understand how vegetative propagation supports the production of food crops such as cassava, bananas, potatoes and yams.
- They appreciate the importance of reliable planting materials in increasing food availability.

3. Health and safety

- Learners observe safety when handling knives, secateurs, machetes and other sharp tools.
- They maintain hygiene when preparing planting materials.

4. Entrepreneurship

- Learners explore opportunities for establishing nurseries and selling quality planting materials.
- They appreciate the economic value of producing grafted fruit seedlings and other vegetatively propagated crops.

D. Suggested learning experiences

The learner is guided to:

1. Search for information from print and digital media to illustrate the methods of vegetative propagation.
2. Identify examples of crops propagated using grafting, budding, layering and cuttings.
3. Collect or observe natural propagules such as suckers, slips, crowns, splits, rhizomes, tubers, bulbs and bulbils.
4. Visit a fruit tree nursery to observe grafting and budding.
5. Invite a resource person to demonstrate suitable vegetative propagation techniques.
6. Carry out vegetative propagation using locally available materials.
7. Maintain a nursery containing different vegetatively propagated crops.
8. Discuss the advantages and disadvantages of vegetative propagation.
9. Compare the suitability of different propagation methods for different crops.
10. Present findings to the class and reflect on the success of the activities.

1.3.15 ASSESSMENT ACTIVITIES

Section A: Multiple-choice questions

Choose the correct answer in each question.

1. A farmer wants to multiply a desirable cassava variety. Which planting material should the farmer use?

A. Seeds
B. Stem cuttings
C. Flower buds
D. Leaf scales

2. Which one of the following best describes vegetative propagation?

A. Production of plants through fertilisation
B. Production of plants from vegetative parts
C. Production of plants through pollination
D. Production of plants through seed formation

3. The part of a grafted plant that provides the desired shoot characteristics is known as the:

A. Rootstock
B. Scion
C. Rhizome
D. Sucker

4. Which one of the following crops is commonly propagated using suckers?

A. Banana
B. Maize
C. Wheat
D. Beans

5. A farmer inserts a single bud from a desirable plant into a compatible rootstock. Which method is being used?

A. Layering
B. Grafting
C. Budding
D. Splitting

6. Which one of the following is a characteristic of a rhizome?

A. It is a fleshy leaf base.
B. It is a horizontal underground stem.
C. It is a swollen aerial fruit.
D. It is a modified flower.

7. Which structure is commonly used to propagate Irish potatoes?

A. Bulb
B. Tuber
C. Crown
D. Slip

8. The leafy top portion of a pineapple fruit used for propagation is known as a:

A. Sucker
B. Crown
C. Rhizome
D. Bulbil

9. Which one of the following is a suitable example of a crop propagated using rhizomes?

A. Ginger
B. Maize
C. Beans
D. Sunflower

10. The main purpose of aligning cambium layers during grafting is to:

A. Increase leaf size.
B. Encourage successful union of the scion and rootstock.
C. Prevent flowering.
D. Reduce root growth.

11. Which method involves encouraging roots to develop on a stem while it remains attached to the parent plant?

A. Cutting
B. Layering
C. Budding
D. Splitting

12. Which one of the following is an example of a bulb?

A. Ginger
B. Irish potato
C. Onion
D. Cassava

13. Which type of banana sucker is generally preferred for planting?

A. Water sucker
B. Sword sucker
C. Flower sucker
D. Leaf sucker

14. Which one of the following is a disadvantage of vegetative propagation?

A. It preserves desirable characteristics.
B. It may transmit diseases from parent plants.
C. It can produce uniform plants.
D. It may allow early production.

15. A farmer wants to produce many tea plants from selected parent plants. Which method is commonly suitable?

A. Stem cuttings
B. Seed broadcasting
C. Pollination
D. Seed scarification

16. Which structure consists mainly of solid, swollen underground stem tissue?

A. Bulb
B. Corm
C. Leaf
D. Fruit

17. The main difference between budding and grafting is that budding uses:

A. A whole root system.
B. A single bud.
C. A whole fruit.
D. A seedling leaf.

18. Which one of the following is important when selecting planting materials for vegetative propagation?

A. Presence of disease symptoms
B. Poor growth of the parent plant
C. Health and vigour of the parent plant
D. Damaged growing points

19. A farmer separates a mature plant clump into smaller sections, each with growing points and roots. Which method is being used?

A. Splitting
B. Budding
C. Grafting
D. Air layering

20. Which one of the following is an important reason for using vegetative propagation in commercial fruit production?

A. It increases genetic variation in every plant.
B. It maintains desirable characteristics of selected varieties.
C. It eliminates the need for crop management.
D. It prevents all crop diseases.

Section B: Structured questions

21.

a) Define vegetative propagation. (2 marks)

b) Distinguish between natural and artificial vegetative propagation. (4 marks)

c) State four examples of crops propagated through vegetative methods. (4 marks)

22.

a) Explain the procedure for carrying out grafting in fruit trees. (8 marks)

b) State four advantages of grafting in crop production. (4 marks)

c) Give three precautions that should be observed when carrying out grafting. (3 marks)

23.

a) Describe the procedure for propagating a suitable ornamental plant using stem cuttings. (7 marks)

b) Explain four factors that influence the success of rooting in cuttings. (8 marks)

24.

a) Explain five natural vegetative propagation structures used in crop production. (10 marks)

b) Give one crop example for each of the structures described in (a). (5 marks)

25.

a) Differentiate between budding and grafting. (4 marks)

b) Describe the procedure for carrying out T-budding. (6 marks)

c) State five advantages of vegetative propagation. (5 marks)

26.

A farmer in Kenya intends to establish a commercial fruit orchard using improved fruit varieties.

a) Explain four reasons why the farmer may prefer vegetative propagation to seed propagation. (8 marks)

b) Discuss four disadvantages of vegetative propagation. (4 marks)

c) Identify three factors the farmer should consider when selecting a vegetative propagation method. (3 marks)

1.3.16 CBE INTEGRATED PROJECT: ESTABLISHING A SCHOOL NURSERY

Project title: Establishing a nursery for vegetatively propagated crops.

Project objective: To enable learners to apply different methods of vegetative propagation and develop practical crop production skills.

Project activities

1. Identify a suitable location within the school compound.
2. Select crops that can be propagated using available materials.
3. Collect healthy planting materials from suitable parent plants.
4. Prepare nursery containers and growing media.
5. Carry out propagation using at least three methods, such as:
    - ✓ Stem cuttings.
    - ✓ Suckers.
    - ✓ Rhizomes.
    - ✓ Bulbs.
    - ✓ Layering, where suitable plants are available.
6. Label each propagation method and crop variety.
7. Water and maintain the nursery.
8. Monitor plant establishment and growth.
9. Record the number of successful and unsuccessful propagules.
10. Present the findings to the class.

Expected project outcomes

By completing the project, learners should be able to:

- Identify suitable vegetative planting materials.
- Demonstrate practical propagation skills.
- Select appropriate methods for different crops.
- Maintain a nursery.
- Observe and record plant growth.
- Explain the advantages and limitations of different propagation methods.
- Appreciate the economic importance of producing quality planting materials.

Suggested project assessment criteria

Assessment area	Evidence of achievement
Selection of materials	Healthy and suitable propagules are selected.
Preparation	Tools and planting materials are prepared correctly.
Practical skills	The learner demonstrates the correct propagation procedure.
Safety	Tools are handled safely and hygienically.
Nursery management	Plants are watered, weeded and protected appropriately.
Record keeping	Observations are accurately recorded.
Communication	The learner explains and presents the findings clearly.
Reflection	The learner identifies challenges and suggests improvements.

Key terms to remember

Term	Meaning
Vegetative propagation	Production of new plants from vegetative parts.
Scion	Shoot or twig used in grafting.
Rootstock	Rooted plant onto which a scion or bud is joined.
Grafting	Joining a scion to a compatible rootstock.
Budding	Inserting a single bud into a rootstock.
Layering	Encouraging roots to develop on an attached stem.
Cutting	A detached plant part used to produce a new plant.
Sucker	A shoot arising from the base or underground part of a plant.
Rhizome	Horizontal underground stem with nodes and buds.
Tuber	Swollen storage organ with buds.
Bulb	Short stem surrounded by fleshy storage leaf bases.
Corm	Solid, swollen underground stem.
Bulbil	Small bulb-like structure capable of developing into a new plant.
Slip	Young shoot commonly used in pineapple propagation.
Crown	Leafy top of a pineapple fruit.

STRAND 1.0: CROP PRODUCTION

SUB-STRAND 1.4: AGROFORESTRY

1.4.1 Introduction to agroforestry

Agroforestry is a land-use management system in which trees and shrubs are deliberately integrated with crops and/or livestock on the same piece of land, either at the same time or in a planned sequence.

It combines the production of trees with agricultural activities to improve farm productivity, conserve natural resources, protect biodiversity and promote environmental sustainability.

In agroforestry, trees are not planted only for timber. They may also provide fruits, fodder, firewood, shade, medicines, soil fertility improvement, wind protection and other environmental benefits.

Agroforestry is particularly important in Kenya because it helps farmers manage soil erosion, improve soil fertility, conserve water, provide livestock feed and reduce pressure on natural forests.

Examples of agroforestry practices in Kenya include:

- Planting grevillea trees along farm boundaries in agricultural areas.
- Growing fruit trees such as mangoes, avocados and citrus among food crops.
- Planting calliandra and leucaena for livestock fodder.
- Integrating trees with coffee and tea plantations.
- Planting indigenous trees such as croton and markhamia on farms.
- Growing trees on contours to control soil erosion.
- Establishing woodlots for firewood and timber.
- Planting trees around homesteads to provide shade and improve the environment.

Important terms used in agroforestry

1. Agroforestry: Integration of trees and shrubs with crops and/or livestock on the same land management unit.
2. Agroforestry tree: A tree deliberately grown on agricultural land to provide products, services or environmental benefits.
3. Shrub: A woody plant that is usually shorter than a tree and often has several stems arising near the ground.
4. Forest tree: A tree species commonly associated with woodland or forest ecosystems and which may be planted for timber, biodiversity or environmental conservation.
5. Fodder tree: A tree whose leaves, shoots, pods or fruits are used as feed for livestock.
6. Fruit tree: A tree grown to produce edible fruits for human consumption or sale.

7. Natural regeneration: The process through which vegetation re-establishes naturally from seeds, roots, stumps, seedlings or other existing plant structures without planting every individual plant.
8. Assisted natural regeneration: Protection and management of naturally occurring seedlings, root sprouts and other regenerating vegetation to encourage their growth.
9. Soil conservation: Practices that protect soil from erosion, degradation and loss of fertility.
10. Windbreak: A line or belt of trees or shrubs established to reduce wind speed and protect crops, livestock, soil and buildings.
11. Shelterbelt: A wider belt of trees and shrubs planted to provide protection against strong winds over a larger area.
12. Mulching: Covering the soil surface with organic or inorganic materials to conserve moisture, reduce erosion and suppress weeds.
13. Biodiversity: The variety of living organisms, including plants, animals and microorganisms, in an ecosystem.
14. Carbon sequestration: The process through which plants absorb carbon dioxide from the atmosphere and store carbon in their tissues and in the soil.
15. Woodlot: A small area of land deliberately planted with trees for products such as firewood, poles and timber.

1.4.2 CHARACTERISTICS OF AGROFORESTRY

Agroforestry has distinct characteristics that differentiate it from ordinary crop production and conventional forestry.

1. Integration of trees with agricultural activities

- Agroforestry involves growing trees and shrubs together with crops and/or livestock.
- Trees may be planted within crop fields, along boundaries, around homesteads or in grazing areas.
- The arrangement is planned to ensure that the different components benefit one another.
- Example: Growing grevillea trees along farm boundaries while cultivating maize and beans in the field.

2. Multiple land-use functions

- The same piece of land is used to produce several products and provide different environmental services.
- Trees may provide timber, fruits, firewood, fodder and shade.
- Crops provide food and income, while livestock provide meat, milk and manure.
- This helps farmers obtain more benefits from limited land.

3. Deliberate selection of tree species

- Farmers select trees according to their purpose, climate, soil type and compatibility with crops or livestock.
- Suitable trees should provide useful products without excessively competing with crops.
- Examples include calliandra for fodder, mango for fruits and suitable indigenous trees for conservation.

4. Different plant growth habits and root systems

- Agroforestry combines plants with different heights, crown shapes and root systems.
- Some trees have deep roots, while others have relatively shallow roots.
- Appropriate combinations can allow better use of sunlight, water and nutrients.
- However, tree roots and crowns must be managed to avoid excessive competition with crops.

5. Long-term land management

- Trees take longer to mature than most annual crops.
- Agroforestry therefore requires planning and continuous management over several years.
- Farmers may harvest annual crops while waiting for trees to mature.
- This allows both short-term and long-term benefits.

6. Environmental conservation

- Agroforestry protects the soil against erosion.
- Tree roots bind soil particles and stabilise slopes.
- Tree canopies reduce the impact of raindrops on the soil surface.
- Trees also provide habitats for birds, insects and other organisms.

7. Improvement of soil fertility

- Some agroforestry trees, particularly leguminous species, can contribute to soil fertility through biological nitrogen fixation when associated with compatible nitrogen-fixing microorganisms.
- Leaf litter decomposes and adds organic matter to the soil.
- Pruned leaves and branches can be used as green manure or mulch.
- Examples include calliandra, leucaena and sesbania.

8. Efficient use of available resources

- Trees, crops and livestock can use different resources within the same farm.
- Trees may obtain water and nutrients from deeper soil layers, depending on their rooting patterns.
- Crops use resources in the upper soil layers.

- Livestock utilise fodder from suitable trees and shrubs.
- Good planning reduces unnecessary competition.

9. Provision of a favourable microclimate

- Trees modify environmental conditions around crops and livestock.
- They can reduce wind speed, provide shade and moderate temperature.
- This may reduce heat stress in livestock and protect certain crops from harsh conditions.
- Excessive shading, however, may reduce the growth and yields of light-demanding crops.

10. Economic diversification

- Agroforestry provides different products that can be sold or consumed by the household.
- Farmers may earn income from fruits, timber, poles, fodder, honey and other tree products.
- This reduces dependence on one agricultural enterprise.

11. Adaptability to different farming systems

- Agroforestry can be practised in small-scale and large-scale farms.
- It can be integrated into crop farms, livestock farms, mixed farms and community restoration programmes.
- The species and arrangement are selected according to local conditions.

12. Use of both planted and naturally regenerating trees

- Agroforestry may involve planting nursery-raised seedlings.
- It may also involve protecting naturally growing trees and shrubs.
- This makes it possible to conserve existing vegetation while establishing additional useful trees.

1.4.3 TYPES OF AGROFORESTRY SYSTEMS

Agroforestry systems are classified according to the agricultural components integrated with trees.

A. Agrosilvicultural system

This is an agroforestry system in which trees or shrubs are grown together with agricultural crops.

The trees and crops may be grown simultaneously or in a planned sequence.

Examples:

- Growing maize and beans between rows of trees.
- Growing coffee under suitable shade trees.
- Planting fruit trees in a field where annual crops are also grown.

- Growing vegetables between widely spaced young fruit trees.

Characteristics of agrosilvicultural systems

1. Trees and crops are grown on the same land.
2. Trees may be planted in rows, boundaries or scattered arrangements.
3. The system can provide both food crops and tree products.
4. Trees may improve soil protection and provide organic matter.
5. Proper spacing is necessary to reduce competition for light, water and nutrients.

B. Silvopastoral system

This is an agroforestry system in which trees and shrubs are integrated with livestock and pasture production.

Trees provide shade, fodder, shelter and other benefits to livestock, while pasture provides grazing materials.

Examples:

- Cattle grazing under suitable scattered trees.
- Planting fodder trees such as calliandra and leucaena along livestock paddocks.
- Integrating suitable trees into pasture fields.
- Establishing trees around livestock enclosures for shade and shelter.

Characteristics of silvopastoral systems

1. Trees, pasture and livestock are integrated.
2. Trees may provide supplementary livestock feed.
3. Tree cover can provide shade and reduce heat stress.
4. Tree roots help stabilise soil.
5. Livestock manure can contribute nutrients to the soil.
6. Fencing or protection may be necessary to prevent animals from damaging young trees.

C. Agrosilvopastoral system

This is a system in which trees, agricultural crops and livestock are integrated on the same farm.

It combines the features of agrosilvicultural and silvopastoral systems.

Examples:

- Growing maize and beans, maintaining fruit trees and keeping dairy cattle on the same farm.
- Growing fodder trees around a farm where crops and livestock are also maintained.

- Integrating fruit trees, food crops and poultry production.

Characteristics

1. It integrates trees, crops and livestock.
2. It provides several farm products.
3. Crop residues may be used as livestock feed.
4. Livestock manure can be used to improve soil fertility.
5. Trees may provide fodder, fruits, timber and shade.
6. It requires proper planning to prevent competition and damage to crops and trees.

D. Other agroforestry arrangements

1. Boundary planting

- Trees are planted along farm boundaries.
- They may serve as windbreaks, sources of timber, poles, fruits or firewood.
- They can also mark farm boundaries.
- Example: Planting grevillea or suitable indigenous trees along farm edges.

2. Alley cropping

- Trees or shrubs are planted in rows with crops grown in the spaces between them.
- The trees may be pruned regularly to reduce shading.
- Pruned leaves and branches may be used as mulch or green manure.
- Example: Growing maize between rows of suitable fodder or soil-improving shrubs.

3. Home gardens

- Different trees, shrubs, crops and sometimes livestock are integrated around homesteads.
- They provide fruits, vegetables, shade, medicines and other household products.
- Example: Growing mangoes, avocadoes, vegetables and other useful plants around a homestead.

4. Woodlots

- A section of farmland is set aside for growing trees.
- Trees are grown for timber, firewood, poles or other products.
- Woodlots can reduce pressure on natural forests when managed sustainably.

5. Improved fallows

- Fast-growing trees or shrubs are planted on land that is temporarily taken out of annual crop production.
- The vegetation is managed to improve soil cover and organic matter.
- Some leguminous species may contribute nitrogen to the soil.
- The land is later returned to crop production.

6. Riparian agroforestry

- Suitable trees and shrubs are maintained or planted along rivers and streams.
- Vegetation helps stabilise riverbanks, filter runoff and protect water sources.
- Only appropriate species and management practices should be used near watercourses.

1.4.4 CHARACTERISTICS OF SUITABLE AGROFORESTRY TREES

Agroforestry trees should be selected carefully because not every tree is suitable for integration with crops and livestock.

A suitable agroforestry tree should provide useful products, conserve the environment and coexist with other farm enterprises without causing excessive competition.

A. General characteristics

1. Fast growth rate

- Suitable agroforestry trees should grow relatively fast and establish within a reasonable period.
- Fast-growing trees provide benefits such as shade, fodder, firewood and soil protection sooner.
- They may also provide income within a shorter period than slow-growing species.
- Examples include suitable varieties of calliandra, leucaena and grevillea.

2. Deep root system

- Trees with deep root systems may obtain water and nutrients from deeper soil layers.
- This can reduce competition with shallow-rooted crops when the species and spacing are appropriate.
- Deep roots also help anchor trees firmly in the soil.
- However, deep rooting alone does not guarantee that a tree will not compete with crops.

3. Small or manageable canopy

- Suitable trees should have a canopy that can be managed through pruning.
- A manageable canopy allows sufficient sunlight to reach crops growing beneath or between trees.
- Excessively dense crowns may cause shading and reduce crop yields.
- Farmers should select tree species according to the light requirements of associated crops.

4. Ability to improve soil fertility

- Some trees have the ability to contribute to soil fertility through nitrogen fixation.
- This occurs when compatible root-nodule bacteria form a relationship with the roots of certain leguminous trees.
- Their fallen leaves and pruned materials also add organic matter to the soil.
- Examples include calliandra, leucaena and sesbania.

5. Resistance or tolerance to pests and diseases

- Suitable agroforestry trees should be relatively resistant or tolerant to common pests and diseases in the area.
- Healthy trees require less corrective management and are more likely to survive.
- Farmers should use quality planting materials from reliable sources.

6. Adaptability to local climatic conditions

- Agroforestry trees should be suitable for the rainfall, temperature, altitude and other climatic conditions of the area.
- Trees selected for dry areas should tolerate periods of limited rainfall.
- Trees selected for wetter areas should be able to grow under the prevailing moisture conditions.
- Local indigenous species are often valuable choices because they may be adapted to local conditions.

7. Ability to withstand pruning

- Some agroforestry trees are regularly pruned to control their size and reduce competition with crops.
- Suitable species should recover well after appropriate pruning.
- Pruned leaves and branches may be used as livestock fodder, mulch or green manure.
- Calliandra is an example of a fodder tree that can be managed through repeated harvesting.

8. Multiple uses

- A good agroforestry tree should ideally provide more than one benefit.
- It may provide timber, firewood, fruits, fodder, shade, medicines or soil conservation services.
- Multiple-use trees improve the value obtained from limited farmland.

9. Non-invasive growth habit

- Suitable trees should not spread uncontrollably or become difficult to manage.
- Their roots, branches and natural regeneration should not excessively interfere with crops, buildings, drainage channels or neighbouring land.

- Farmers should avoid introducing invasive species into sensitive environments.

10. Good fodder quality where livestock feeding is intended

- Fodder trees should produce leaves and shoots that livestock can consume safely.
- Their leaves should have suitable nutritional value and acceptable palatability.
- Farmers should ensure that the species is suitable for the livestock being kept.
- Calliandra and suitable leucaena varieties are examples of fodder trees, although feeding levels and management should be appropriate to the species.

11. Ability to conserve soil and water

- Suitable trees should have root systems and canopy structures that help protect the soil.
- Their roots hold soil particles together.
- Their leaves and branches reduce the impact of raindrops.
- Tree litter helps cover the soil surface and improve infiltration.

12. Availability of quality planting materials

- The selected tree should have planting materials that can be obtained reliably.
- Seeds, seedlings or vegetative propagules should be accessible.
- Quality planting materials improve establishment and reduce the risk of failure.

13. Economic value

- Suitable agroforestry trees should provide products or services that meet household or market needs.
- Examples include fruit trees for food and sale, timber trees for construction and fodder trees for livestock feed.
- Farmers should consider the time required before the tree begins providing economic returns.

14. Compatibility with crops and livestock

- Trees should be compatible with the other enterprises on the farm.
- They should not excessively compete with crops for light, water and nutrients.
- They should not be poisonous to livestock.
- Their branches, leaves and fruits should be managed to prevent damage to crops and animals.

B. Characteristics of agroforestry trees for different purposes

1. Forest trees

Forest trees are grown on farms to provide timber, poles, firewood, shade, wind protection, biodiversity habitats and other environmental benefits.

Desirable characteristics

- Strong and well-developed stems.
- Good growth and survival under local conditions.
- Useful timber or wood properties where timber production is intended.
- Suitable root systems for stabilising soil.
- Manageable canopy size.
- Resistance or tolerance to common pests and diseases.
- Ability to withstand appropriate pruning where required.
- Adaptability to local rainfall and soil conditions.

Examples of forest trees suitable for appropriate agroforestry settings in Kenya

Tree	**Main uses**
Grevillea robusta	Timber, poles, shade and boundary planting.
Markhamia lutea	Shade, timber and environmental conservation.
Croton megalocarpus	Shade, biodiversity conservation and suitable wood uses.
Cordia africana	Timber, shade and farm diversification.
Prunus africana	Conservation and carefully regulated medicinal uses.
Podocarpus species	Timber and conservation in suitable highland environments.
Eucalyptus species	Poles, timber and fuelwood in suitable designated sites.

Note: Tree selection should take account of water availability, biodiversity, soil conditions and the intended use. Eucalyptus, for example, should be planted in appropriate locations and managed carefully, particularly near wetlands, rivers and water sources.

2. Fodder trees and shrubs

Fodder trees are woody plants whose leaves, shoots, pods or fruits are used as livestock feed.

They are particularly useful during dry periods when pasture and other green fodder may be limited.

Desirable characteristics of fodder trees

- Produce abundant leaves and tender shoots.
- Have good nutritional value.
- Are palatable to the intended livestock.
- Regrow well after harvesting or pruning.

- Tolerate repeated cutting where appropriate.
- Have relatively high leaf-to-stem ratios.
- Are adapted to local climatic conditions.
- Are safe for livestock when fed at recommended levels.
- Can be harvested without killing the plant.

Examples of fodder trees and shrubs in Kenya

Fodder tree/shrub	**Uses and characteristics**
Calliandra calothyrsus	Produces leafy fodder rich in protein; useful as supplementary feed.
Leucaena leucocephala	Provides nutritious leaves and pods; requires careful feeding management because it contains mimosine.
Sesbania sesban	Fast-growing leguminous shrub; provides fodder and may improve soil fertility.
Gliricidia sepium	Provides fodder, living fences and green manure; feeding should be managed appropriately.
Morus alba (mulberry)	Leaves can be used as livestock feed, including for some ruminants and silkworms.
Faidherbia albida	Provides pods and leaves for livestock and has value in dryland agroforestry.

Importance of fodder trees

1. Provide supplementary feed during dry seasons.
2. Improve the availability of livestock feed.
3. Diversify livestock diets.
4. Provide a source of protein and other nutrients.
5. Reduce dependence on purchased commercial feeds when properly integrated.
6. Provide green fodder during periods when pasture is scarce.
7. Some species contribute to soil fertility.
8. Their pruning materials may also be used as mulch or green manure.

3. Fruit trees

Fruit trees are grown in agroforestry systems to provide fruits for household consumption, sale and processing.

They can be planted along farm boundaries, in home gardens, within suitable crop fields or in orchards integrated with other farm enterprises.

Desirable characteristics

- Produce fruits of good quality.
- Adapt to local climatic and soil conditions.
- Have good productivity.
- Resist or tolerate common pests and diseases.
- Have manageable canopies.
- Provide economic returns.
- Have suitable root systems for the intended planting arrangement.
- Produce fruits with good market demand.

Examples of fruit trees in Kenya

Fruit tree	**Main uses**
Mango	Fruits for fresh consumption, processing and sale.
Avocado	Fruits for household consumption and commercial markets.
Citrus	Oranges, lemons and other fruits for consumption and processing.
Guava	Fruits for fresh consumption and processing.
Pawpaw (papaya)	Fruits for household consumption and sale.
Macadamia	Nuts for commercial processing and sale.
Passion fruit	Fruits for fresh consumption and juice processing; commonly grown on supports rather than as a conventional tree.
Loquat	Fruits for consumption and sale in suitable environments.

1.4.5 NATURAL REGENERATION

Meaning of natural regeneration

Natural regeneration is the process through which trees, shrubs and other vegetation re-establish and grow naturally in an area without the deliberate planting of every individual plant.

It occurs when plants reproduce and regenerate through naturally available seeds, roots, stumps, shoots, suckers or other vegetative structures.

Natural regeneration is an important approach to environmental restoration because it allows degraded land and cleared areas to recover vegetation using existing natural regeneration processes.

For example, when a farmer stops clearing naturally growing tree seedlings in a field and protects them from livestock and repeated cutting, the seedlings may grow into mature trees.

Natural regeneration may also occur when seeds from nearby trees are dispersed by wind, birds, animals or water and germinate in suitable locations.

A. How natural regeneration takes place

Natural regeneration occurs through several processes.

1. Regeneration from seeds

- Mature trees produce seeds.
- Seeds are dispersed by wind, water, birds, animals or gravity.
- When seeds reach favourable conditions, they germinate.
- The seedlings develop roots, stems and leaves.
- With suitable protection and management, the seedlings grow into mature trees.

Examples:

- Acacia species regenerating from seeds in suitable dryland environments.
- Indigenous trees regenerating from seeds dispersed by birds.
- Grevillea seedlings emerging from seeds in suitable farm conditions.

2. Regeneration from tree stumps

- Some trees produce new shoots from existing stumps after the main stem has been cut or damaged.
- These shoots are known as coppice shoots.
- The shoots use the established root system of the parent tree.
- Farmers can select and retain healthy shoots to develop into new stems.

Examples: Suitable Eucalyptus species and certain indigenous tree species.

3. Regeneration through root suckers

- Some trees produce new shoots from buds on their roots.
- The shoots emerge from the soil near the parent tree.
- They can develop into independent plants.
- Farmers may protect suitable root suckers to increase tree cover.

4. Regeneration through underground stems

- Some woody or perennial plants produce underground stems that develop new shoots.

- These structures can spread and establish new vegetation.
- New shoots may emerge from underground growing points after the above-ground parts are damaged.

5. Regeneration through natural seed banks

- Some seeds remain dormant in the soil for a period of time.
- When suitable conditions occur, such as adequate moisture, light or disturbance of the soil surface, they germinate.
- This can contribute to the recovery of vegetation after land disturbance.

6. Regeneration through animal-assisted seed dispersal

- Birds and mammals may feed on fruits and later deposit seeds in other locations.
- Seeds may germinate where suitable soil and moisture conditions are available.
- This helps vegetation spread beyond the immediate area occupied by parent trees.

B. Types of natural regeneration

1. Unassisted natural regeneration

This is the recovery of vegetation without deliberate human intervention.

- Seeds are dispersed naturally.
- Seeds germinate under favourable conditions.
- Seedlings and other naturally emerging plants grow without active human management.
- It is more likely to succeed where soil conditions, moisture and protection from disturbance are favourable.

Example: Natural growth of indigenous trees in an abandoned field close to an existing woodland.

2. Assisted natural regeneration (ANR)

Assisted natural regeneration is an approach in which people protect, manage and encourage naturally occurring seedlings, root suckers and coppice shoots to restore vegetation.

It does not rely mainly on planting new seedlings. Instead, it makes better use of existing natural regeneration.

Example: A farmer identifies young indigenous tree seedlings in a degraded grazing area, protects them from livestock and cutting, controls competing weeds and allows them to grow.

Main activities involved in assisted natural regeneration

1. Surveying the land

- Examine the area to identify naturally growing seedlings, root suckers and tree stumps.
- Identify areas with the potential for natural vegetation recovery.

2. Identifying desirable species

- Identify useful indigenous and other suitable tree species.
- Select species that are appropriate for the local environment.

3. Protecting young seedlings

- Protect naturally growing seedlings from livestock, fire, trampling and unnecessary cutting.
- Use simple guards or temporary fencing where necessary.

4. Controlling competing vegetation

- Remove or manage weeds that excessively compete with young trees for light, moisture and nutrients.
- Avoid unnecessary clearing of useful vegetation.

5. Managing tree density

- Select and retain suitable seedlings at appropriate spacing.
- Remove or manage excessive growth where competition becomes a problem.

6. Managing coppice shoots

- Identify healthy shoots growing from tree stumps.
- Retain suitable shoots and remove unwanted ones where appropriate.
- Protect retained shoots until they establish.

7. Preventing uncontrolled grazing

- Restrict livestock from areas where young trees are regenerating.
- Use controlled grazing only when the vegetation is sufficiently established and management permits it.

8. Controlling fires

- Establish appropriate firebreaks where necessary.
- Avoid uncontrolled burning that destroys seedlings and young trees.

9. Monitoring regeneration

- Regularly observe seedling survival, growth and damage.
- Replace missing vegetation through enrichment planting where natural regeneration is insufficient.

10. Community participation

- Involve farmers, learners and local communities in protecting regenerating vegetation.
- Encourage agreed rules on cutting, grazing and fire management.

1.4.6 NATURAL REGENERATION AS AN APPROACH TO ENVIRONMENTAL RESTORATION

Environmental restoration is the process of assisting the recovery of degraded ecosystems so that they regain their ecological functions, biodiversity and ability to provide useful services.

Natural regeneration is one way of restoring degraded forests, woodlands, grazing lands, riverbanks and other ecosystems.

How natural regeneration restores the environment

1. Restores tree cover

- Natural regeneration enables new trees and shrubs to grow in areas where vegetation has been cleared.
- This increases vegetation cover and improves the appearance and ecological condition of degraded land.

2. Reduces soil erosion

- Tree roots bind soil particles together.
- Leaves and branches reduce the direct impact of raindrops.
- Ground vegetation slows surface runoff.
- This reduces the removal of fertile topsoil.

3. Improves soil fertility

- Fallen leaves, twigs and other organic materials decompose.
- Decomposition adds organic matter to the soil.
- Some regenerating leguminous trees may contribute nitrogen through biological nitrogen fixation.

4. Improves water infiltration

- Roots create channels through which water can enter the soil.
- Leaf litter protects the soil surface.
- Reduced surface runoff gives more water an opportunity to infiltrate.

5. Protects water catchment areas

- Regenerating vegetation around water catchments helps stabilise soil.
- Vegetation can reduce sediment movement into rivers, streams and reservoirs.
- It contributes to the protection of water sources.

6. Restores habitats for wildlife

- Trees provide nesting and feeding sites for birds and other organisms.
- Vegetation offers shelter to insects, small mammals and other wildlife.
- This supports biodiversity recovery.

7. Helps restore ecological balance

- Regenerating vegetation provides food and habitats for different organisms.
- It supports interactions between plants, animals and microorganisms.
- It can help restore ecological processes such as nutrient cycling and seed dispersal.

8. Helps reduce atmospheric carbon dioxide

- Growing trees absorb carbon dioxide during photosynthesis.
- Carbon is stored in trunks, branches, roots and soil organic matter.
- This contributes to climate-change mitigation.

9. Reduces land degradation

- Vegetation protects exposed land against wind and water erosion.
- Roots stabilise soil on slopes and other vulnerable areas.
- This can help reverse some forms of land degradation.

10. Supports recovery of indigenous vegetation

- Natural regeneration can encourage the recovery of locally adapted indigenous tree species.
- It may preserve genetic diversity and ecological relationships.
- It is especially valuable where nearby natural vegetation can provide seeds.

11. Improves local microclimates

- Increasing tree cover can provide shade and reduce surface temperatures.
- Trees may reduce wind speed and improve conditions for other vegetation.
- These effects depend on tree density, species and local environmental conditions.

12. Supports community livelihoods

- Properly managed regenerating vegetation may provide fruits, fodder, poles, medicines and other non-timber products.
- It can improve access to useful natural resources while maintaining environmental protection.

C. Advantages of natural regeneration

1. Relatively low establishment costs

- Natural regeneration makes use of existing seeds, seedlings, stumps and root systems.
- It reduces the need to purchase large quantities of seeds and nursery seedlings.

2. Conserves indigenous tree species

- It allows naturally occurring local species to recover.
- This can help maintain locally adapted vegetation.

3. Reduces labour requirements

- Where regeneration is already occurring, farmers may only need to protect and manage existing seedlings.
- This can be less labour-intensive than planting every tree individually.

4. Uses existing natural processes

- It takes advantage of seed dispersal, germination, coppicing and natural root development.

5. Supports biodiversity

- It may encourage the recovery of different plant species and the organisms associated with them.

6. Improves soil protection

- Growing vegetation protects the soil from wind and water erosion.

7. Conserves soil moisture

- Leaf litter and vegetation cover reduce direct exposure of the soil to sunlight and raindrops.
- This can reduce evaporation and improve water infiltration.

8. May improve survival of established seedlings

- Naturally established seedlings may already be adapted to the local soil and environmental conditions.

9. Restores degraded ecosystems

- It can help recover vegetation in degraded farmland, woodland, grazing land and other landscapes.

10. Supports climate-change mitigation

- Growing trees absorb and store carbon.

D. Disadvantages and limitations of natural regeneration

1. Slow recovery in severely degraded areas

- Where seeds, stumps and root systems have been destroyed, natural regeneration may be very limited.
- Such areas may require active planting.

2. Dependence on seed sources

- Natural regeneration may be poor where mature parent trees are far away or have been removed.

3. Uncertain species composition

- The species that regenerate may not always be those preferred by farmers or conservation managers.

4. Competition from weeds

- Fast-growing weeds and grasses may compete with young tree seedlings for moisture, light and nutrients.

5. Damage by livestock

- Grazing animals may eat, trample or break young seedlings.

6. Damage by fire

- Uncontrolled fires can destroy seedlings, root suckers and young trees.

7. Slow economic returns

- Some naturally regenerated trees take many years to become suitable for timber, poles or other products.

8. Requires protection and monitoring

- Regenerating vegetation may fail if it is not protected from cutting, grazing and other disturbances.

9. Invasive species may dominate

- In some degraded areas, invasive plants may establish faster than desirable indigenous trees.
- They may suppress the growth of useful native vegetation.

10. Limited control over spacing

- Naturally emerging seedlings may grow too close together or in unsuitable locations.

11. Not suitable for every degraded site

- Areas with severely eroded soil, little remaining vegetation or unsuitable environmental conditions may require additional restoration measures.

12. Conflicts over land use

- Farmers and communities may need to agree on grazing restrictions, tree protection and harvesting rules.

E. Factors influencing successful natural regeneration

Factor	Explanation
Availability of parent trees	Nearby mature trees provide seeds for regeneration.
Seed viability	Healthy seeds have a greater chance of germinating.
Rainfall and moisture	Adequate moisture supports germination and seedling growth.
Soil condition	Fertile, well-structured soils generally support better seedling establishment.
Temperature	Suitable temperatures support germination and growth.
Protection from livestock	Prevents browsing and trampling of seedlings.
Fire management	Prevents destruction of young regenerating vegetation.
Weed control	Reduces competition for water, nutrients and light.
Human activities	Uncontrolled cutting and land clearing may destroy regenerating vegetation.
Seed dispersal agents	Birds, mammals, wind and water help distribute seeds.
Light availability	Some species require adequate sunlight, while others can establish under partial shade.
Land degradation level	Severely degraded land may have limited natural regeneration potential.

F. Differences between natural regeneration and artificial tree planting

Natural regeneration	Artificial tree planting
New vegetation develops from naturally available seeds, roots, stumps or shoots.	People deliberately plant seeds, seedlings or other planting materials.
Makes use of existing natural regeneration processes.	Requires preparation of planting materials and planting sites.
May require relatively low initial establishment costs.	May involve costs for seeds, nursery materials, labour and transport.
Species composition may be difficult to control.	Farmers can select the species and varieties to plant.
Can conserve naturally occurring indigenous vegetation.	Can introduce selected indigenous or suitable exotic species.
May be slow or unreliable where natural seed sources are limited.	Can establish vegetation in selected locations where natural regeneration is inadequate.

Requires protection and management of naturally growing plants.	Requires nursery management, transplanting and aftercare.

Important: Natural regeneration and artificial planting can be used together. For example, a farmer can protect naturally growing indigenous trees and plant additional fruit or fodder trees where natural regeneration is insufficient. This is known as an integrated restoration approach.

1.4.7 GROWING AGROFORESTRY TREES

Growing agroforestry trees involves selecting suitable species, obtaining quality planting materials, establishing a nursery, raising seedlings, preparing planting sites, transplanting and managing the trees until maturity.

Successful establishment requires careful planning because trees may remain on the farm for many years.

A. Selecting suitable agroforestry trees

Before establishing agroforestry trees, the farmer should consider the following:

1. Purpose of planting

- Decide whether the trees are intended for timber, fruits, fodder, shade, wind protection, soil conservation or other uses.
- Example: Select calliandra for fodder and mango for fruit production.

2. Climatic conditions

- Select trees that can grow under the local rainfall and temperature conditions.
- Avoid species that require climatic conditions unavailable in the area.

3. Soil type

- Consider soil depth, drainage, fertility and texture.
- Some trees perform better in deep, well-drained soils, while others tolerate poorer soil conditions.

4. Availability of water

- Select species whose water requirements are suitable for the area.
- Avoid inappropriate planting of water-demanding trees in sensitive water catchment areas.

5. Growth rate

- Consider how quickly the tree establishes and produces the intended products.

6. Rooting characteristics

- Consider the depth and spread of the roots.
- Trees with extensive surface roots may compete with crops or interfere with structures.

7. Canopy characteristics

- Select trees whose crowns can be managed without excessive shading of crops.

8. Pest and disease resistance

- Prefer healthy planting materials and species or varieties that are suitable for local pest and disease conditions.

9. Economic value

- Consider the market demand for fruits, timber, poles, fodder and other products.

10. Environmental suitability

- Avoid invasive species and select trees that do not threaten local biodiversity.

11. Availability of planting materials

- Select species for which quality seeds or seedlings can be obtained.

12. Compatibility with other farm enterprises

- Consider how trees will interact with crops, pasture, livestock, buildings and water sources.

B. Sources of agroforestry tree planting materials

Agroforestry trees can be established using different planting materials.

1. Seeds

- Seeds are obtained from mature, healthy parent trees.
- They are planted directly in the field or raised in a nursery.
- Seeds should be mature, viable and free from pests and diseases.
- Some tree seeds may require special pretreatment to improve germination.

Examples: Grevillea, acacia and suitable indigenous tree species.

2. Nursery-raised seedlings

- Seeds are germinated and raised in a nursery until seedlings are strong enough for transplanting.
- Seedlings may be raised in polythene pots, root trainers or suitable nursery beds.
- They should be healthy and have well-developed roots and shoots.

3. Vegetative planting materials

- Some agroforestry trees can be propagated using cuttings, root suckers or other vegetative structures.
- These materials may be used to maintain desirable characteristics of selected parent plants.

Examples: Calliandra and suitable fodder tree species can be propagated through appropriate vegetative methods.

4. Naturally regenerated seedlings

- Farmers can identify suitable naturally growing seedlings on their farms.
- The seedlings can be protected where they are already growing or carefully transplanted where appropriate.
- This method makes use of existing natural regeneration.

1.4.8 ESTABLISHING AND MANAGING AN AGROFORESTRY TREE NURSERY

Meaning of a tree nursery

A tree nursery is a prepared area where seeds, cuttings or other planting materials are established and maintained until they develop into healthy seedlings suitable for transplanting.

A nursery provides controlled conditions that promote germination, growth and development of young trees.

A. Requirements for establishing a tree nursery

1. Suitable site

- The nursery should be located on accessible land.
- It should be protected from livestock and unnecessary disturbance.
- The site should have suitable drainage.

2. Reliable water supply

- Water is needed for watering seeds and seedlings.
- The source may be rainwater harvested and stored, a suitable water tank or another reliable source.

3. Suitable soil or growing medium

- The growing medium should support root development.
- It should have adequate drainage, moisture retention and nutrients.

4. Shade materials

- Shade nets, grass or other suitable materials may be used to protect young seedlings from excessive sunlight.
- Shade should be adjusted as seedlings grow.

5. Containers

- Polythene pots, root trainers, seed trays or other suitable containers may be used.
- Containers should have drainage holes.

6. Tools and equipment

- Watering cans, spades, hoes, forks, wheelbarrows, sieves and labels may be required.

7. Seeds or other planting materials

- Obtain suitable, healthy and viable planting materials from reliable sources.

8. Fencing

- A fence protects the nursery from livestock and other animals.

9. Labelling materials

- Labels help identify species, varieties and dates of sowing.

10. Labour

- Labour is needed for preparing the site, filling containers, sowing seeds, watering, weeding and other nursery operations.

B. Steps in establishing a tree nursery

Step 1: Site selection

Select a suitable nursery location based on the following:

- Accessibility.
- Availability of water.
- Good drainage.
- Suitable soil conditions.
- Protection from strong winds.
- Availability of shade.
- Security against livestock and other animals.
- Adequate space for nursery operations.

Step 2: Clearing the site

- Remove unwanted vegetation, stones and rubbish.
- Clear the area without causing unnecessary soil disturbance.
- Remove weeds that may compete with nursery seedlings.
- Ensure the site is clean and accessible.

Step 3: Preparing nursery beds

- Mark out the nursery beds.
- Construct raised beds where necessary to improve drainage.
- Level the surface.

- Leave suitable pathways between beds for movement and management.
- Ensure beds are accessible for watering and inspection.

Step 4: Preparing the growing medium

A suitable growing medium should support germination, root growth, aeration and moisture retention.

A mixture may contain:

- Topsoil.
- Well-decomposed compost or manure.
- Clean river sand or another suitable material to improve drainage.

The proportions depend on the tree species and the growing medium available.

Important precautions:

- Do not use fresh, undecomposed manure.
- Avoid soil contaminated with chemicals or disease-causing organisms.
- Avoid excessively clayey or waterlogged growing media.
- Sieve the medium where necessary to remove stones and large debris.

Step 5: Filling containers

1. Select suitable containers.
2. Ensure that they have adequate drainage holes.
3. Fill them with the prepared growing medium.
4. Firm the medium gently without compacting it excessively.
5. Arrange the containers neatly in nursery beds.
6. Water lightly before sowing where necessary.

Step 6: Obtaining and preparing seeds

- Obtain seeds from healthy and desirable parent trees.
- Select mature and viable seeds.
- Remove damaged, mouldy or insect-attacked seeds.
- Clean seeds where necessary.
- Identify whether the species requires pretreatment before sowing.

Common seed pretreatment methods

a) Soaking in water

- Seeds are soaked in clean water for a suitable period depending on the species.
- This may soften the seed coat and encourage water absorption.
- It is useful for certain seeds with hard seed coats.

b) Scarification

- The hard seed coat is carefully scratched, nicked or weakened to allow water entry.
- Care must be taken not to damage the embryo.
- It is useful for some hard-coated seeds.

c) Hot-water treatment

- Some hard-coated seeds are treated with hot water under a species-specific procedure.
- The treatment helps soften the seed coat.
- Excessive heat may kill the embryo, so recommended methods should be followed.

d) Removal of fleshy coverings

- Fleshy fruit coverings may be removed from certain seeds before sowing.
- Cleaning reduces the risk of rotting and may assist germination.

Note: Not all tree seeds require pretreatment. Some species germinate readily when planted directly.

Step 7: Sowing seeds

1. Select suitable containers or nursery beds.
2. Sow seeds at an appropriate depth according to their size and species requirements.
3. Cover lightly with the growing medium where necessary.
4. Avoid sowing seeds too deeply.
5. Water gently.
6. Label the containers or beds with the species name and sowing date.
7. Provide suitable shade and protection.

Step 8: Watering

- Water the nursery regularly according to weather conditions and seedling requirements.
- Apply water gently to avoid exposing seeds or damaging young seedlings.
- Avoid excessive watering because it can cause waterlogging, seed rotting and damping-off disease.

- Watering is often best done during cooler parts of the day.

Step 9: Shading

- Provide shade to protect young seedlings from excessive sunlight.
- Use shade materials that allow adequate air movement.
- Gradually reduce shade as seedlings become established and approach transplanting.

Step 10: Weeding

- Remove weeds growing in containers and nursery beds.
- Weeds compete with seedlings for light, water and nutrients.
- Hand weeding is often suitable because it reduces damage to young roots.

Step 11: Pricking out

Pricking out is the process of transferring young seedlings from a crowded seedbed to individual containers or wider spacing to allow proper growth.

Procedure:

1. Water the seedbed before removing seedlings.
2. Select healthy seedlings.
3. Lift seedlings carefully using a suitable tool.
4. Hold seedlings by their leaves rather than squeezing the delicate stems.
5. Make a hole in the prepared container.
6. Place the seedling roots carefully into the hole.
7. Cover the roots with growing medium.
8. Firm the medium gently around the roots.
9. Water the seedlings.
10. Place them under suitable shade as they recover.

Step 12: Pest and disease control

- Inspect seedlings regularly.
- Remove diseased or badly damaged seedlings.
- Maintain nursery cleanliness.
- Avoid overcrowding.

- Use appropriate pest and disease control measures when necessary.
- Ensure that watering and drainage are properly managed.

Step 13: Hardening off

Hardening off is the gradual adjustment of nursery seedlings to the environmental conditions they will experience after transplanting.

It helps seedlings withstand field conditions.

Procedure:

1. Gradually reduce the amount of shade.
2. Gradually reduce watering without allowing seedlings to wilt severely.
3. Increase exposure to normal sunlight and airflow.
4. Monitor the seedlings for signs of stress.
5. Maintain suitable care until they are ready for transplanting.

Step 14: Sorting and selecting seedlings

- Select healthy and vigorous seedlings.
- Choose seedlings with strong stems and well-developed roots.
- Remove weak, diseased or badly deformed seedlings.
- Group seedlings according to species and size.
- Prepare the selected seedlings for transportation and transplanting.

1.4.9 TRANSPLANTING AGROFORESTRY TREE SEEDLINGS

Meaning of transplanting

Transplanting is the process of moving a seedling from a nursery bed or container and planting it in its permanent growing position in the field.

It is carried out when seedlings have developed sufficiently to withstand field conditions.

Transplanting should be done carefully to minimise damage to roots and reduce transplanting shock.

A. Factors to consider before transplanting

1. Seedling age and size

- Seedlings should be sufficiently developed to withstand field conditions.
- The appropriate size varies with the tree species.

2. Root development

- Seedlings should have healthy, well-developed roots.
- Roots should not be severely twisted, damaged or excessively crowded.

3. Weather conditions

- Transplanting is preferably done when there is adequate soil moisture.
- In rain-fed areas, the onset of reliable rains is often suitable.
- Avoid transplanting during extremely hot, dry or windy conditions.

4. Condition of the planting site

- The site should be prepared and free from excessive weeds.
- Planting holes should be ready before seedlings are removed from containers.

5. Availability of water

- Water should be available for watering seedlings immediately after planting when necessary.

6. Species requirements

- Different tree species require different planting depths, spacing and site conditions.

7. Protection

- The planting site should be protected from livestock, fire and physical damage.

8. Purpose of planting

- Spacing and arrangement should reflect whether trees are intended for fodder, fruits, timber, windbreaks or soil conservation.

B. Procedure for transplanting agroforestry seedlings

Step 1: Prepare the planting site

- Identify the positions where trees will be planted.
- Clear unwanted weeds and vegetation around the planting points.
- Mark the spacing according to the species and intended use.
- Prepare planting holes before bringing seedlings to the field.

Step 2: Dig planting holes

- Dig holes large enough to accommodate the roots without bending them.
- Separate topsoil from subsoil where appropriate.

- Break up hard soil at the bottom of the hole.
- The dimensions depend on the tree species, soil condition and seedling size.

Step 3: Prepare the seedlings

- Water seedlings before transplanting to keep the root ball moist.
- Remove damaged or unhealthy seedlings.
- Handle seedlings carefully to avoid breaking stems or disturbing roots.
- Transport seedlings in a way that protects them from strong wind and excessive sunlight.

Step 4: Remove seedlings from containers

- Carefully remove the polythene pot or container.
- Support the root ball to prevent it from breaking apart.
- Avoid pulling the seedling by its stem.
- Where roots are twisted or severely root-bound, carefully correct the problem without unnecessarily damaging the roots.

Step 5: Plant the seedlings

1. Place the seedling upright in the centre of the planting hole.
2. Ensure that the root collar is approximately at ground level.
3. Spread the roots naturally without bending them upwards.
4. Return the topsoil around the roots.
5. Firm the soil gently to remove large air spaces.
6. Avoid burying the stem too deeply.

Step 6: Water after transplanting

- Apply sufficient water to settle the soil around the roots.
- Watering helps reduce transplanting shock where soil moisture is inadequate.
- Avoid excessive watering in poorly drained soils.

Step 7: Mulch around the seedlings

- Apply dry grass, crop residues or other suitable organic materials around the seedling.
- Mulching conserves soil moisture and suppresses weeds.
- Leave a small clear space around the stem to reduce the risk of rotting and pest damage.

Step 8: Protect the seedlings

- Use tree guards, stakes or fencing where necessary.
- Protect young trees from livestock, wildlife, fire and accidental damage.
- In windy areas, provide suitable support where required.

Step 9: Monitor establishment

- Check seedlings regularly after planting.
- Observe wilting, pest attack, disease symptoms and physical damage.
- Water when necessary.
- Replace seedlings that fail to establish.

C. Importance of transplanting at the onset of rains

1. Improves seedling survival

- Adequate soil moisture supports root establishment.

2. Reduces watering costs

- Rainfall supplies part of the water required by young seedlings.

3. Reduces transplanting shock

- Moist soil helps seedlings recover from root disturbance.

4. Encourages root development

- Suitable soil moisture supports the development of new roots.

5. Provides a longer establishment period

- Seedlings have more time to establish before the next dry period.

6. Reduces labour requirements

- Farmers may spend less time carrying and applying water.

1.4.10 SPACING AND ARRANGEMENT OF AGROFORESTRY TREES

Spacing refers to the distance maintained between trees or between trees and other crops during planting.

Correct spacing is important because it influences sunlight availability, root competition, airflow, tree development and crop yields.

A. Factors influencing spacing

1. Purpose of planting

- Trees grown for timber may require different spacing from trees grown for fodder or wind protection.

2. Tree species

- Large trees generally require more space than small shrubs.

3. Canopy size

- Trees with wide crowns need adequate space to reduce excessive shading.

4. Root system

- Trees with extensive root systems may require wider spacing to reduce competition.

5. Associated crops

- Light-demanding crops may require wider spacing between trees.

6. Soil fertility

- Trees growing on fertile soils may develop larger crowns and require appropriate spacing.

7. Rainfall and water availability

- In areas with limited water, high tree density may increase competition for moisture.

8. Farm size and shape

- Available land influences the number and arrangement of trees.

9. Management practices

- Regular pruning may allow some trees to be grown at closer spacing.

10. Accessibility

- Adequate spaces should be left for movement, machinery and farm operations where necessary.

B. Common arrangements of agroforestry trees

1. Boundary planting

Trees are planted along the edges of a farm.

Uses:

- Marking farm boundaries.
- Providing wind protection.
- Producing timber and poles.
- Providing fruits or fodder.
- Reducing wind erosion.

2. Scattered tree planting

Individual trees are maintained at selected positions within crop fields or grazing areas.

Uses:

- Providing shade.
- Protecting soil.
- Providing fruits and fodder.
- Supporting biodiversity.
- Improving the farm microclimate.

3. Row planting

Trees are planted in straight lines at planned intervals.

Uses:

- Facilitating farm operations.
- Simplifying pruning and harvesting.
- Supporting alley cropping.
- Improving organisation of farm space.

4. Contour planting

Trees and shrubs are planted along contour lines across slopes.

Uses:

- Reducing the speed of surface runoff.
- Trapping soil particles.
- Reducing soil erosion.
- Improving water infiltration.
- Stabilising sloping land.

5. Woodlot arrangement

Trees are planted in a designated section of the farm.

Uses:

- Producing firewood.

- Producing poles and timber.
- Reducing pressure on natural forests.
- Providing long-term farm income.

1.4.11 MANAGEMENT OF AGROFORESTRY TREES

After transplanting, agroforestry trees require proper management to ensure healthy growth, survival and productivity.

1. Watering

- Young trees require adequate moisture for establishment.
- Water seedlings during dry periods where irrigation is available.
- Watering should be based on soil moisture and the requirements of the species.
- Avoid waterlogging, which can cause root rotting.

2. Mulching

- Apply suitable organic materials around young trees.
- Mulch reduces evaporation from the soil surface.
- It suppresses weeds and moderates soil temperature.
- As organic mulch decomposes, it contributes organic matter to the soil.
- Keep mulch away from direct contact with the stem to reduce rotting.

3. Weeding

- Remove weeds around young trees.
- Weeds compete with trees for nutrients, moisture and sunlight.
- Keep the area around seedlings relatively weed-free.
- Avoid damaging tree roots when weeding.

4. Fertiliser and manure application

- Apply well-decomposed manure or recommended fertilisers where necessary.
- Organic manure improves soil structure and supplies nutrients.
- Fertiliser application should be based on soil fertility and species requirements.
- Avoid placing fertiliser directly against the stem or roots.

5. Pruning

Pruning is the removal of selected branches, shoots or parts of a tree to improve its growth, shape, health or productivity.

Reasons for pruning agroforestry trees

- To reduce excessive shading of crops.
- To improve the shape of trees.
- To remove dead and diseased branches.
- To encourage desirable branching.
- To provide fodder and mulch materials.
- To improve airflow through the canopy.
- To remove damaged branches that may fall and cause injuries.

Common types of pruning

a) Formative pruning

- Carried out when trees are young.
- It helps develop a strong and desirable tree structure.
- It removes poorly positioned or competing branches.

b) Sanitary pruning

- Involves removing dead, diseased or damaged branches.
- It helps improve tree health and reduces sources of infection.

c) Crown thinning

- Selected branches are removed to reduce excessive crown density.
- It allows more light and air to pass through the canopy.

d) Pollarding

- The upper branches of a tree are cut back at a suitable height to encourage new shoots.
- It may be used to obtain fodder, fuelwood or other products from suitable tree species.

e) Coppicing

- A tree stem is cut near ground level to encourage new shoots from the stump.
- It is used in managing suitable trees for poles, fuelwood and repeated harvesting.

Precautions during pruning

- Use sharp and clean tools.
- Avoid removing too many branches at once.
- Make appropriate cuts to reduce damage.
- Avoid pruning at unsuitable times for the species.
- Do not damage the main stem unnecessarily.
- Dispose of diseased branches appropriately.

6. Pest and disease control

- Inspect trees regularly for signs of pests and diseases.
- Remove and dispose of heavily infected plant parts appropriately.
- Maintain proper spacing and airflow.
- Use suitable control methods based on the pest or disease identified.
- Obtain professional advice where serious outbreaks occur.

7. Protection from livestock

- Fence young trees or use individual tree guards.
- Avoid uncontrolled grazing around young trees.
- Protect stems from browsing, rubbing and trampling.
- Where appropriate, allow controlled grazing after trees have become sufficiently established.

8. Protection from fire

- Establish firebreaks in areas at risk of bush fires.
- Remove excessive dry vegetation from sensitive areas.
- Avoid uncontrolled burning.
- Organise community awareness on fire prevention.

9. Replacement of dead seedlings

- Inspect the farm to identify seedlings that have failed.
- Replace them with healthy planting materials.
- Replacement is preferably done when soil moisture is adequate.
- Identify possible causes of failure to avoid repeated losses.

10. Training and support

- Stake young trees where necessary to support them against strong winds.
- Remove supports when they are no longer needed.
- Avoid tying materials too tightly around the stem.

11. Soil and water conservation

- Maintain mulch and ground cover.
- Establish suitable contour structures on slopes.
- Avoid cultivation that exposes soil around tree roots.
- Manage drainage to prevent erosion and waterlogging.

12. Record keeping

Farmers should maintain records showing:

- Tree species planted.
- Source of planting materials.
- Number of seedlings planted.
- Date of planting.
- Spacing used.
- Survival rate.
- Pruning and management activities.
- Pest and disease observations.
- Products harvested.
- Income obtained from tree products.

1.4.12 IMPORTANCE OF AGROFORESTRY IN ENVIRONMENTAL CONSERVATION

Agroforestry contributes to environmental conservation by integrating trees into agricultural landscapes. It helps protect soil, water, biodiversity and the climate while supporting agricultural production.

1. Control of soil erosion

- Tree roots bind soil particles together.
- Roots help stabilise slopes and riverbanks.
- Tree canopies reduce the direct impact of raindrops on the soil.
- Fallen leaves form a protective layer on the soil surface.

- Trees and shrubs planted along contours slow surface runoff.
- This reduces the loss of fertile topsoil.

Example: Planting suitable shrubs and trees along contours on sloping farms in parts of the Kenyan highlands.

2. Improvement of soil fertility

- Fallen leaves, twigs and other organic materials decompose and add organic matter to the soil.
- Organic matter improves soil structure and water-holding capacity.
- Some leguminous trees fix atmospheric nitrogen through symbiotic relationships with root-nodule bacteria.
- Pruned materials can be incorporated into the soil or used as mulch.
- Improved soil conditions support crop growth.

Examples: Calliandra, leucaena and sesbania.

3. Conservation of water

- Tree roots improve soil structure and may create channels that facilitate water infiltration.
- Leaf litter reduces direct exposure of soil to sunlight.
- Tree cover can reduce surface runoff.
- Vegetation along watercourses helps trap sediment before it reaches water bodies.
- Properly selected trees contribute to the protection of water catchments.

Example: Maintaining suitable indigenous vegetation along riverbanks and around springs.

4. Reduction of wind erosion

- Trees and shrubs act as windbreaks.
- They reduce wind speed near the ground.
- This reduces the movement of loose soil particles.
- Windbreaks also protect crops from damage caused by strong winds.

Example: Establishing suitable rows of trees around exposed farms.

5. Carbon sequestration and climate-change mitigation

- Trees absorb carbon dioxide during photosynthesis.
- Carbon is stored in trunks, branches, leaves and roots.
- Organic matter from trees can increase carbon storage in the soil.
- Agroforestry therefore contributes to reducing the amount of carbon dioxide in the atmosphere.

- It also provides renewable tree products that may reduce pressure on some natural forest resources.

6. Conservation of biodiversity

- Trees provide habitats for birds, insects and other organisms.
- They provide nesting sites, food and shelter.
- A variety of tree species can support different organisms.
- Agroforestry may create links between fragmented natural habitats.
- Indigenous trees are particularly valuable in maintaining local biodiversity.

7. Protection of water catchment areas

- Trees help stabilise soils in water catchment areas.
- Vegetation reduces the movement of sediment into rivers and reservoirs.
- Root systems help hold riverbanks and slopes together.
- Suitable tree cover contributes to the long-term protection of water sources.

8. Improvement of the microclimate

- Tree canopies provide shade.
- Trees reduce wind speed.
- They may moderate extreme temperatures around crops and livestock.
- They can reduce heat stress in animals.
- Suitable shade may improve conditions for shade-tolerant crops.

9. Prevention of desertification and land degradation

- Tree cover protects exposed land.
- Roots help stabilise soil.
- Organic matter improves soil condition.
- Trees and shrubs can reduce wind erosion.
- Agroforestry can contribute to restoring degraded dryland landscapes when drought-adapted species are selected.

10. Provision of wildlife habitats

- Trees provide nesting sites for birds.
- They provide food and shelter for insects and other organisms.
- Indigenous tree species may support pollinators and seed-dispersing animals.

- This contributes to ecological balance.

11. Reduction of pressure on natural forests

- Farmers can obtain firewood, poles and timber from sustainably managed farm trees.
- This may reduce the need to obtain all wood products from natural forests.
- Woodlots and boundary trees can provide alternative sources of wood products.
- This benefit depends on sustainable harvesting and replanting.

12. Improvement of air quality

- Trees absorb carbon dioxide during photosynthesis.
- Leaves can trap some airborne dust particles.
- Trees release oxygen during photosynthesis.
- Vegetation can contribute to a healthier local environment.

13. Protection of crops against harsh environmental conditions

- Trees can reduce the impact of strong winds.
- They may provide shade to crops that require partial shade.
- Tree belts can reduce wind damage to crops.
- Appropriate species and spacing are important to avoid excessive shading and competition.

14. Provision of organic materials for soil improvement

- Leaves and small branches can be used as mulch.
- Pruned materials may be composted.
- Decomposed organic materials improve soil structure.
- This can reduce dependence on some purchased soil amendments.

15. Improvement of landscape beauty

- Trees and shrubs improve the appearance of farms and settlements.
- They create green spaces and attractive landscapes.
- They can provide shade and improve the comfort of homesteads and public spaces.

16. Support for sustainable agriculture

- Agroforestry integrates crop production with tree conservation.
- It improves the use of land resources.

- It can diversify farm products and income.
- It helps maintain environmental functions while supporting agricultural production.

1.4.13 ECONOMIC AND SOCIAL IMPORTANCE OF AGROFORESTRY

Apart from conserving the environment, agroforestry contributes to household income, food security, employment and community development.

A. Economic importance

1. Source of income

- Farmers sell tree products such as fruits, timber, poles, firewood and fodder.
- Tree products provide additional income alongside crop and livestock enterprises.
- Example: Farmers may sell mangoes, avocados and macadamia nuts.

2. Provision of timber and building materials

- Suitable trees provide timber for furniture, construction and other uses.
- Trees may also provide poles for fencing, roofing and farm structures.
- Farm-grown timber can reduce dependence on wood harvested from natural forests.

3. Provision of firewood

- Trees provide firewood for domestic and commercial energy needs.
- Woodlots and boundary trees can supply fuelwood.
- This may reduce pressure on natural woodlands when harvesting is sustainable.

4. Provision of livestock feed

- Fodder trees provide leaves, shoots and pods for livestock.
- They supplement pasture and other feeds during periods of scarcity.
- This may reduce the cost of purchasing supplementary feeds.

5. Employment creation

- Agroforestry creates employment in seed collection, nursery establishment, seedling production, planting, pruning and harvesting.
- Tree nurseries can provide business opportunities for youth and community groups.
- Tree products also create opportunities in transport, processing and marketing.

6. Food production

- Fruit trees provide food for household consumption.

- Some tree products can be processed into juices, jams, oils and other products.
- This increases food diversity and may improve household nutrition.

7. Diversification of farm enterprises

- Farmers obtain income from different sources instead of relying on one crop.
- If one enterprise performs poorly, other tree or livestock products may still provide income.
- This can reduce financial risks.

8. Production of medicinal products

- Some tree species provide materials traditionally used in herbal medicine.
- Such uses should be based on safe, appropriate and legally acceptable practices.
- Sustainable harvesting helps protect the species.

9. Production of bee forage

- Some trees provide nectar and pollen for bees.
- They can support beekeeping and honey production.
- Flowering trees also support pollinators.

10. Reduction of farm production costs

- Fodder trees may reduce the need to purchase supplementary animal feeds.
- Farm-produced firewood may reduce expenditure on cooking fuel.
- Organic tree materials can be used as mulch and compost inputs.

B. Social importance

1. Improvement of household food security: Fruit trees provide additional food sources for families.

2. Improvement of nutrition: A variety of fruits and other tree products can contribute vitamins, minerals and dietary diversity.

3. Provision of shade: Trees provide shade around homes, schools, livestock enclosures and community facilities.

4. Cultural conservation: Indigenous trees may have cultural, traditional and educational importance to local communities.

5. Community cooperation: Tree planting programmes encourage communities, schools and farmers to work together.

6. Educational value: School agroforestry projects provide learners with practical environmental and agricultural skills.

7. Improvement of living environments: Trees can improve the appearance and comfort of homesteads and institutions.

8. Intergenerational benefits: Properly managed trees provide products and environmental services over many years.

1.4.14 CHALLENGES OF AGROFORESTRY AND POSSIBLE SOLUTIONS

Although agroforestry has many benefits, farmers may experience challenges during establishment and management.

Challenge	Explanation	Possible solution
Competition for water	Trees and crops may compete for soil moisture, especially during dry periods.	Select suitable species, maintain appropriate spacing and prune trees where necessary.
Competition for sunlight	Large tree canopies may shade crops and reduce their growth.	Select trees with manageable crowns and prune them appropriately.
Competition for nutrients	Trees and crops may use nutrients from the same soil layers.	Maintain soil fertility through organic manure, compost and suitable fertiliser practices.
High establishment costs	Seedlings, fencing, labour and nursery materials may be expensive.	Use locally available materials, establish trees gradually and use natural regeneration where suitable.
Slow returns	Some timber and fruit trees take several years to provide significant income.	Integrate trees with annual crops and short-term enterprises.
Damage by livestock	Animals may browse, trample or break young trees.	Fence the planting area or use individual tree guards.
Pest and disease attack	Trees may be damaged by insects, fungi and other harmful organisms.	Use healthy planting materials, monitor trees and apply appropriate control measures.
Fire outbreaks	Bush fires can destroy young trees and established vegetation.	Establish firebreaks and practise community fire prevention.
Limited technical knowledge	Farmers may not know the best species, spacing or management practices.	Seek guidance from agricultural extension officers and trained resource persons.
Limited planting materials	Quality seedlings or seeds may not be readily available.	Establish community nurseries and collect seeds responsibly from suitable parent trees.
Inappropriate species selection	Unsuitable or invasive species may negatively affect farms and ecosystems.	Select locally appropriate, non-invasive species with advice from forestry and agricultural experts.
Land shortage	Farmers may have limited land for integrating trees and crops.	Use boundary planting, scattered trees and carefully planned alley cropping.
Damage to	Some roots and branches may interfere	Plant trees at appropriate distances from

infrastructure	with buildings, roads, drainage and power lines.	structures and select suitable species.
Uncertain markets	Farmers may lack reliable markets for tree products.	Identify market opportunities before establishing commercial tree enterprises.

A. Ways of improving the success of agroforestry

1. Promote the use of suitable indigenous and locally adapted tree species.
2. Provide farmers with training on tree selection and management.
3. Establish accessible community and school tree nurseries.
4. Encourage protection of naturally regenerating trees.
5. Promote appropriate tree spacing and pruning.
6. Encourage sustainable harvesting and replanting.
7. Involve local communities in environmental restoration.
8. Provide access to quality seeds and seedlings.
9. Encourage the integration of trees with crops and livestock according to local conditions.
10. Promote awareness of invasive species and environmentally sensitive planting sites.
11. Strengthen collaboration between farmers, schools, forestry institutions and agricultural extension officers.
12. Encourage farmers to keep records of tree establishment, survival and productivity.

1.4.15 DIFFERENCES BETWEEN AGROFORESTRY AND CONVENTIONAL FORESTRY

Agroforestry	**Conventional forestry**
Integrates trees with crops and/or livestock.	Mainly focuses on growing and managing trees and forest vegetation.
Land provides agricultural and tree products.	Land is mainly managed for forest products and ecosystem services.
Trees may be planted in crop fields, boundaries, grazing areas and homesteads.	Trees are commonly managed in forest plantations, woodlots or natural forests.
Products may include crops, livestock products, fruits, fodder, timber and firewood.	Products may include timber, poles, fuelwood and non-timber forest products.
Requires management of interactions between trees, crops and livestock.	Mainly requires management of forest vegetation and associated resources.
Can be practised on smallholder farms.	Can be practised on small or large forest areas.

1.4.16 DIFFERENCES BETWEEN AGROFORESTRY AND ORDINARY CROP FARMING

Agroforestry	Ordinary crop farming
Trees or shrubs are deliberately integrated with crops and/or livestock.	Mainly involves growing agricultural crops.
Produces agricultural and tree products.	Mainly produces crop products.
Provides long-term tree cover.	Tree cover may be limited or absent.
Can provide timber, fruits, fodder and environmental services.	Mainly provides food, fibre and other crop products.
Tree roots and canopies may contribute to soil and water conservation.	Soil conservation depends on the crop cover and other management practices.
Requires management of tree-crop competition.	Does not normally require management of tree-crop interactions.

1.4.17 PRACTICAL AGRICULTURE ACTIVITIES

Learners should be given opportunities to identify, establish and manage agroforestry trees in their school or local environment.

Practical activity 1: Identifying agroforestry trees in the local environment

Materials required

- Exercise books.
- Pens and pencils.
- Camera or mobile device where available.
- Tree identification guides.
- Measuring tape.
- Resource person or teacher.

Procedure

1. Organise an excursion to a farm, tree nursery, school compound or suitable natural vegetation area.
2. Identify different trees and shrubs.
3. Observe the height, stem, leaves, branches and canopy of each tree.
4. Identify the products obtained from each tree.
5. Classify the trees as forest trees, fodder trees or fruit trees.
6. Observe how the trees are arranged in relation to crops and livestock.

7. Identify any environmental benefits provided by the trees.
8. Record the findings in a table.
9. Discuss the suitability of each tree for agroforestry.
10. Present the findings to the class.

Suggested observation table

Tree identified	**Category**	**Main products**	**Environmental benefits**
Grevillea	Forest tree	Timber, poles	Wind protection, soil conservation
Mango	Fruit tree	Fruits	Shade, carbon storage
Calliandra	Fodder tree	Livestock feed	Soil cover, organic matter
Croton	Indigenous tree	Shade and other suitable wood products	Habitat and biodiversity

Practical activity 2: Establishing a tree nursery

Materials required

- Suitable tree seeds.
- Nursery containers or seed trays.
- Topsoil.
- Well-decomposed manure or compost.
- Clean sand where appropriate.
- Watering can.
- Spade and hoe.
- Labels.
- Shade materials.
- Protective fencing materials.

Procedure

1. Select a suitable nursery site.
2. Clear the site and remove unwanted materials.
3. Prepare nursery beds or arrange containers.

4. Prepare a suitable growing medium.
5. Fill the containers with the growing medium.
6. Obtain quality seeds of suitable agroforestry trees.
7. Apply the recommended seed pretreatment where necessary.
8. Sow the seeds at suitable depths.
9. Water gently.
10. Label the species and sowing dates.
11. Provide suitable shade.
12. Weed and water the nursery regularly.
13. Prick out seedlings where necessary.
14. Harden seedlings before transplanting.
15. Record the number of seedlings that germinate and survive.

Expected outcomes

- Learners establish a functional tree nursery.
- Learners identify the requirements for raising agroforestry seedlings.
- Learners develop practical nursery management skills.
- Learners appreciate the importance of quality planting materials.

Practical activity 3: Transplanting agroforestry trees

Materials required

- Healthy nursery seedlings.
- Spades or hoes.
- Watering cans.
- Manure or compost.
- Mulching materials.
- Tree guards or fencing materials.
- Labels.

Procedure

1. Select a suitable planting site.

2. Identify the purpose of planting.
3. Determine appropriate spacing.
4. Mark the planting positions.
5. Dig planting holes.
6. Water the seedlings before transplanting.
7. Remove the seedlings carefully from their containers.
8. Plant each seedling at the correct depth.
9. Firm the soil around the roots.
10. Water the seedlings where necessary.
11. Apply mulch.
12. Protect the seedlings from livestock and other damage.
13. Label the planted trees.
14. Monitor their survival and growth.

Practical activity 4: Investigating natural regeneration

Objective: To identify naturally regenerating vegetation and examine the role of protection in environmental restoration.

Procedure

1. Identify an area with naturally growing seedlings, shrubs or tree shoots.
2. Observe and identify the species where possible.
3. Record the number and condition of the young plants.
4. Identify possible sources of seeds or vegetative regeneration.
5. Observe evidence of grazing, fire, cutting or trampling.
6. Select a small suitable area for protection, with permission from the landowner or relevant authority.
7. Mark the area and protect the naturally growing plants.
8. Monitor the seedlings over an agreed period.
9. Record growth, damage and survival.
10. Present findings and suggest ways of improving natural regeneration.

Suggested observation table

Observation	Initial record	Follow-up record
Number of young trees	_____	_____
Number of damaged seedlings	_____	_____
Evidence of grazing	_____	_____
Evidence of fire damage	_____	_____
New seedlings observed	_____	_____
General vegetation condition	_____	_____

ASSESSMENT ACTIVITIES

Section A: Multiple-choice questions

Choose the correct answer in each question.

1. Which one of the following best describes agroforestry?

A. Growing crops without trees
B. Integrating trees with crops and/or livestock
C. Growing trees only for timber
D. Keeping livestock without pasture

2. A farmer plants calliandra trees to provide supplementary livestock feed. The trees are classified as:

A. Fruit trees
B. Fodder trees
C. Timber trees
D. Ornamental trees

3. Which one of the following is a characteristic of a suitable agroforestry tree?

A. It is highly invasive.
B. It competes excessively with crops.
C. It is adapted to local climatic conditions.
D. It cannot withstand appropriate management.

4. Which agroforestry system integrates trees with agricultural crops?

A. Silvopastoral
B. Agrosilvicultural
C. Monocropping
D. Pastoral

5. A farmer grows trees, pasture and keeps cattle on the same farm. Which system is being practised?

A. Agrosilvicultural
B. Silvopastoral
C. Agrosilvopastoral
D. Monocropping

6. The process through which vegetation re-establishes naturally from seeds, roots, stumps and shoots is known as:

A. Artificial irrigation
B. Natural regeneration
C. Grafting
D. Transplanting

7. Which one of the following is an example of assisted natural regeneration?

A. Clearing all naturally growing seedlings
B. Protecting naturally growing seedlings from livestock

C. Burning all vegetation
D. Removing all indigenous trees

8. New shoots developing from a tree stump after cutting are referred to as:

A. Scions
B. Coppice shoots
C. Slips
D. Crowns

9. Which one of the following is an important benefit of leguminous agroforestry trees?

A. They always remove nitrogen from the soil.
B. They may contribute nitrogen through biological nitrogen fixation.
C. They prevent all crop diseases.
D. They eliminate the need for water.

10. Which one of the following is an example of a fodder tree?

A. Calliandra
B. Wheat
C. Maize
D. Irish potato

11. Which agroforestry arrangement involves planting trees along farm boundaries?

A. Alley cropping
B. Boundary planting
C. Monocropping
D. Broadcasting

12. The main purpose of hardening off nursery seedlings is to:

A. Make them grow taller immediately.
B. Prepare them gradually for field conditions.
C. Prevent all pests from attacking them.
D. Stop root development.

13. Which one of the following materials improves moisture conservation when applied around young agroforestry trees?

A. Dry grass mulch
B. Plastic waste
C. Fresh chemical waste
D. Stones mixed with chemicals

14. A farmer establishes trees along contour lines on a sloping field. The main purpose is to:

A. Increase the speed of runoff.
B. Reduce soil erosion.
C. Increase wind erosion.
D. Encourage soil compaction.

15. Which one of the following is a suitable reason for selecting agroforestry trees with manageable canopies?

A. To encourage excessive shading
B. To reduce unnecessary shading of crops
C. To prevent flowering
D. To increase competition for sunlight

16. Which one of the following is an important activity during tree nursery management?

A. Allowing weeds to dominate the seedlings
B. Overwatering seedlings continuously
C. Regular watering and weeding
D. Keeping seedlings without drainage

17. What is the main purpose of pruning agroforestry trees?

A. To destroy the root system
B. To manage tree growth and remove unwanted branches
C. To prevent all new shoots
D. To stop the tree from absorbing water

18. Which one of the following contributes to carbon sequestration?

A. Burning all vegetation
B. Growing and maintaining trees
C. Removing all plant cover
D. Exposing soil continuously

19. Which one of the following is a major challenge of agroforestry?

A. Competition between trees and crops for resources
B. Availability of several farm products
C. Improved soil cover
D. Provision of shade

20. Which one of the following activities supports successful natural regeneration?

A. Uncontrolled grazing
B. Repeated burning
C. Protecting naturally growing seedlings
D. Clearing all vegetation

Section B: Structured questions

21.

a) Define agroforestry. (2 marks)

b) Explain five characteristics of agroforestry. (5 marks)

c) Identify three examples of agroforestry systems. (3 marks)

22.

a) Explain six characteristics of suitable agroforestry trees. (6 marks)

b) Distinguish between forest trees, fodder trees and fruit trees. (6 marks)

c) Give three examples of fodder trees suitable for livestock production. (3 marks)

23.

a) Define natural regeneration. (2 marks)

b) Explain five ways through which natural regeneration occurs. (5 marks)

c) Describe six activities involved in assisted natural regeneration. (6 marks)

d) State two limitations of natural regeneration. (2 marks)

24.

a) Explain eight steps involved in establishing an agroforestry tree nursery. (8 marks)

b) Describe the procedure for transplanting tree seedlings from a nursery to the field. (7 marks)

25.

a) Explain eight ways in which agroforestry contributes to environmental conservation. (8 marks)

b) State four economic benefits of agroforestry to farmers. (4 marks)

c) Identify three challenges faced by farmers practising agroforestry. (3 marks)

26.

A farmer in Kenya intends to establish an agroforestry system on a farm where maize, beans and dairy cattle are produced.

a) Identify four categories of trees that the farmer may consider planting. (4 marks)

b) Explain five factors the farmer should consider when selecting agroforestry trees. (5 marks)

c) Describe four management practices necessary for the successful establishment of agroforestry trees. (4 marks)

d) Explain two ways agroforestry may improve the productivity and sustainability of the farm. (2 marks)

1.4.20 CBE INTEGRATED PROJECT: ESTABLISHING AN AGROFORESTRY DEMONSTRATION FARM

Project title: Establishing and managing an agroforestry demonstration plot.

Project objective: To enable learners to identify, select, grow and manage suitable agroforestry trees for environmental conservation and agricultural production.

Project requirements

- Suitable land within the school compound.
- Quality tree seeds or seedlings.
- Nursery containers.
- Topsoil and well-decomposed manure.
- Watering cans.
- Spades and hoes.
- Mulching materials.
- Tree guards or fencing materials.
- Labels and record books.

Project activities

1. Identify a suitable site for the demonstration plot.
2. Examine the environmental conditions of the site.
3. Identify the intended purpose of planting.
4. Select suitable forest, fodder and fruit trees.
5. Search for information on the characteristics of the selected trees.
6. Obtain quality seeds or seedlings.
7. Establish a nursery where necessary.
8. Raise and manage seedlings.
9. Prepare the planting site.
10. Determine appropriate spacing and arrangement.
11. Transplant seedlings.
12. Apply mulch and water where necessary.
13. Protect the young trees from livestock and other damage.
14. Carry out weeding and appropriate pruning.
15. Record seedling survival and growth.
16. Investigate the environmental benefits of the growing trees.

17. Present the project findings to the school community.

Expected project outcomes

By completing the project, learners should be able to:

- Identify appropriate agroforestry trees.
- Explain the characteristics of different tree categories.
- Establish and manage a tree nursery.
- Transplant and manage tree seedlings.
- Explain natural regeneration.
- Appreciate the role of trees in environmental conservation.
- Demonstrate responsibility in caring for planted trees.
- Identify economic opportunities associated with agroforestry.

Suggested project assessment criteria

Assessment area	**Evidence of achievement**
Tree selection	Suitable species are selected for the intended purpose.
Nursery establishment	A functional nursery is prepared and managed.
Seedling preparation	Healthy seedlings are selected for planting.
Transplanting	Seedlings are planted correctly.
Management	Watering, weeding, mulching and protection are carried out appropriately.
Environmental conservation	Learner explains the benefits of the trees to the environment.
Record keeping	Growth and survival information is recorded accurately.
Collaboration	Learners share responsibilities during project activities.
Responsibility	Learners demonstrate persistence in caring for the trees.
Presentation	Findings are communicated clearly.

1.4.21 REVISION SUMMARY

Agroforestry is the deliberate integration of trees and shrubs with crops and/or livestock on the same piece of land.

The main agroforestry systems include:

1. Agrosilvicultural system: Integration of trees and crops.
2. Silvopastoral system: Integration of trees, shrubs and livestock.
3. Agrosilvopastoral system: Integration of trees, crops and livestock.

Suitable agroforestry trees should have desirable characteristics such as adaptability to local conditions, manageable canopies, useful products, appropriate root systems, good growth and resistance or tolerance to common pests and diseases.

Agroforestry trees may be grouped according to their main uses into:

- Forest trees.
- Fodder trees and shrubs.
- Fruit trees.

Natural regeneration is the process through which vegetation re-establishes from naturally available seeds, roots, stumps, suckers and other growing structures.

Assisted natural regeneration involves protecting and managing naturally growing vegetation to encourage environmental restoration.

Agroforestry trees are established through appropriate site selection, nursery establishment, seed preparation, sowing, seedling management, hardening off and transplanting.

After transplanting, trees require watering, mulching, weeding, pruning, pest and disease control, livestock protection and regular monitoring.

Agroforestry is important because it:

- Controls soil erosion.
- Improves soil fertility.
- Conserves water.
- Reduces wind erosion.
- Supports biodiversity.
- Provides habitats for wildlife.
- Absorbs and stores carbon.
- Improves the microclimate.
- Provides food, fodder, timber and firewood.
- Generates income and employment.
- Supports sustainable agriculture.

- Helps restore degraded environments.

1.4.22 KEY TERMS AND DEFINITIONS

Term	Meaning
Agroforestry	Integration of trees and shrubs with crops and/or livestock.
Agrosilviculture	Growing trees and crops together.
Silvopastoral system	Integration of trees with livestock and pasture.
Agrosilvopastoral system	Integration of trees, crops and livestock.
Natural regeneration	Natural re-establishment of vegetation from seeds, roots, stumps or shoots.
Assisted natural regeneration	Protecting and managing naturally growing vegetation to encourage recovery.
Coppicing	Cutting a tree stem near ground level to encourage new shoots from the stump.
Fodder tree	A tree whose leaves, shoots, pods or fruits are used as livestock feed.
Woodlot	An area of land planted with trees for products such as timber, poles and firewood.
Windbreak	Trees or shrubs planted to reduce wind speed.
Shelterbelt	A belt of trees and shrubs established to protect a larger area from wind.
Alley cropping	Growing crops between rows of trees or shrubs.
Mulching	Covering the soil surface with suitable materials to conserve moisture and protect the soil.
Pruning	Removing selected branches or shoots to manage tree growth.
Pollarding	Cutting back the upper branches of a tree at a suitable height to encourage new shoots.
Transplanting	Moving seedlings from a nursery to their permanent planting positions.
Hardening off	Gradually preparing nursery seedlings for field conditions.
Nursery	A place where seeds and planting materials are raised into seedlings.
Carbon sequestration	Absorption and storage of carbon in vegetation and soil.
Biodiversity	Variety of living organisms in an ecosystem.
Contour planting	Planting trees or crops along lines of equal elevation to help control runoff and soil erosion.

Improved fallow	Growing selected vegetation on land temporarily removed from annual crop production to improve soil and vegetation conditions.

STRAND 1.0: CROP PRODUCTION

SUB-STRAND 1.5: CROP PROTECTION – PEST CONTROL

Introduction to crop protection

Crop protection refers to the practices and measures used to prevent, reduce or manage damage caused by pests, diseases and weeds in crop production. It aims at ensuring healthy crop growth, high yields, good-quality produce and reduced post-harvest losses.

Pests are among the major challenges affecting crop production in Kenya. They attack crops at different stages of growth, from planting and germination to flowering, fruit formation, harvesting and storage.

Examples include:

- Fall armyworms feeding on maize leaves and growing points.
- Aphids sucking sap from vegetables and other crops.
- Maize stalk borers feeding inside maize stems.
- Quelea birds feeding on cereal grains.
- Rats and mice damaging crops in the field and stored produce.
- Weevils and larger grain borers destroying stored cereals.

Effective pest control involves identifying the pest correctly, understanding its life cycle and feeding habits, selecting an appropriate control method and monitoring the results.

Key terms used in pest control

1. Crop pest: Any organism that damages crops or crop produce, reduces their quality or quantity, or interferes with successful crop production.

2. Pest control: The use of appropriate methods to prevent, reduce or manage pest populations and the damage they cause.

3. Pest infestation: The presence and multiplication of pests in a crop field, store or other production environment.

4. Economic damage: Losses in crop yield, quality or market value caused by pest activity.

5. Economic injury level: The pest population at which the cost of damage is approximately equal to the cost of controlling the pest.

6. Economic threshold: The pest population level at which control action should be taken to prevent the population from reaching the economic injury level.

7. Pest monitoring: Regular observation and assessment of pest populations, crop damage and the effectiveness of control measures.

8. Integrated Pest Management (IPM): An approach that combines different compatible pest-control methods to keep pest populations below economically damaging levels while minimising risks to people and the environment.

1. CATEGORIES OF PESTS IN CROP PRODUCTION

Crop pests can be classified according to several characteristics, including:

1. Where they attack crops or crop produce.
2. The stage of crop growth they attack.
3. The parts of the crop they damage.
4. Their biological grouping.
5. Their feeding habits and the nature of damage they cause.

1.1 Classification according to where they attack

According to the location where they cause damage, pests are classified into two main categories:

A. Field pests

Field pests are organisms that attack crops while they are growing in the field, before harvesting.

They may attack seeds, seedlings, roots, stems, leaves, flowers, fruits and developing grains.

Examples of field pests and their damage

1. Fall armyworm

- Feeds mainly on maize leaves and growing points.
- Produces irregular holes and ragged edges on leaves.
- Heavy infestation may destroy the maize growing point and affect plant development.

2. Maize stalk borer

- Larvae bore into maize stems and feed on internal tissues.
- Causes dead hearts in young plants.
- Weakens stems and may cause lodging.
- Interferes with the movement of water and nutrients within the plant.

3. Aphids

- Small insects that occur in colonies on young shoots and the undersides of leaves.
- Suck plant sap, causing leaves to curl, yellow and become distorted.
- Some species transmit plant viruses.

4. Cutworms

- Larvae live in or near the soil.
- Cut young seedlings at or just below the soil surface.
- May cause gaps in crop stands and necessitate replanting.

5. Fruit flies

- Adult females lay eggs in developing fruits.
- The larvae feed inside the fruit.
- Cause rotting, premature fruit dropping and reduced market quality.

6. Whiteflies

- Feed on plant sap, especially on the undersides of leaves.
- Cause yellowing and weakening of plants.
- Some species transmit viral diseases.
- Produce honeydew that encourages the growth of sooty mould.

7. Bean stem maggots

- Larvae feed within the stems of young bean plants.
- Damage vascular tissues and weaken plants.
- Can cause wilting and death of seedlings.

B. Storage pests

Storage pests are organisms that attack harvested crops and crop products during storage, processing or transportation.

They mainly affect grains, seeds, pulses, dried fruits and other stored agricultural products.

Examples of storage pests and their damage

1. Maize weevils

- Adults and larvae attack stored maize grains.
- Larvae develop inside the grains and feed on the internal contents.
- Create holes in grains and reduce their weight and quality.
- Heavy infestation may make maize unsuitable for consumption or sale.

2. Larger grain borers

- Attack stored maize and dried cassava products.
- Bore into grains and produce powdery residues.
- Cause serious quantitative and qualitative losses.

3. Bean bruchids

- Attack stored beans, cowpeas and other pulses.

- Females lay eggs on the seeds.
- Larvae enter the seeds and feed on their contents.
- Cause holes, reduced seed weight and poor germination.

4. Rats and mice

- Feed on stored grains and other food products.
- Tear storage bags and contaminate produce with urine, faeces and hair.
- May spread diseases and cause serious hygiene problems.

5. Flour beetles

- Attack flour, broken grains and other processed cereal products.
- Contaminate food with their bodies and waste products.
- Reduce the quality and market value of stored food.

6. Moths

- Larvae of certain storage moths feed on grains and processed products.
- Produce webbing and contaminate stored produce.
- May cause clumping and deterioration of grain quality.

Differences between field pests and storage pests

Field pests	**Storage pests**
Attack crops before harvesting.	Attack harvested produce during storage.
Damage growing plants and developing crops.	Damage grains, seeds and other stored products.
May attack roots, stems, leaves, flowers and fruits.	Commonly attack grains, pulses, flour and dried products.
Examples include aphids, cutworms and fall armyworms.	Examples include weevils, bruchids and flour beetles.
Controlled through field sanitation, crop rotation, biological control and other field practices.	Controlled through proper drying, cleaning, sanitation, airtight storage and appropriate protective treatments.

1.2 Classification according to the stage of crop growth attacked

Crop pests may be classified according to the developmental stage at which they attack a crop.

The main stages include:

A. Seed and germination stage pests

These are pests that attack seeds before or during germination.

Examples and their effects

1. Seed-corn maggots

- Feed on germinating seeds and young seedlings.
- Damage the embryo and growing tissues.
- May cause poor germination and missing plants.

2. Termites

- May attack planted seeds and emerging seedlings.
- Feed on plant tissues and roots.
- Can cause poor crop establishment.

3. Wireworms

- Soil-dwelling larvae of click beetles.
- Feed on seeds, roots and underground plant parts.
- May cause seedling death and gaps in crop stands.

B. Seedling stage pests

These pests attack young plants soon after emergence.

Examples

1. Cutworms cut seedlings at the base.
2. Aphids suck sap from young leaves and shoots.
3. Thrips damage tender leaves and growing points.
4. Termites attack roots and stems of young plants.
5. Leaf-feeding caterpillars consume young leaves.

Effects on crops

- Reduced plant population.
- Poor crop establishment.
- Stunted growth.
- Uneven crop development.
- Increased cost of replanting.

C. Vegetative growth stage pests

These pests attack crops during the period of active leaf, stem and root development.

Examples

1. Fall armyworms feed on maize leaves.
2. Stem borers tunnel into crop stems.
3. Aphids suck sap from leaves and shoots.
4. Leaf miners feed between the upper and lower surfaces of leaves.
5. Root-knot nematodes attack plant roots.
6. Spider mites suck cell contents from leaves.

Effects

- Reduced photosynthesis.
- Stunted growth.
- Wilting and yellowing.
- Weak stems.
- Reduced crop vigour.

D. Flowering stage pests

These pests attack flowers, flower buds and reproductive structures.

Examples

1. Thrips

- Feed on flower tissues.
- Cause flower discolouration and distortion.
- May interfere with fertilisation and fruit formation.

2. Flower beetles

- Feed on petals, pollen and reproductive structures.
- May destroy flowers and reduce fruit or seed formation.

3. Bollworms

- Attack reproductive structures of crops such as cotton.
- Feed on flower buds and developing bolls.

- Reduce the number and quality of harvested bolls.

Effects

- Flower dropping.
- Poor pollination.
- Reduced seed formation.
- Reduced fruit set.
- Low crop yield.

E. Fruit and grain development stage pests

These pests attack fruits, pods, cobs and developing grains.

Examples

1. Fruit flies attack developing fruits.
2. Pod borers feed on developing seeds inside pods.
3. Bollworms attack cotton bolls.
4. Birds feed on developing cereal grains.
5. Stink bugs suck sap from developing seeds and fruits.

Effects

- Premature fruit dropping.
- Damaged fruits and seeds.
- Reduced grain weight.
- Poor market quality.
- Increased post-harvest losses.

F. Harvesting and post-harvest stage pests

These pests attack mature crops during harvesting, handling, transportation and storage.

Examples include:

- Maize weevils.
- Bean bruchids.
- Larger grain borers.
- Rats and mice.

- Storage moths.
- Flour beetles.

They cause physical damage, contamination, weight loss, poor quality and reduced market value.

1.3 Classification according to the parts of crops attacked

Pests can also be classified according to the specific plant parts they feed on or damage.

A. Root pests

These are pests that attack the roots and underground parts of crops.

Examples

1. Root-knot nematodes

- Microscopic, worm-like organisms that attack plant roots.
- Cause swollen areas known as root galls.
- Interfere with the absorption of water and mineral salts.
- Lead to stunted growth and wilting.

2. White grubs

- Soil-dwelling larvae of certain beetles.
- Feed on roots and underground plant parts.
- Cause poor growth and wilting.

3. Termites

- Some species feed on roots and underground stems.
- Weaken plants and may cause them to die.

4. Wireworms

- Feed on roots, seeds and underground stems.
- Cause damage to young crops.

Effects of root pests

- Poor absorption of water and nutrients.
- Stunted growth.
- Yellowing of leaves.
- Wilting.

- Reduced crop yield.
- Plant death in severe cases.

B. Stem pests

These are pests that feed on or bore into plant stems and branches.

Examples

1. Maize stalk borers.
2. Bean stem maggots.
3. Termites.
4. Stem-boring beetle larvae.

Effects

- Weakening of stems.
- Breaking and lodging of crops.
- Interference with the movement of water and nutrients.
- Formation of dead hearts in young cereals.
- Reduced crop productivity.

C. Leaf pests

These pests feed on leaf tissues or suck sap from leaves.

Examples

1. Aphids.
2. Fall armyworms.
3. Locusts.
4. Grasshoppers.
5. Leaf miners.
6. Spider mites.
7. Whiteflies.

Effects

- Reduced leaf surface area.
- Reduced photosynthesis.

- Leaf curling and yellowing.
- Premature leaf dropping.
- Stunted growth.

D. Flower pests

These pests attack flower buds, petals, pollen and other reproductive parts.

Examples include:

- Thrips.
- Flower beetles.
- Certain caterpillars.
- Bollworms.

Effects

- Destruction of flowers.
- Poor fertilisation.
- Reduced fruit formation.
- Reduced seed production.

E. Fruit and pod pests

These pests feed on developing fruits, pods and seeds.

Examples:

- Fruit flies.
- Pod borers.
- Bollworms.
- Stink bugs.
- Birds.

Effects

- Fruit rotting.
- Pod destruction.

- Seed damage.
- Premature fruit dropping.
- Reduced market value.

F. Grain pests

These pests attack grains before or after harvesting.

Examples:

- Maize weevils.
- Larger grain borers.
- Bean bruchids.
- Storage moths.

Effects

- Loss of grain weight.
- Reduced seed viability.
- Contamination.
- Reduced food quality.
- Increased storage costs.

1.4 Classification according to biological grouping

Crop pests can be grouped according to their biological characteristics. The major groups include:

1. Insects.
2. Mites.
3. Nematodes.
4. Molluscs.
5. Birds.
6. Rodents.

A. Insects

Insects are small invertebrate animals belonging to the class Insecta. Many are important agricultural pests because they feed on different parts of crops.

General characteristics of insects

1. Their bodies are divided into three main regions:

- Head.
- Thorax.
- Abdomen.

2. They have three pairs of jointed legs, making six legs in total.

3. Most adult insects have one or two pairs of wings, although some are wingless.

4. They possess one pair of antennae used for sensing the environment.

5. They have compound eyes in most cases.

6. They have an external skeleton called an exoskeleton.

7. They reproduce mainly by laying eggs.

8. They undergo either complete or incomplete metamorphosis.

9. They possess different types of mouthparts adapted to their feeding habits.

Examples of insect pests and their characteristics

Insect pest	**Main crop attacked**	**Nature of damage**
Fall armyworm	Maize	Feeds on leaves and growing points.
Maize stalk borer	Maize and sorghum	Bores into stems.
Aphids	Beans, vegetables and other crops	Suck plant sap.
Whiteflies	Tomatoes and other vegetables	Suck sap and transmit some viruses.
Maize weevil	Stored maize	Larvae feed inside grains.
Bean bruchid	Stored beans and pulses	Larvae feed inside seeds.
Fruit flies	Mangoes and other fruits	Larvae feed inside fruits.
Cutworms	Various young crops	Cut seedlings near the soil surface.
Locusts	Cereals and other crops	Feed on leaves and tender plant parts.
Thrips	Onions, vegetables and flowers	Scrape tissues and suck plant fluids.

Types of insect mouthparts and their feeding habits

Insects have mouthparts adapted to the type of food they consume.

1. Biting and chewing mouthparts

- Used for cutting, biting and chewing plant tissues.

- Common in grasshoppers, caterpillars and beetles.
- They cause holes, missing leaf portions and damaged stems.

2. Piercing and sucking mouthparts

- Used to pierce plant tissues and suck sap.
- Common in aphids, whiteflies and some bugs.
- Cause yellowing, curling and weakening of plants.

3. Rasping and sucking mouthparts

- Used to scrape plant surfaces and suck the released cell contents.
- Common in thrips.
- Cause silvery patches, scars and leaf distortion.

4. Siphoning mouthparts

- Long, coiled mouthparts used to suck liquid food.
- Found in adult butterflies and moths.
- Generally adapted to feeding on nectar rather than causing the typical caterpillar damage.

5. Sponging mouthparts

- Adapted for absorbing liquid food.
- Found in houseflies.
- Houseflies are mainly hygiene pests and are not usually direct crop-feeding pests.

Types of insect metamorphosis

Metamorphosis refers to the changes an insect undergoes as it develops from an egg to an adult.

Complete metamorphosis

It involves four distinct stages:

1. Egg – the first stage of development.
2. Larva – the feeding and growing stage.
3. Pupa – the resting and transformation stage.
4. Adult – the reproductive stage.

Examples:

- Butterflies.

- Moths.
- Beetles.
- Houseflies.
- Mosquitoes.

Incomplete metamorphosis

It involves three main stages:

1. Egg – the initial stage.
2. Nymph – a young insect that resembles a small adult but is not fully developed.
3. Adult – the mature reproductive stage.

Examples:

- Grasshoppers.
- Locusts.
- Aphids.
- Cockroaches.
- Some bugs.

Importance of understanding insect metamorphosis in pest control

1. Helps identify the most damaging stage of a pest.
2. Helps farmers select the correct time to apply control measures.
3. Makes it possible to interrupt the pest life cycle.
4. Helps farmers monitor eggs, larvae, nymphs and adults.
5. Supports the use of biological control agents that attack particular life stages.
6. Helps prevent pests from multiplying and spreading.

B. Mites

Mites are very small arthropods belonging to the group Arachnida. Some species attack crops by sucking the contents of plant cells.

Characteristics of mites

1. They are generally very small and may require a hand lens or microscope for proper observation.
2. Adult mites usually have four pairs of legs.
3. Their bodies are not divided into three distinct regions like those of insects.

4. They do not have antennae.
5. Many species reproduce rapidly under favourable environmental conditions.
6. Some produce fine webbing on infested plants.
7. They feed by piercing plant cells and sucking their contents.

Examples of crop-damaging mites

- Red spider mites.
- Two-spotted spider mites.
- Broad mites.
- Rust mites.

Crops attacked

- Tomatoes.
- Beans.
- French beans.
- Tea.
- Citrus.
- Ornamentals.
- Other vegetables and horticultural crops.

Nature of damage caused by mites

1. They suck the contents of leaf cells.
2. Cause tiny yellow or pale spots on leaves.
3. Heavy infestation causes leaves to bronze or turn brown.
4. Some species cause leaf curling and distortion.
5. Some produce fine webs on leaves and shoots.
6. Severe infestation causes premature leaf dropping.
7. Reduce photosynthesis and crop vigour.
8. Lower the quality and market value of horticultural produce.

C. Nematodes

Nematodes are microscopic or very small, elongated, unsegmented, worm-like organisms. Some species are plant parasites that attack crop roots and other plant tissues.

Characteristics of plant-parasitic nematodes

1. They have elongated, cylindrical and unsegmented bodies.
2. Most are microscopic and cannot be seen clearly with the naked eye.
3. They live in soil, water or plant tissues.
4. Many possess a specialised feeding structure called a stylet.
5. The stylet is used to pierce plant cells and withdraw their contents.
6. They reproduce through eggs and developmental stages.
7. Their activity is influenced by soil moisture, temperature and host availability.
8. Some attack roots while others attack stems, leaves, bulbs or seeds.

Examples of plant-parasitic nematodes

1. Root-knot nematodes (Meloidogyne species).
2. Lesion nematodes (Pratylenchus species).
3. Cyst nematodes (Heterodera and Globodera species).
4. Burrowing nematodes (Radopholus species).
5. Stem and bulb nematodes (Ditylenchus species).

Crops attacked

- Tomatoes.
- Potatoes.
- Bananas.
- Carrots.
- Beans.
- Maize.
- Onions.
- Various vegetable crops.

Nature of damage caused by nematodes

1. Cause swelling and galls on roots.
2. Damage root tissues.
3. Reduce the absorption of water and mineral salts.

4. Cause yellowing and stunted growth.
5. Lead to wilting, especially under dry conditions.
6. Reduce the ability of plants to withstand drought.
7. Cause poor crop establishment and reduced yields.
8. Create wounds that may allow other disease-causing organisms to enter plant tissues.

D. Molluscs

Molluscs are soft-bodied invertebrate animals. Some agricultural molluscs feed on leaves, seedlings, fruits and other tender plant parts.

The main crop-damaging molluscs are slugs and snails.

Characteristics of molluscs

1. They have soft, unsegmented bodies.
2. Snails possess a protective external shell, while slugs generally lack an external shell.
3. They move using a muscular foot.
4. They produce mucus that helps them move.
5. They commonly prefer moist and cool environments.
6. They feed using a rasping feeding structure called a radula.
7. Many are active during the night or in damp weather.
8. They lay eggs in moist soil or other protected places.

Examples

- Garden snails.
- Giant African land snails.
- Slugs.

Crops attacked

- Cabbages.
- Lettuce.
- Spinach.
- Tomatoes.
- Seedlings of many vegetables.
- Ornamentals.

Nature of damage

1. They chew irregular holes in leaves.
2. They may destroy tender seedlings.
3. They feed on fruits and vegetables.
4. They leave shiny mucus trails on plants and surfaces.
5. They contaminate harvested produce.
6. Heavy infestation may cause serious loss of marketable leaves and fruits.

E. Birds

Birds are vertebrate animals that may become agricultural pests when they feed on planted seeds, developing grains, fruits and other crop products.

Characteristics of birds

1. They have feathers covering their bodies.
2. They possess two wings and two legs.
3. They have beaks instead of teeth.
4. They lay eggs.
5. They have good eyesight, which helps them locate food.
6. Many species are mobile and can move from one field to another.
7. Some occur in large flocks and can cause extensive crop damage.
8. They have different feeding habits depending on their species.

Examples of bird pests

1. Quelea birds

- Feed on cereal crops, especially sorghum, millet and other small grains.
- Occur in large flocks.
- Can cause severe losses when they invade fields during grain development.

2. Weaver birds

- Feed on developing cereal grains.
- May damage sorghum, millet and other crops.

3. Parrots

- May feed on maize, fruits and other crops.
- Can damage cobs and fruits.

4. Pigeons and doves

- May feed on planted seeds and developing grains.
- Can cause losses in fields and seedbeds.

Nature of damage caused by birds

1. Feed on planted seeds before germination.
2. Uproot or damage emerging seedlings.
3. Feed on ripening grains.
4. Peck and damage fruits.
5. Break branches while feeding or perching.
6. Cause considerable yield losses when they occur in large numbers.
7. Contaminate produce with droppings.

F. Rodents

Rodents are mammals characterised by continuously growing front incisors that they use for gnawing. Some species are serious pests in crop fields, stores and granaries.

Characteristics of rodents

1. They are mammals with bodies usually covered in fur.
2. They have two pairs of prominent front incisors.
3. Their incisors grow continuously and must be worn down through gnawing.
4. Most reproduce rapidly under favourable conditions.
5. They have a well-developed sense of smell and hearing.
6. Many are active at night.
7. They can burrow into the soil and hide in vegetation or storage structures.
8. They feed on a wide range of food materials.

Examples of rodent pests

- Rats.
- House mice.
- Field mice.

- Mole rats.
- Voles, where present.

Nature of damage caused by rodents

1. Feed on planted seeds and emerging seedlings.
2. Eat mature grains and fruits.
3. Gnaw maize cobs and other crop produce.
4. Damage stems and roots.
5. Dig burrows that may interfere with crop production.
6. Tear storage bags and damage store structures.
7. Contaminate stored food with urine, faeces and hair.
8. Spread disease-causing organisms and create health risks.

2. CONTROL OF CROP PESTS

Pest control refers to the application of suitable methods to prevent, reduce or manage pest populations and minimise the damage they cause to crops and crop produce.

The main aim of pest control is not necessarily to eliminate every pest but to maintain pest populations below levels that cause unacceptable economic losses.

Effective pest control helps farmers to:

1. Protect crops from damage.
2. Increase crop yields.
3. Improve the quality of harvested produce.
4. Reduce losses during storage.
5. Improve food security.
6. Increase farmers' income.
7. Reduce the cost of replacing damaged crops.
8. Protect the environment and beneficial organisms.
9. Produce safe food for consumers.
10. Improve the sustainability of agricultural production.

2.1 Factors to consider when selecting a pest-control method

Before selecting a control method, a farmer should consider the following:

1. Type of pest: Different pests require different control measures. For example, rodents may be controlled using traps, while aphids may be managed using natural enemies or approved insecticides where necessary.

2. Nature of damage: The farmer should establish whether the pest attacks roots, stems, leaves, flowers, fruits or stored produce.

3. Stage of pest development: Some control methods are more effective against eggs or young larvae than against adults.

4. Level of infestation: The farmer should determine whether the pest population is high enough to justify control action.

5. Cost of control: The cost of controlling the pest should be compared with the expected economic benefit.

6. Availability of control materials: The farmer should consider whether the required equipment, labour, biological agents or approved pesticides are available.

7. Environmental effects: The selected method should minimise harm to soil, water, wildlife and beneficial organisms.

8. Safety of workers and consumers: Control methods should not expose farmers, farm workers or consumers to unnecessary risks.

9. Crop type and growth stage: A method suitable for maize may not be appropriate for vegetables, fruits or other crops.

10. Weather conditions: Rainfall, temperature and wind may influence the effectiveness and safety of some pest-control methods.

11. Market requirements: Crops intended for fresh consumption or export may have strict pesticide residue requirements.

12. Legal requirements: Only pesticides and other pest-control products approved for the intended use should be applied according to their labels and relevant regulations.

2.2 Physical control of pests

Physical control involves using physical barriers, devices, materials or environmental conditions to prevent pests from reaching crops or to remove and destroy them.

It may involve manually collecting pests, trapping them, excluding them from crops or using physical barriers.

Methods of physical pest control

A. Hand-picking

This involves manually collecting visible pests from plants and destroying them safely.

Procedure

1. Inspect crops regularly.

2. Identify the pest correctly.
3. Collect visible insects, caterpillars, snails or egg masses.
4. Place collected pests in a suitable container.
5. Destroy or dispose of them safely in accordance with recommended practices.
6. Repeat the exercise until the infestation is reduced.

Examples

- Removing caterpillars from cabbage leaves.
- Collecting snails and slugs from vegetable gardens.
- Removing egg masses of certain crop pests.
- Picking heavily infested leaves where appropriate.

Advantages

1. It is simple and inexpensive on small farms.
2. It does not require expensive machinery.
3. It avoids unnecessary pesticide application.
4. It can be used in organic farming systems.
5. It allows farmers to observe pest populations closely.

Disadvantages

1. It is labour-intensive.
2. It may be difficult on large farms.
3. It may not be effective against very small or hidden pests.
4. Some pests reproduce rapidly and may return.
5. Workers may be exposed to harmful insects or irritating plant materials if they do not use protective equipment.

B. Trapping

Trapping involves using devices designed to attract and capture pests.

Types of traps

1. Light traps

- Use light to attract certain flying insects.
- The attracted insects are captured or collected.
- They may be used for monitoring and, in some situations, reducing pest populations.

2. Sticky traps

- Have sticky surfaces that capture insects when they land on them.
- Yellow sticky traps are commonly used to monitor whiteflies, aphids and some other flying insects.
- Blue sticky traps are often used to monitor thrips.

3. Pheromone traps

- Use synthetic chemicals that imitate insect communication chemicals.
- Attract particular insect species, commonly males of certain moth pests.
- Help monitor pest populations and guide decisions on when to control pests.

4. Rodent traps

- Designed to capture or kill rats and mice.
- Examples include suitable snap traps and live-capture traps.
- Should be positioned safely away from children, livestock and non-target animals.

5. Pitfall traps

- Containers or devices placed at ground level to capture crawling insects.
- Often used for monitoring ground-dwelling pests.

Advantages of trapping

- Helps monitor pest populations.
- Reduces pest numbers in some situations.
- Can reduce reliance on pesticides.
- Some traps are species-specific.
- Useful in greenhouses, orchards and crop stores.

Limitations

- Some traps capture only a small proportion of pests.
- Traps require regular inspection and maintenance.

- Their effectiveness may depend on weather and pest behaviour.
- Traps may capture beneficial insects if poorly selected or positioned.

C. Use of barriers and netting

This involves placing physical materials between pests and crops to prevent access.

Examples

1. Bird nets placed over fruit trees and vegetable plots.
2. Insect-proof nets used in nurseries and greenhouses.
3. Mesh screens fitted to greenhouse openings.
4. Protective collars around seedlings to reduce cutworm damage.
5. Fencing used to keep livestock and some larger animals away from crops.
6. Suitable covers placed over seedbeds.

Advantages

- Prevents pests from reaching protected crops.
- Reduces the need for chemical pesticides.
- Protects crops during vulnerable growth stages.
- Can be reused when properly maintained.

Disadvantages

- Initial installation may be expensive.
- Nets may be damaged by wind, animals or poor handling.
- Some barriers may interfere with pollination if not properly managed.
- They require regular inspection and maintenance.

D. Heat treatment

Heat treatment involves exposing infested materials to controlled high temperatures for a specified period to kill pests.

Examples

- Controlled heat treatment of stored grains.
- Heat treatment of seeds where recommended.
- Use of hot water to treat certain planting materials against specific pests.

Advantages

1. Can kill pests at different developmental stages.
2. May reduce the need for chemical treatments.
3. Can be useful for treating selected planting materials and stored products.

Limitations

1. Incorrect temperatures may damage seeds and reduce germination.
2. Requires proper temperature control.
3. Not suitable for all crops and products.

E. Cold treatment

Cold treatment involves exposing certain stored products to suitably low temperatures to slow down or kill pests.

Examples

- Refrigeration or freezing of selected stored products.
- Controlled cold storage of horticultural produce to suppress certain pests.

Advantages

- Reduces pest activity.
- May preserve the quality of some products.
- Can reduce the need for chemical treatments.

Limitations

- Requires suitable equipment.
- Some pests can survive low temperatures.
- Incorrect temperature management may damage crops.

2.3 Cultural control of pests

Cultural control involves modifying farm practices and the crop-growing environment to make conditions less favourable for pest survival, multiplication and spread.

It is based on good agricultural practices that reduce pest populations and minimise crop damage.

Methods of cultural pest control

A. Crop rotation

Crop rotation is the practice of growing different crops on the same piece of land in a planned sequence over different seasons.

How it controls pests

1. Breaks the life cycle of pests that depend on particular host crops.
2. Reduces the continuous availability of food for specialised pests.
3. Helps reduce the build-up of soil-borne pests.
4. Improves soil health when appropriate crops are included.
5. Reduces the need for repeated pesticide application.

Example

A farmer may rotate maize with beans or another suitable non-host crop to help manage certain pests and improve soil fertility.

Important consideration: Crop rotation is most effective when the crops selected are not hosts of the same pest. Some pests have wide host ranges and may survive on several crops.

B. Field sanitation

Field sanitation involves keeping the farm clean by removing materials that harbour pests.

Practices

1. Remove and appropriately destroy heavily infested crop residues.
2. Remove volunteer crops that act as alternative hosts for pests.
3. Remove fallen and rotting fruits from orchards.
4. Clear unwanted vegetation that harbours particular pests.
5. Clean farm tools and equipment.
6. Dispose of infested plant materials safely.
7. Maintain clean harvesting and handling areas.

Importance

- Removes breeding and hiding places.
- Reduces pest populations.

- Prevents pests from spreading to healthy crops.
- Reduces reinfestation.
- Improves farm hygiene.

C. Timely planting

Timely planting involves sowing crops at the most appropriate time based on local weather patterns and recommended agronomic practices.

How it controls pests

1. Allows crops to establish under favourable conditions.
2. Helps crops avoid periods when particular pests are most active.
3. Enables crops to pass through vulnerable stages before peak pest populations develop.
4. Promotes uniform crop growth.
5. May reduce the need for chemical pest control.

Example: Planting cereals at the recommended onset of rains may allow the crop to establish well before some pest populations increase.

D. Early planting or synchronised planting

In some farming systems, early planting or planting at the same time as neighbouring farmers can reduce pest damage.

How it works

1. Reduces the period during which crops remain vulnerable to certain pests.
2. May reduce the concentration of pests on a few isolated fields.
3. Helps crops mature before some pest populations reach damaging levels.

Example: Synchronous planting of cereal crops in an area may reduce the availability of continuously growing host plants for certain pests.

E. Timely harvesting

This involves harvesting crops as soon as they reach the recommended maturity stage.

Importance

1. Reduces the period during which mature crops are exposed to field pests.
2. Prevents unnecessary field losses caused by birds and insects.
3. Reduces exposure to weather damage.
4. Helps prevent pest multiplication in over-mature crops.

5. Improves the quality of produce taken to storage.

F. Deep ploughing

Deep ploughing involves turning the soil to expose certain soil-dwelling pests to predators, sunlight and unfavourable environmental conditions.

How it controls pests

1. Exposes some insect larvae and pupae to birds and other predators.
2. Buries some pests and crop residues.
3. Disturbs the habitats of certain soil-dwelling pests.
4. May reduce the survival of some pests between cropping seasons.

Limitations

- It may increase soil erosion when improperly practised.
- It can disturb soil structure and beneficial organisms.
- It should be used according to soil type, slope and conservation requirements.

G. Intercropping

Intercropping involves growing two or more crops together on the same piece of land during the same season.

How it helps control pests

1. Reduces the concentration of a preferred host crop.
2. May interfere with the ability of pests to locate their host plants.
3. Encourages biodiversity.
4. May provide habitats for beneficial insects.
5. Can reduce the spread of certain pests between plants.

Example: Growing maize together with beans may help diversify the field environment. However, the choice of intercrop should consider pests that may attack both crops.

H. Use of resistant crop varieties

This involves growing crop varieties that can withstand or tolerate attack by particular pests.

Types of resistance

1. Antixenosis: The plant has characteristics that discourage pests from feeding, laying eggs or settling on it.
2. Antibiosis: The plant affects the survival, growth or reproduction of the pest.
3. Tolerance: The plant withstands pest damage and maintains reasonable growth or yield.

Advantages

- Reduces crop losses.
- May reduce pesticide use.
- Provides protection throughout much of the crop growth period.
- Can be economical over several seasons.

Limitation: Resistance may be specific to particular pests and may break down when pest populations adapt. Farmers should use recommended varieties and avoid relying on one control method.

I. Proper spacing

Proper spacing refers to planting crops at recommended distances to avoid overcrowding and create favourable growing conditions.

How it helps

1. Improves air circulation.
2. Allows adequate light penetration.
3. Reduces excessive humidity within the crop canopy.
4. Makes crop inspection easier.
5. Helps identify pest infestations early.
6. Allows easier application of recommended control measures.

J. Weed control

Weeds may act as alternative hosts or shelters for certain crop pests.

How weed control helps

1. Removes alternative food sources for some pests.
2. Reduces pest breeding and hiding places.
3. Improves crop vigour by reducing competition.
4. Makes it easier to inspect crops.
5. Reduces the spread of some pests from weeds to cultivated crops.

Important: Not all weeds are harmful to beneficial organisms. Some non-crop vegetation provides food and shelter for natural enemies. Weed management should therefore be selective and appropriate.

K. Water and nutrient management

Proper irrigation and balanced fertiliser application help crops grow vigorously and withstand some pest damage.

1. Avoid excessive nitrogen application, which may encourage some sap-sucking pests.
2. Avoid water stress, which weakens crops.
3. Maintain appropriate drainage to prevent waterlogging.
4. Apply fertilisers according to soil-test results and crop requirements.
5. Maintain healthy soil to support strong crop development.

L. Use of trap crops

Trap cropping involves growing a plant that is more attractive to a particular pest than the main crop.

How it works

1. The trap crop attracts the target pest.
2. The pest concentrates on the trap crop.
3. The farmer manages the pest on the trap crop using an appropriate method.
4. The main crop receives reduced pest pressure.

Example: Certain trap-crop arrangements may be used in vegetable production to attract selected caterpillar pests away from the main crop.

Limitation: Trap crops must be managed properly. If neglected, they may become breeding sites and increase pest populations.

2.4 Biological control of pests

Biological control involves using living organisms or their natural products to reduce pest populations.

It makes use of natural enemies such as predators, parasitoids and disease-causing microorganisms.

Groups of biological control agents

A. Predators

Predators are organisms that feed on other organisms (prey), usually killing and consuming several individuals during their lifetime.

Examples

1. Ladybird beetles

- Feed on aphids and some other soft-bodied insects.
- Help reduce aphid populations in vegetable crops and orchards.

2. Green lacewing larvae

- Feed on aphids, whiteflies, thrips and small insect eggs.
- Are useful natural enemies in horticultural production.

3. Spiders

- Capture and feed on different insect pests.
- Help maintain ecological balance in crop fields.

4. Predatory mites

- Feed on plant-feeding mites and other small pests.
- Are used in some greenhouse and horticultural systems.

5. Birds

- Some insect-eating birds feed on caterpillars, beetles and other insects.
- They may help reduce pest populations, although some birds also damage crops.

B. Parasitoids

Parasitoids are organisms, usually insects, whose immature stages develop on or inside a host insect and eventually kill it.

Examples

1. Parasitic wasps

- Some lay eggs inside or on pest insects.
- Their larvae develop by feeding on the host.
- The host eventually dies.

2. Trichogramma wasps

- Lay eggs inside the eggs of certain moth pests.
- Prevent the pest eggs from developing into damaging larvae.

3. Braconid wasps

- Some species parasitise caterpillars and other insect pests.
- Help reduce populations of harmful insects.

C. Pathogens

Pathogens are disease-causing organisms that infect pests and may cause their death.

Important biological control pathogens include:

1. Bacteria

- Bacillus thuringiensis (Bt) is used in biological pest management.

- Certain strains produce toxins that affect susceptible insect larvae when ingested.
- It is used against selected caterpillar pests.

2. Fungi

- Beauveria bassiana infects susceptible insects through their outer body covering.
- Metarhizium anisopliae infects various insect pests.
- These fungi can be used in selected biological control products.

3. Viruses

- Certain insect-specific viruses infect particular pest species.
- Baculoviruses are used against some caterpillar pests.
- They are often relatively specific to their target insect groups.

D. Use of natural enemies through conservation biological control

This involves protecting and encouraging naturally occurring beneficial organisms within the farm environment.

Practices

1. Avoid unnecessary broad-spectrum pesticide application.
2. Maintain suitable flowering plants that provide nectar and pollen to beneficial insects.
3. Provide suitable habitats for natural enemies.
4. Avoid destroying beneficial organisms during field operations.
5. Use selective pest-control products where necessary.
6. Maintain appropriate field biodiversity.

Advantages of biological control

1. Reduces dependence on chemical pesticides.
2. Can provide long-term pest suppression.
3. May be environmentally friendly when properly selected.
4. Can reduce pesticide residues on produce.
5. Some biological agents are specific to particular pests.
6. Helps conserve beneficial organisms.
7. Can be incorporated into integrated pest management.

Disadvantages of biological control

1. Some biological agents act more slowly than chemical pesticides.
2. Their effectiveness may depend on temperature, humidity and other environmental conditions.
3. Some agents are difficult or expensive to produce and distribute.
4. They may not control severe infestations quickly enough.
5. Incorrect introduction of biological control organisms may cause ecological problems.
6. They require correct identification of the pest and suitable natural enemy.

2.5 Chemical control of pests

Chemical control involves using pesticides to kill, repel, prevent or manage pests.

Pesticides are substances or mixtures used to control harmful organisms. The type of pesticide selected depends on the pest being controlled and the crop being protected.

Types of pesticides according to the target pest

1. Insecticides

- Chemicals used to control insect pests.
- Examples of target pests include aphids, caterpillars, beetles and whiteflies.

2. Acaricides

- Products used to control mites and ticks.
- In crop production, they are commonly used against plant-feeding mites.

3. Nematicides

- Products used to control plant-parasitic nematodes.
- They may be applied to soil or planting materials according to the product label.

4. Molluscicides

- Products used to control snails and slugs.
- Some are supplied as pellets or baits.

5. Rodenticides

- Products used to control rats and mice.
- They must be handled and placed carefully to prevent poisoning of people, livestock and wildlife.

6. Avicides

- Products intended to control birds.

- Their use is highly regulated and should only be considered where specifically authorised. Non-chemical deterrents and exclusion methods are often preferable.

Classification of insecticides according to how they act

1. Contact insecticides

- Kill insects when the chemical comes into direct contact with their bodies.
- Proper coverage of the target pest is important.

2. Stomach insecticides

- Kill insects after they ingest treated plant material or the insecticide.
- Commonly used against certain chewing insects.

3. Systemic insecticides

- Are absorbed and transported within plant tissues.
- Affect susceptible pests feeding on treated plant parts.
- Must be used only on crops and against pests specified on the label.

4. Fumigants

- Produce toxic gases used to control pests in enclosed spaces or stored products.
- They require specialised equipment, training and strict safety precautions.
- They should only be applied by appropriately authorised and trained persons.

Forms of pesticide application

1. Spraying

- The pesticide is mixed and applied as a liquid using suitable spraying equipment.
- Used for selected insecticides and other crop-protection products.

2. Dusting

- A formulated pesticide is applied as a dry powder.
- It is used only where the product is specifically labelled for this method.

3. Baiting

- The pesticide is incorporated into an attractive food material.
- Commonly used in the management of rodents and some other pests.

4. Seed treatment

- Suitable products are applied to seeds before planting.

- Protects seeds and young seedlings from specified pests and diseases.

5. Soil application

- A labelled product is applied to soil to manage target soil-dwelling pests.
- The method depends on the pesticide formulation and label instructions.

6. Granule application

- Granular products are placed or applied according to the label.
- Some are used against particular soil or crop pests.

Advantages of chemical pest control

1. Can provide rapid control of severe pest infestations.
2. Suitable products are available for many pest groups.
3. Can be applied over relatively large areas using appropriate equipment.
4. Helps protect crops during vulnerable growth stages.
5. May reduce crop losses and improve marketable yield.
6. Can be useful when other methods are insufficient.

Disadvantages of chemical pest control

1. Some pesticides are poisonous to humans and animals.
2. They may kill beneficial insects such as pollinators and natural enemies.
3. Repeated use of the same mode of action can lead to pesticide resistance.
4. Some pesticides may leave residues on crops.
5. They may contaminate soil and water if misused.
6. They may cause secondary pest outbreaks by destroying natural enemies.
7. They increase production costs.
8. Some require special equipment and trained operators.
9. Incorrect disposal of containers may pollute the environment.
10. Some pests may recover or multiply after pesticide application if the treatment is ineffective.

Safe use of pesticides

Pesticides must be handled responsibly to protect farmers, farm workers, consumers, livestock and the environment.

Safety measures before application

1. Correctly identify the pest before choosing a pesticide.
2. Use only products registered and approved for the intended crop and pest.
3. Read and follow the product label.
4. Check the recommended application rate and timing.
5. Wear the personal protective equipment specified on the label.
6. Check spraying equipment for leaks and damage.
7. Avoid spraying during strong winds or when rain is likely to wash the product off, unless the label provides different instructions.
8. Keep children, livestock and unauthorised persons away from the mixing and spraying area.

Safety measures during application

1. Wear the required protective clothing, gloves, boots, eye protection and respirator where specified.
2. Avoid eating, drinking or smoking while handling pesticides.
3. Do not blow through blocked spray nozzles using the mouth.
4. Avoid spraying against the wind.
5. Do not allow pesticide drift onto neighbouring crops, water sources, homes or animals.
6. Use the recommended application rate.
7. Avoid unnecessary spraying.
8. Do not mix products unless the labels specifically permit the mixture.
9. Maintain the recommended buffer zones around sensitive areas.

Safety measures after application

1. Observe the re-entry interval before entering treated fields without the required protection.
2. Observe the pre-harvest interval before harvesting treated crops.
3. Wash hands and exposed body parts thoroughly.
4. Wash protective clothing separately from ordinary clothing.
5. Clean spraying equipment according to the label instructions.
6. Store pesticides in their original, labelled containers.
7. Keep pesticides in a secure, locked storage area away from food, animal feeds and children.
8. Dispose of empty containers according to the label and applicable regulations.
9. Never reuse pesticide containers for storing water, food or other household materials.

10. Seek immediate medical assistance if pesticide poisoning is suspected and take the product label or container information where safe to do so.

Important pesticide safety terms

- Pre-harvest interval (PHI): The minimum period that must elapse between the last pesticide application and harvesting the crop.
- Re-entry interval (REI): The minimum period that must elapse before people can safely re-enter a treated area without the specified protective equipment.
- Pesticide residue: A small amount of pesticide or its breakdown products that remains on or in agricultural produce, soil or other materials after application.
- Pesticide resistance: The inherited ability of some individuals in a pest population to survive a pesticide treatment that previously controlled the population.
- Pesticide drift: Movement of pesticide droplets or vapour away from the intended application area.

2.6 Legislative control of pests

Legislative control involves using laws, regulations, standards and official procedures to prevent the introduction, spread and multiplication of harmful agricultural pests.

It is implemented by governments and authorised regulatory agencies.

Methods of legislative pest control

A. Plant quarantine

Plant quarantine involves restricting the movement of plants, seeds, planting materials or agricultural products from areas where dangerous pests occur to prevent their spread.

Importance

1. Prevents the introduction of new pests into pest-free areas.
2. Reduces the spread of dangerous crop pests.
3. Protects farmers from losses caused by invasive pests.
4. Protects national agricultural production.
5. Supports safe international agricultural trade.

B. Inspection of planting materials

Agricultural authorities inspect seeds, seedlings, cuttings, tubers and other planting materials before movement or distribution.

Importance

- Prevents the movement of infested materials.
- Helps ensure planting materials meet required standards.

- Reduces the spread of pests between farms and regions.

C. Certification of seeds and planting materials

Seed certification involves official procedures for ensuring that seeds meet specified quality and regulatory requirements.

It helps farmers obtain planting materials that meet recognised standards, including requirements relating to purity, germination and other quality characteristics.

D. Restriction of movement of infested materials

Authorities may restrict the movement of infested crops, soil, plants or agricultural products from affected areas.

This prevents pests from spreading to unaffected farms and regions.

E. Destruction of severely infested materials

Where required by law or official plant-health instructions, heavily infested plant materials may be destroyed using approved methods.

This helps prevent further multiplication and spread of dangerous pests.

F. Regulation of pesticide use

Pesticide regulation involves controlling the registration, sale, distribution, storage and use of agricultural pesticides.

In Kenya, the Pest Control Products Board (PCPB) is a key regulatory institution responsible for regulating pest control products.

Importance of legislative control

1. Protects crops from dangerous invasive pests.
2. Prevents the spread of pests across geographical boundaries.
3. Protects farmers and consumers.
4. Promotes responsible pesticide use.
5. Protects the environment.
6. Supports the production and distribution of safe planting materials.
7. Facilitates compliance with agricultural trade requirements.

Limitations of legislative control

1. Requires adequate inspection and enforcement personnel.
2. Monitoring large borders and farming areas may be difficult.
3. Farmers may lack awareness of regulations.

4. Enforcement may be expensive.
5. Illegal movement of planting materials may still occur.
6. Some pests may spread naturally through wind, water, birds or insects.

2.7 Integrated Pest Management (IPM)

Integrated Pest Management is an approach that combines different compatible pest-control methods to manage pest populations below economically damaging levels while minimising risks to human health, beneficial organisms and the environment.

IPM does not depend on a single method. It combines cultural, physical, biological, legislative and carefully selected chemical methods.

Principles of Integrated Pest Management

1. Correct pest identification

- Farmers should identify the pest accurately before taking action.
- This prevents the use of inappropriate control methods.

2. Regular monitoring

- Crops should be inspected frequently.
- Farmers should record pest numbers, crop damage and changes in infestation levels.

3. Understanding pest life cycles

- Knowledge of pest development helps farmers identify the most vulnerable stages.
- It also helps in selecting suitable control methods.

4. Setting action thresholds

- Farmers should determine when pest populations are likely to cause economic damage.
- Control should be undertaken at the appropriate time.

5. Prevention

- Use clean planting materials, crop rotation, resistant varieties, field sanitation and proper crop management.
- Prevention reduces the likelihood of serious infestation.

6. Combining control methods

- Use compatible cultural, physical, biological and chemical approaches.
- Avoid relying entirely on pesticides.

7. Selective pesticide use

- Apply pesticides only when justified.
- Choose products that target the pest while reducing harm to beneficial organisms.

8. Evaluation

- Assess the effectiveness of control measures.
- Make adjustments where necessary.

Steps followed when implementing IPM

1. Identify the crop and the pest affecting it.
2. Inspect the crop to determine the level of infestation.
3. Assess the nature and extent of damage.
4. Determine whether the pest population has reached the action threshold.
5. Select suitable preventive and control measures.
6. Apply the selected methods correctly and safely.
7. Monitor the crop after treatment.
8. Record the results.
9. Evaluate whether the methods reduced pest damage.
10. Improve the management plan where necessary.

Example: Integrated management of fall armyworm in maize

IPM component	Practice
Monitoring	Inspect maize plants regularly, especially the whorls, for eggs and larvae.
Cultural control	Plant at the recommended time and maintain field sanitation.

Physical control	Remove and destroy heavily infested plant parts where practical and appropriate.
Biological control	Conserve natural enemies and use approved biological control products where suitable.
Resistant varieties	Plant recommended varieties with suitable tolerance or resistance where available.
Chemical control	If justified, use an approved pesticide labelled for fall armyworm on maize, following all safety instructions.
Evaluation	Inspect the field after intervention and record the level of control achieved.

Advantages of Integrated Pest Management

1. Reduces unnecessary pesticide application.
2. Helps delay the development of pesticide resistance.
3. Protects beneficial organisms.
4. Reduces environmental pollution.
5. Promotes safer agricultural produce.
6. Combines short-term and long-term pest-management measures.
7. May reduce production costs over time.
8. Encourages farmers to monitor crops and make informed decisions.
9. Promotes sustainable crop production.
10. Supports environmental conservation.

Challenges of Integrated Pest Management

1. Requires knowledge and training.
2. Regular monitoring takes time.
3. Some biological control methods may act slowly.
4. Biological control agents may not always be readily available.
5. Farmers may need to invest in traps and monitoring equipment.
6. It requires careful planning and record keeping.
7. It may be difficult to coordinate pest control among neighbouring farmers.

3. ECONOMIC IMPORTANCE OF PESTS IN CROP PRODUCTION

Pests have significant economic effects on crop production. Although some organisms classified as pests may have ecological or other beneficial roles, their presence in agricultural production can result in serious economic losses.

Economic importance refers to the effects pests have on the quantity, quality, production costs, market value and profitability of agricultural products.

Pests can have both negative and indirect positive effects on agriculture and the environment. Their effects depend on the species, population size, feeding habits and the conditions under which they occur.

3.1 Negative economic importance of crop pests

A. Reduction in crop yields

Pests feed on different parts of crops, reducing their ability to grow and produce.

1. Leaf-feeding insects destroy leaf tissues and reduce photosynthesis.
2. Root-feeding pests interfere with water and mineral absorption.
3. Stem borers damage stems and interfere with the movement of water and nutrients.
4. Flower-feeding pests reduce fruit and seed formation.
5. Grain-feeding pests destroy developing grains.

Example: Fall armyworm infestation in maize may destroy leaves and growing points, resulting in reduced grain yields.

B. Reduction in the quality of agricultural produce

Pests damage the physical appearance, texture and quality of agricultural products.

1. Fruit flies cause rotting and discolouration of fruits.
2. Aphids may contaminate vegetables with honeydew and shed skins.
3. Weevils damage stored grains by creating holes.
4. Caterpillars leave feeding marks on vegetables.
5. Rodents contaminate stored produce with urine and faeces.

Poor-quality produce may fail to meet market standards.

C. Increased cost of production

Farmers spend money and resources controlling pests.

Expenses may include:

1. Purchasing pesticides.
2. Buying protective clothing.

3. Purchasing sprayers and traps.
4. Paying workers to monitor and remove pests.
5. Purchasing resistant planting materials.
6. Repairing damaged storage structures.
7. Paying for professional pest-control services.

These expenses increase the total cost of crop production.

D. Increased post-harvest losses

Storage pests destroy agricultural produce after harvesting.

Examples:

- Maize weevils destroy stored maize.
- Bean bruchids damage stored beans.
- Larger grain borers attack maize and dried cassava.
- Rats and mice consume and contaminate stored produce.

Effects

1. Reduced quantity of produce available for consumption.
2. Reduced marketable surplus.
3. Increased food wastage.
4. Reduced household food security.
5. Increased cost of replacing lost produce.

E. Transmission of crop diseases

Some pests act as vectors by transmitting disease-causing organisms from infected plants to healthy ones.

Examples

1. Aphids transmit several plant viruses.
2. Whiteflies transmit important viral diseases in crops such as tomatoes and cassava.
3. Some thrips transmit plant viruses.
4. Certain insect pests transmit bacterial or other disease-causing organisms.

Economic effects

- Increased disease-control costs.

- Reduced crop quality and yields.
- Premature death of plants.
- Loss of marketable produce.

F. Destruction of seedlings and poor crop establishment

Pests such as cutworms, termites, wireworms and seed-corn maggots may destroy seeds and seedlings.

This results in:

1. Poor germination.
2. Missing plants.
3. Uneven crop stands.
4. Increased cost of replanting.
5. Delayed crop maturity.
6. Reduced final yield.

G. Reduction in farmers' income

When pests reduce the quantity and quality of produce, farmers may earn less from their harvest.

This can result in:

1. Reduced household income.
2. Lower profits.
3. Difficulty meeting farm expenses.
4. Increased borrowing.
5. Reduced investment in future crop production.

H. Increased food prices

Severe pest infestations may reduce the supply of agricultural products in markets.

When the supply of a commodity falls while demand remains high, its market price may increase.

Example: Serious losses of stored maize due to insect pests may reduce the quantity available for sale and consumption.

I. Damage to planting materials

Some pests attack seeds, tubers, bulbs, cuttings and seedlings intended for planting.

This may:

1. Reduce seed viability.
2. Lower germination percentage.
3. Increase the cost of purchasing replacement materials.
4. Spread pests to new farms.
5. Reduce the availability of quality planting materials.

J. Loss of export markets

Pests and pest-related contamination may cause agricultural products to fail to meet phytosanitary and quality requirements in export markets.

Consequences

1. Rejection of consignments.
2. Loss of export income.
3. Increased inspection and treatment costs.
4. Damage to the reputation of agricultural exporters.
5. Restrictions on the movement of produce from affected areas.

K. Damage to farm structures and equipment

Some pests, particularly rodents and termites, damage farm infrastructure.

Examples:

- Rats gnaw storage bags and electrical cables.
- Termites damage wooden structures.
- Rodents damage irrigation pipes and storage materials.

This increases repair and replacement costs.

L. Competition with beneficial organisms

Some pests and invasive organisms may interfere with beneficial organisms by competing for resources or disrupting ecological relationships.

For example, invasive pests may disrupt existing ecological balance and affect organisms that are important in crop production.

3.2 Positive and indirect ecological importance of some organisms regarded as pests

Not every organism that is undesirable in one agricultural situation is harmful in every ecological context. Some organisms classified as pests under particular circumstances also perform useful ecological functions.

1. Food for natural enemies

- Some insects and other organisms regarded as pests provide food for predators, parasitoids and insect-eating birds.
- This supports food chains and biodiversity.

2. Contribution to decomposition

- Some organisms feed on dead plant materials and organic matter.
- They help break down organic materials and return nutrients to the soil.
- However, this benefit does not justify allowing crop-damaging populations to multiply.

3. Food for other animals

- Some insects, birds and rodents form part of food chains.
- They provide food for predators and other wildlife.

4. Contribution to scientific research

- Some pest organisms are used in scientific studies on genetics, ecology, behaviour and pest-management methods.

5. Pollination by certain insect species

- Some insects that may occasionally damage crops also visit flowers and contribute to pollination.
- Their pollination role depends on the species; many important pollinators are beneficial insects rather than crop pests.

6. Support for ecological balance

- Pest organisms form part of natural ecosystems.
- Their populations may be regulated by predators, parasitoids, pathogens and environmental conditions.

Important distinction: The ecological role of an organism does not mean that a damaging pest population should be left unmanaged. Farmers should manage crop pests in ways that protect beneficial organisms and maintain ecological balance.

3.3 Summary of the economic effects of crop pests

Negative effect	Explanation	Example
Yield reduction	Pests destroy crop tissues and reduce production.	Fall armyworm in maize.
Poor quality	Pests damage the appearance and condition of	Fruit flies in mangoes.

	produce.	
Increased production costs	Farmers spend more on control measures.	Purchase of insecticides and traps.
Storage losses	Pests destroy harvested products.	Maize weevils in stored maize.
Disease transmission	Some pests transmit plant pathogens.	Aphids transmitting plant viruses.
Poor establishment	Pests destroy seeds and seedlings.	Cutworms in vegetables.
Reduced income	Lower yields and quality reduce profits.	Damaged tomato harvest.
Export restrictions	Infested produce may fail to meet market requirements.	Pest-infested horticultural produce.
Infrastructure damage	Pests destroy storage materials and structures.	Rodents damaging grain bags.

4. COMPARISON OF DIFFERENT PEST-CONTROL METHODS

Farmers should understand the strengths and weaknesses of different pest-control methods before selecting an appropriate approach.

Method	Main approach	Examples	Main advantage
Physical control	Uses physical devices, barriers or manual removal.	Hand-picking, traps, nets.	Reduces reliance on pesticides.
Cultural control	Modifies farm practices to make conditions unfavourable for pests.	Crop rotation, field sanitation, timely planting.	Helps prevent pest build-up.
Biological control	Uses natural enemies and biological agents.	Ladybirds, parasitoid wasps, Bt.	Can provide environmentally considerate pest suppression.
Chemical control	Uses pesticides to manage pests.	Insecticides, acaricides, rodenticides.	Can provide relatively rapid control when correctly selected.
Legislative control	Uses laws and regulations to prevent pest introduction and spread.	Quarantine, inspection, pesticide regulation.	Protects areas and agricultural systems from dangerous pests.
Integrated pest management	Combines compatible pest-management methods.	Monitoring, crop rotation, biological control and selective pesticide use.	Provides a more sustainable management approach.

5. PRACTICAL ACTIVITIES IN CROP PEST CONTROL

Practical activities enable learners to apply classroom knowledge to real agricultural situations.

Activity 1: Identification and classification of crop pests

Objective: To identify common crop pests and classify them according to their biological groups and the nature of damage they cause.

Materials

- Infested crop leaves.
- Maize cobs.
- Beans.
- Photographs of crop pests.
- Hand lens.
- Specimen containers.
- Observation notebook.

Procedure

1. Visit a crop farm, school garden or agricultural demonstration plot.
2. Observe crops showing signs of pest attack.
3. Identify visible pests using appropriate identification guides.
4. Collect safe specimens where permitted.
5. Use a hand lens to examine small pests.
6. Classify the pests into insects, mites, nematodes, molluscs, birds and rodents.
7. Identify the plant parts attacked.
8. Record the type of damage observed.
9. Discuss the most appropriate control methods.

Suggested observation table

Crop	Pest identified	Biological group	Part attacked	Nature of damage
Maize	Fall armyworm	Insect	Leaves and growing point	Holes and ragged leaf edges
Beans	Aphids	Insect	Leaves and shoots	Sap sucking and curling
Tomato	Root-knot	Nematode	Roots	Root galls

	nematodes			
Cabbage	Slugs	Mollusc	Leaves	Irregular holes
Sorghum	Quelea birds	Bird	Grains	Feeding on developing grains
Stored maize	Rats	Rodent	Grain and bags	Consumption and contamination

Expected learning outcomes

- Ability to identify common crop pests.
- Ability to classify pests into appropriate biological groups.
- Ability to recognise pest damage.
- Ability to recommend suitable control methods.

Activity 2: Investigating the damage caused by pests

Objective: To examine the effects of different pests on crops and crop produce.

Procedure

1. Obtain samples of healthy and pest-damaged crop materials.
2. Observe the differences in appearance.
3. Examine leaves for holes, spots and curling.
4. Examine stems for holes and tunnels.
5. Examine roots for galls and feeding damage.
6. Examine fruits for rotting and feeding marks.
7. Examine stored grains for holes and powdery residues.
8. Record the differences.
9. Explain how the damage affects crop yield and quality.

Activity 3: Demonstrating physical pest control

Objective: To demonstrate the use of simple physical methods in pest control.

Procedure

1. Establish a small vegetable plot.
2. Inspect the plants for visible pests.
3. Hand-pick visible caterpillars and snails where safe and practical.

4. Install suitable yellow or blue sticky monitoring traps.
5. Place protective netting over selected plants.
6. Observe pest numbers and crop damage over time.
7. Compare protected plants with unprotected plants.
8. Record findings.

Safety: Learners should not handle unknown pests, pesticide products or potentially contaminated specimens without appropriate supervision and protective equipment.

Activity 4: Demonstrating cultural pest control

Objective: To investigate how agricultural practices can reduce pest infestation.

Procedure

1. Establish two small plots of a suitable crop.
2. Apply recommended cultural practices to one plot.
3. Maintain the second plot using the agreed comparison conditions.
4. Observe pest numbers and crop damage regularly.
5. Record the findings.
6. Compare the results.
7. Explain how the cultural practices influenced pest occurrence.

Possible practices include field sanitation, crop rotation, proper spacing and timely weeding.

Activity 5: Observing biological pest control

Objective: To recognise natural enemies of crop pests.

Procedure

1. Visit a vegetable garden or demonstration farm.
2. Observe insects and other organisms on crops.
3. Identify possible predators such as ladybird beetles and spiders.
4. Search for evidence of parasitism where suitable.
5. Discuss how natural enemies reduce pest populations.
6. Explain why indiscriminate pesticide use may destroy beneficial organisms.

Activity 6: Developing an integrated pest-management plan

Objective: To develop a practical pest-management plan for a selected crop.

Procedure

1. Select a crop commonly grown in the locality.
2. Identify pests that commonly attack it.
3. Describe the nature of damage caused by each pest.
4. Select suitable preventive measures.
5. Recommend physical and biological control methods.
6. Identify when chemical control may be necessary.
7. Include safety precautions.
8. Prepare a monitoring and record-keeping plan.
9. Present the plan to the class.

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives given.

1. Which one of the following is an example of a field pest?

A. Maize weevil
B. Bean bruchid
C. Fall armyworm
D. Flour beetle

2. Which pest causes swelling of crop roots?

A. Aphid
B. Root-knot nematode

C. Grasshopper
D. Fruit fly

3. Which one of the following pests belongs to the group Mollusca?

A. Spider mite
B. Cutworm
C. Garden snail
D. Whitefly

4. Which of the following is a characteristic of insects?

A. They have four pairs of legs.
B. They have three pairs of legs.
C. They have no antennae.
D. They have soft unsegmented bodies without an exoskeleton.

5. Which one of the following pests attacks stored beans?

A. Bean bruchid
B. Fall armyworm
C. Cutworm
D. Thrips

6. The stage of an insect that feeds actively and grows after hatching is called:

A. Pupa
B. Egg
C. Larva
D. Adult

7. Which one of the following is an example of a rodent pest?

A. Locust
B. Rat
C. Aphid
D. Snail

8. Which crop pest causes damage by boring into maize stems?

A. Whitefly
B. Maize stalk borer
C. Spider mite
D. Bean bruchid

9. Which one of the following is a method of physical pest control?

A. Crop rotation
B. Application of insecticide
C. Hand-picking caterpillars
D. Use of parasitoid wasps

10. Growing different crops on the same piece of land in a planned sequence is known as:

A. Intercropping
B. Crop rotation
C. Mulching
D. Thinning

11. Which one of the following is an example of a biological control agent?

A. Ladybird beetle
B. Rodenticide
C. Pheromone trap
D. Insecticide

12. The use of an organism that develops on or inside a pest and eventually kills it is known as:

A. Physical control
B. Chemical control
C. Parasitism
D. Crop rotation

13. Which one of the following pesticides is specifically used to control mites?

A. Herbicide
B. Acaricide
C. Molluscicide
D. Rodenticide

14. The minimum period between the last pesticide application and harvesting a crop is called:

A. Re-entry interval
B. Pre-harvest interval
C. Germination period
D. Withdrawal period of seeds

15. Which one of the following is a major disadvantage of indiscriminate pesticide use?

A. Increased biodiversity
B. Conservation of natural enemies
C. Development of pesticide resistance
D. Improved environmental quality

16. Which one of the following practices helps to reduce the build-up of specialised crop pests?

A. Continuous monocropping
B. Crop rotation
C. Poor field sanitation
D. Delayed harvesting

17. Quelea birds mainly cause damage by:

A. Boring into crop stems.
B. Sucking plant sap.
C. Feeding on developing cereal grains.
D. Attacking crop roots.

18. Which one of the following is an important principle of Integrated Pest Management?

A. Applying pesticides every week.
B. Destroying all insects in the field.
C. Monitoring pest populations before taking control action.
D. Using only chemical methods.

19. Which institution regulates pest control products in Kenya?

A. KICD
B. PCPB
C. KNEC
D. KNBS

20. Which one of the following is an economic effect of crop pests?

A. Increased crop yield
B. Reduced production costs
C. Improved grain quality
D. Reduced farmers' income

Section B: Structured questions

21.

a) Define the term crop pest. (2 marks)

b) Distinguish between field pests and storage pests. (4 marks)

c) Give four examples of field pests and state one crop attacked by each. (4 marks)

d) Explain four effects of field pests on crop production. (8 marks)

22.

a) Name six biological groups into which crop pests can be classified. (6 marks)

b) State four characteristics of insects. (4 marks)

c) Describe four types of insect mouthparts and give one example of an insect for each type. (8 marks)

d) Distinguish between complete and incomplete metamorphosis. (2 marks)

23.

a) What is physical pest control? (2 marks)

b) Describe five methods of physical pest control used in crop production. (10 marks)

c) State four advantages of physical pest control. (4 marks)

d) Explain two limitations of physical pest control. (4 marks)

24.

a) Define biological pest control. (2 marks)

b) Explain the roles of the following biological control agents:

i. Predators. (3 marks)

ii. Parasitoids. (3 marks)

iii. Pathogens. (3 marks)

c) Give four examples of biological control agents used in managing crop pests. (4 marks)

d) State five advantages of biological pest control. (5 marks)

25.

a) Define chemical pest control. (2 marks)

b) Differentiate between the following pesticides:

i. Insecticides. (2 marks)

ii. Acaricides. (2 marks)

iii. Nematicides. (2 marks)

iv. Rodenticides. (2 marks)

c) Explain five safety precautions that should be observed when applying pesticides. (5 marks)

d) Explain five disadvantages of chemical pest control. (5 marks)

26.

a) Explain the meaning of Integrated Pest Management. (2 marks)

b) Describe six principles of Integrated Pest Management. (6 marks)

c) Explain six negative economic effects of crop pests. (6 marks)

d) Explain three ways in which legislation helps control crop pests. (3 marks)

e) State three ways of developing responsibility when carrying out pest-control activities. (3 marks)

8. KEY TERMS AND THEIR MEANINGS

Term	Meaning
Crop pest	An organism that damages crops or agricultural produce.
Field pest	A pest that attacks crops while they are growing in the field.
Storage pest	A pest that attacks harvested produce during storage.
Infestation	The presence and multiplication of pests in a particular area.
Insecticide	A pesticide used to control insects.
Acaricide	A product used to control mites and ticks.

Nematicide	A product used to control nematodes.
Molluscicide	A product used to control snails and slugs.
Rodenticide	A product used to control rodents.
Biological control	Management of pests using living organisms or their biological products.
Predator	An organism that captures and feeds on other organisms.
Parasitoid	An organism whose immature stage develops on or inside a host and eventually kills it.
Metamorphosis	The developmental changes an insect undergoes as it grows.
Crop rotation	Growing different crops on the same land in a planned sequence.
Field sanitation	Keeping crop fields clean by removing materials that harbour pests.
Quarantine	Restriction of the movement of plants or agricultural materials to prevent the spread of pests.
Pest monitoring	Regular observation of pest populations and crop damage.
IPM	Integrated Pest Management; combining compatible methods to manage pests sustainably.
Pesticide resistance	The inherited ability of some pests to survive a pesticide that previously controlled them.
PHI	Pre-harvest interval; the required period between the last pesticide application and harvesting.
REI	Re-entry interval; the required period before people can safely re-enter a treated area without specified protection.
Economic injury level	Pest population level at which the cost of damage equals the cost of control.
Economic threshold	Pest population level at which control action should be taken to prevent economic injury.

STRAND 1.0: CROP PRODUCTION

SUB-STRAND 1.6: CROP PRODUCTION STRUCTURES

INTRODUCTION TO CROP PRODUCTION STRUCTURES

Crop production structures are specially designed buildings, enclosures or facilities constructed to support and improve crop production activities. They provide suitable conditions for growing crops, protecting planting materials, handling agricultural produce and storing harvested crops.

Crop production structures help farmers to control environmental conditions such as temperature, light intensity, humidity, wind and water availability. They also protect crops from adverse weather, pests, birds and other destructive agents.

In modern agriculture, structures are important because they enable farmers to produce crops throughout the year, improve the quality of produce, increase productivity and reduce losses.

Examples of crop production structures include:

1. Greenhouses.
2. Shade-net houses.
3. Granaries.
4. Plant nurseries.
5. Irrigation structures.
6. Screen houses.
7. Crop drying structures.
8. Cold storage facilities.
9. Hydroponic growing structures.
10. Rainwater harvesting and storage structures.

This sub-strand mainly focuses on three important structures:

- Shade-net houses.
- Greenhouses.
- Granaries.

1.1 Meaning of important terms

1. Crop production structure: A building, enclosure or facility constructed to support crop-growing activities, protect crops or store agricultural produce.

2. Greenhouse: An enclosed structure covered with transparent or translucent material that allows sunlight to enter and helps create a controlled environment for crop production.

3. Shade-net house: A structure covered with special netting that reduces the intensity of sunlight and provides partial protection against insects, birds, wind and other environmental factors.

4. Granary: A specially constructed structure used for storing harvested grains and other dry agricultural produce.

5. Construction materials: Materials used to build a structure, such as timber, metal, stones, cement, wire mesh, plastic sheets and shade nets.

6. Ventilation: The movement and exchange of air within a structure to regulate temperature, humidity and air quality.

7. Irrigation system: An arrangement of equipment and facilities used to supply water to crops artificially.

8. Structural framework: The supporting skeleton of a structure, consisting of posts, beams, rafters, arches and other supporting components.

9. Cladding: The material used to cover the outside of a structure, such as greenhouse plastic, shade netting or metal sheets.

10. Foundation: The base of a structure that transfers its weight safely to the ground and provides stability.

11. Durability: The ability of a structure or material to withstand use, weather conditions and wear over time.

12. Crop protection: Measures taken to protect crops from harmful weather, pests, animals and other factors that reduce production.

2. IMPORTANCE OF CROP PRODUCTION STRUCTURES

Crop production structures play an important role in modern farming. They help farmers improve production, protect crops and manage agricultural activities more efficiently.

2.1 Provision of a suitable environment for crop growth

Structures such as greenhouses and shade-net houses help farmers modify the growing environment to suit particular crops.

1. Greenhouses allow farmers to regulate temperature and humidity.
2. Shade nets reduce excessive sunlight and heat.
3. Ventilation openings improve air circulation.
4. Irrigation facilities provide water when rainfall is inadequate.
5. The growing environment can be adjusted to suit sensitive crops.

Example: Tomato farmers may use greenhouses to provide a more controlled growing environment and reduce exposure to heavy rainfall.

2.2 Protection of crops from adverse weather conditions

Some structures protect crops against unfavourable weather.

1. Greenhouse coverings protect crops from direct rainfall.
2. Shade nets reduce excessive solar radiation.
3. Some structures reduce the effects of strong winds.
4. Protected growing areas can reduce physical damage caused by hail.
5. Granaries protect harvested grains from rain and direct exposure to moisture.

Example: A shade-net house can protect leafy vegetables from excessive sunlight and wind.

2.3 Protection against pests and animals

Appropriately designed structures help prevent certain pests and animals from reaching crops.

1. Insect-proof netting reduces entry of selected insect pests.
2. Bird netting protects fruits and seedlings from birds.
3. Greenhouse screens may reduce entry of flying insect pests.
4. Secure granaries prevent rodents and birds from accessing stored grains.
5. Properly sealed storage structures reduce contamination by pests.

Example: A screen house fitted with suitable insect-proof mesh can reduce whitefly entry into a vegetable production area.

2.4 Improvement of crop quality

Crop production structures can help farmers produce uniform and high-quality produce.

1. Controlled environmental conditions support uniform crop growth.
2. Protection from excessive rain reduces physical damage to some crops.
3. Appropriate ventilation reduces excessive humidity.
4. Protected cultivation may reduce blemishes caused by weather.
5. Proper grain storage helps maintain the quality of harvested produce.

2.5 Promotion of year-round crop production

Some structures allow farmers to grow crops even when outdoor conditions are less favourable.

1. Greenhouses may allow production during dry or rainy seasons when properly managed.
2. Irrigation facilities provide water during dry periods.
3. Shade-net houses support the production of selected horticultural crops.
4. Nursery structures enable seedlings to be raised before the main planting season.
5. Storage structures allow farmers to preserve produce for future use and sale.

2.6 Reduction of post-harvest losses

Granaries and other storage facilities help reduce losses after harvesting.

1. Protect grains from rainfall and excessive moisture.
2. Reduce access by rodents and birds.
3. Provide a secure place for storing harvested produce.
4. Allow proper handling and organisation of produce.
5. Help farmers store produce until market prices are favourable, where storage conditions permit.

2.7 Efficient use of land

Structures such as greenhouses and hydroponic units can support intensive crop production.

1. Crops can be grown in a relatively small area.
2. Vertical growing systems can use available space efficiently.
3. Nursery structures allow many seedlings to be raised in a limited space.
4. Irrigation systems can supply water directly to crop-growing areas.
5. Production activities can be organised more systematically.

2.8 Facilitation of agricultural research and learning

1. Structures provide suitable environments for demonstrating modern crop production practices.
2. Learners can observe crop growth under different conditions.
3. Farmers can compare different crop varieties.
4. They support experiments on irrigation, fertiliser application and pest management.
5. They provide practical training opportunities.

2.9 Improvement of farm income

1. Structures may increase the quantity and quality of marketable produce.
2. Farmers may produce crops during seasons when market supply is low.
3. Reduced losses improve the amount of produce available for sale.
4. Protected production can support higher-value horticultural enterprises.
5. Proper storage enables farmers to manage the timing of sales.

3. TYPES OF STRUCTURES USED IN CROP PRODUCTION

3.1 SHADE-NET HOUSE

Meaning of a shade-net house

A shade-net house is a framed structure covered with special woven or knitted netting designed to reduce the amount of sunlight reaching crops.

The netting also provides varying levels of protection against wind, birds and certain insect pests, depending on the type and size of mesh used.

Shade-net houses are commonly used in horticultural production, nurseries and the raising of seedlings.

In Kenya, shade-net houses are useful in the production of vegetables, flowers, herbs, tree seedlings and other crops that require protection from excessive sunlight.

A. Main parts of a shade-net house

1. Foundation

- This is the base on which the structure is supported.
- It may consist of concrete, stones or firmly anchored posts.
- It prevents the structure from being easily displaced by strong winds.

2. Supporting posts

- These are vertical members that support the roof and netting.
- They may be made of treated timber, steel or other durable materials.
- They should be firmly fixed to the ground.

3. Roof framework

- It forms the upper supporting section of the structure.
- It holds the shade net in position.
- It may consist of rafters, beams, arches or crossbars.

4. Shade net

- This is the special netting used to cover the roof and sides.
- It reduces sunlight intensity.
- It may also provide protection against birds and some insects.

5. Side netting

- Covers the sides of the structure.
- Helps protect crops from wind and selected pests.
- Allows air movement through the structure.

6. Entrance

- Provides access to the inside of the structure.
- It should be designed to reduce unnecessary entry of animals and pests.
- Some structures use a double-door entrance to improve insect exclusion.

7. Fastening materials

- Include clips, wires, ropes, ties and other fixing materials.
- They secure the netting to the supporting framework.

8. Ventilation openings

- Allow air to circulate through the structure.
- Help reduce excessive heat and humidity.

9. Drainage system

- Directs excess water away from the structure.
- Prevents waterlogging around the growing area.

10. Growing area

- The internal space where crops are planted.
- It may contain raised beds, planting containers, seedling benches or irrigation lines.

B. Characteristics of a good shade-net house

1. It should be constructed on a well-drained site.
2. It should have a strong supporting framework.
3. It should be covered with suitable shade netting.
4. The netting should provide the required shade level for the crop.
5. It should allow adequate air circulation.
6. It should have a convenient entrance.
7. It should be securely anchored against strong winds.
8. It should have an effective drainage system.
9. It should be easy to clean and maintain.
10. It should have sufficient internal space for crop management activities.

C. Types of shade nets

Shade nets are available in different colours, materials and shade percentages.

1. Green shade nets

- Commonly used in nurseries and horticultural production.
- Reduce excessive sunlight.
- Provide partial shade for seedlings and selected crops.

2. Black shade nets

- Reduce the amount of sunlight reaching crops.

- Are commonly used in nurseries and outdoor growing areas.
- Their performance depends on the shade percentage and material.

3. White shade nets

- Diffuse sunlight and reduce direct solar radiation.
- May help distribute light more evenly within the structure.
- Are used in selected horticultural production systems.

4. Coloured or specialised shade nets

- May be designed to modify light characteristics.
- Are used in specialised crop production.
- Their suitability depends on the crop and the manufacturer's specifications.

D. Shade percentage

Shade percentage refers to the proportion of incoming sunlight blocked by the netting.

For example:

- 30% shade net: blocks approximately 30% of incoming sunlight.
- 50% shade net: blocks approximately 50% of incoming sunlight.
- 75% shade net: blocks approximately 75% of incoming sunlight.

The correct shade percentage depends on the crop, climate, season and production purpose.

Examples of crop requirements

- Some vegetable seedlings require moderate shade during early growth.
- Certain ornamental plants require higher shade levels.
- Crops such as tomatoes generally require sufficient light for good growth and fruit production.

A farmer should select the shade level according to crop requirements rather than assuming that heavier shade is always better.

E. Uses of shade-net houses in crop production

1. Raising vegetable seedlings.
2. Raising tree seedlings in nurseries.
3. Growing leafy vegetables.
4. Producing selected flowers and ornamentals.
5. Protecting crops from excessive sunlight.

6. Reducing wind damage.
7. Protecting crops against birds.
8. Reducing the entry of selected insect pests when appropriate mesh is used.
9. Providing a suitable environment for hardening seedlings before transplanting.
10. Supporting research and demonstration activities.

F. Advantages of shade-net houses

1. Reduce excessive sunlight: They protect crops that are sensitive to intense solar radiation.

2. Improve seedling establishment: Seedlings can be raised under more favourable light conditions.

3. Reduce wind damage: Properly installed netting reduces the direct force of wind.

4. Protect against selected pests: Suitable insect-proof netting can reduce the entry of some insects.

5. Protect against birds: Netting can prevent birds from feeding on seedlings and fruits.

6. Improve crop quality: Reduced environmental stress can improve the appearance and condition of selected crops.

7. Relatively affordable: Some shade-net structures are less expensive to construct than fully enclosed greenhouses.

8. Allow air circulation: Their porous covering allows air to pass through, reducing heat build-up compared with some enclosed structures.

9. Support nursery activities: They provide suitable conditions for raising and managing seedlings.

10. Can be expanded: Additional sections can be constructed as the farming enterprise grows.

G. Disadvantages of shade-net houses

1. Initial construction cost: Posts, nets and fixing materials require capital.

2. Net deterioration: Exposure to sunlight and weather gradually weakens some net materials.

3. Limited environmental control: They do not provide the same level of control as properly equipped greenhouses.

4. Possible pest entry: Some insects may pass through the netting if the mesh is unsuitable.

5. Wind damage: Poorly anchored structures may be damaged by strong winds.

6. Reduced light: Excessive shading may reduce photosynthesis and crop yields.

7. Maintenance requirements: Nets may tear and require regular repair or replacement.

8. Not suitable for every crop: Some crops require high light intensity and may not perform well under heavy shading.

H. Maintenance of shade-net houses

1. Inspect the supporting posts regularly.
2. Repair torn netting immediately.
3. Tighten loose fixing materials.
4. Remove weeds growing around the structure.
5. Keep drainage channels clear.
6. Clean the internal growing area.
7. Replace damaged posts and other structural members.
8. Ensure that the entrance closes properly.
9. Monitor temperature and humidity.
10. Replace worn-out netting when necessary.

3.2 GREENHOUSE

Meaning of a greenhouse

A greenhouse is an enclosed structure covered with transparent or translucent materials that allow sunlight to enter while providing a degree of control over the internal growing environment.

The covering material allows solar radiation to reach crops and helps retain heat. Temperature, humidity, ventilation, irrigation and other environmental conditions can be managed to suit the crop being grown.

Greenhouses are widely used in horticulture, especially for crops such as tomatoes, capsicum, cucumbers, herbs, flowers and selected high-value vegetables.

A. Main parts of a greenhouse

1. Foundation

- The base that supports the greenhouse structure.
- May be made of concrete, masonry or anchored posts.
- Provides stability and prevents movement.

2. Framework

- The supporting skeleton of the greenhouse.
- May be constructed from galvanised steel, aluminium or treated timber.
- Supports the roof, walls and covering material.

3. Roof

- The upper part of the greenhouse.
- Allows sunlight to enter.
- Its shape helps direct rainwater away from the structure.

4. Greenhouse covering

- The transparent or translucent material used to cover the structure.
- Commonly consists of specialised greenhouse plastic film, polycarbonate panels or glass.
- Allows sunlight to reach crops while protecting them from external weather.

5. Side walls

- Enclose the sides of the greenhouse.
- May consist of plastic, polycarbonate, glass or a combination of materials.
- Help protect crops from rain, wind and some pests.

6. Ventilation openings

- Allow the movement of air into and out of the greenhouse.
- Help regulate temperature and humidity.
- May be positioned along the sides or roof.

7. Doors

- Provide entry and exit.
- Should be properly fitted to reduce the entry of pests.
- Some greenhouses use a double-door entrance.

8. Insect-proof netting

- Fitted to selected ventilation openings.
- Helps prevent the entry of certain insect pests.
- Allows air to pass through.

9. Irrigation system

- Supplies water to crops.
- Commonly includes water tanks, filters, pipes, valves and drip lines.
- Helps provide water efficiently.

10. Drainage system

- Removes excess water from the greenhouse.
- Prevents waterlogging and excessive moisture accumulation.

11. Growing beds or containers

- Provide the growing area for crops.
- May consist of soil beds, grow bags, pots or other suitable containers.

12. Trellising system

- Supports climbing and tall crops such as tomatoes and cucumbers.
- May consist of wires, strings, stakes and support frames.

13. Shading system

- Reduces excessive sunlight and heat when required.
- May consist of internal or external shade screens.

14. Environmental monitoring equipment

- Includes thermometers, hygrometers and other sensors.
- Helps farmers monitor internal growing conditions.

B. Types of greenhouses

Greenhouses can be classified according to their shape, construction materials and level of environmental control.

1. Tunnel greenhouse

- Has a curved or semi-circular roof.
- Commonly constructed using metal or other suitable arches.
- Covered with greenhouse plastic.
- Often used for vegetable production.
- Relatively simple to construct compared with some complex greenhouse designs.

2. Even-span greenhouse

- Has two roof slopes of equal or similar dimensions.
- Provides a relatively spacious internal growing area.
- Allows installation of ventilation and irrigation facilities.
- Can be used for commercial horticultural production.

3. Uneven-span greenhouse

- Has roof slopes of unequal dimensions.
- May be designed to suit particular site conditions.
- Can be useful on selected sloping or uneven sites when properly engineered.
- Requires careful structural design.

4. Multi-span greenhouse

- Consists of several greenhouse sections joined together.
- Provides a large production area.
- Suitable for commercial crop production.
- May have shared drainage, irrigation and ventilation systems.
- Requires proper engineering and management.

5. Lean-to greenhouse

- Built against an existing wall or building.
- Uses the existing building as one supporting side.
- Suitable for small-scale production and demonstration.
- Its design must provide adequate light and ventilation.

C. Characteristics of a good greenhouse

1. It should have a strong and stable framework.
2. It should be covered with suitable greenhouse material.
3. It should allow sufficient sunlight to reach crops.
4. It should have adequate ventilation.
5. It should have an effective drainage system.
6. It should have a reliable water supply.

7. It should provide enough space for crop management.
8. It should have secure doors and suitable insect-proof screens.
9. It should be located on well-drained land.
10. It should be designed to withstand local wind and weather conditions.
11. It should be easy to clean and maintain.
12. It should be accessible for farm operations and transportation of produce.

D. Construction materials used in greenhouses

1. Galvanised steel

- Used for supporting frames, arches and posts.
- Strong and durable.
- Resistant to rusting when properly galvanised and maintained.

2. Aluminium

- Used in greenhouse frames and fittings.
- Lightweight and resistant to corrosion.
- Can be more expensive than some alternative materials.

3. Treated timber

- Used for posts, frames and support structures.
- May be locally available.
- Requires treatment and maintenance to prevent rotting and termite attack.

4. Greenhouse plastic film

- Used to cover the roof and sides.
- Allows sunlight to enter.
- Specialised greenhouse films may have ultraviolet (UV) stabilisation to improve durability.

5. Polycarbonate sheets

- Used for roofing and wall coverings.
- Strong and relatively durable.
- Available in transparent and translucent forms.

6. Glass

- Allows light to enter.
- Durable when properly installed.
- Heavy, fragile and generally more expensive than plastic film.

7. Concrete

- Used for foundations and floor sections.
- Provides strong support.
- Requires proper mixing, curing and construction.

8. Nails, bolts and screws

- Used to join structural components.
- Help secure the framework and coverings.

9. Insect-proof mesh

- Fitted to ventilation openings.
- Reduces entry of selected insect pests.

10. Drip irrigation pipes and fittings

- Used to supply water to crops.
- Help distribute water efficiently.

E. Uses of greenhouses in crop production

1. Production of tomatoes.
2. Production of capsicum.
3. Production of cucumbers.
4. Production of selected herbs.
5. Production of flowers.
6. Raising seedlings.
7. Production of high-value horticultural crops.
8. Conducting crop research and demonstrations.
9. Protecting crops from heavy rainfall.
10. Supporting production during unfavourable outdoor weather conditions.

F. Advantages of greenhouses

1. Control of growing conditions: Farmers can regulate ventilation, irrigation, shading and other environmental factors.

2. Protection against adverse weather: Crops are protected from direct rainfall, strong winds and some forms of physical damage.

3. Extended production seasons: Crops can be grown during periods when outdoor conditions are less favourable.

4. Improved crop quality: Controlled growing conditions can produce more uniform and marketable produce.

5. Reduced pest entry: Properly fitted insect-proof screens and doors can reduce the entry of selected pests.

6. Efficient water use: Drip irrigation can deliver water directly to the crop root zone.

7. Higher production per unit area: Intensive crop management can increase productivity from limited land.

8. Reduced weed growth: Covered structures may reduce the introduction of some weed seeds, although weeds can still occur inside.

9. Better crop monitoring: Farmers can inspect crops more easily and manage growing conditions.

10. Improved farm income: Higher-quality produce and better production planning may improve profitability.

G. Disadvantages of greenhouses

1. High initial cost: Construction materials, irrigation systems and fittings may require substantial investment.

2. High maintenance costs: Covering materials, frames and irrigation equipment require regular maintenance.

3. Need for technical skills: Farmers require knowledge of ventilation, irrigation, crop nutrition and pest management.

4. Heat accumulation: Poor ventilation can cause excessive temperatures that damage crops.

5. Disease development: High humidity and poor air circulation can encourage some fungal and bacterial diseases.

6. Dependence on water: Reliable water supply is necessary for successful production.

7. Covering material deterioration: Plastic films may become weak or damaged through prolonged exposure to sunlight and weather.

8. Power requirements: Some advanced greenhouses require electricity for pumps, fans, cooling systems and automated equipment.

9. Pest outbreaks: Once pests enter, they may multiply rapidly if monitoring and control are inadequate.

10. Market risks: High production costs may result in losses when market prices are low.

H. Management of a greenhouse

Proper management is necessary to maintain favourable growing conditions and ensure successful crop production.

1. Temperature management

- Monitor temperature regularly.
- Open ventilation openings when temperatures become too high.
- Use shade screens where necessary.
- Avoid overcrowding crops.
- Maintain suitable conditions for the crop being grown.

2. Ventilation management

- Open side and roof vents where available.
- Maintain adequate air circulation.
- Avoid blocking ventilation openings.
- Use fans where required in advanced systems.

3. Irrigation management

- Supply water according to crop requirements.
- Check drip lines for blockage.
- Repair leaking pipes.
- Avoid overwatering.
- Maintain filters and water tanks.

4. Nutrient management

- Apply fertilisers according to crop requirements.
- Use soil or growing-media tests where appropriate.
- Avoid excessive fertiliser application.
- Monitor crop symptoms for possible nutrient deficiencies.

5. Pest and disease management

- Inspect plants regularly.
- Remove and appropriately dispose of heavily infested plant materials.
- Maintain field and greenhouse hygiene.
- Use suitable insect-proof screens.
- Apply integrated pest-management methods.

6. Weed management

- Remove weeds from beds and pathways.
- Clean containers before reuse.
- Avoid introducing contaminated soil and growing media.

7. Structural maintenance

- Repair torn plastic covering.
- Tighten loose fittings.
- Inspect frames and foundations.
- Clear drainage channels.
- Replace damaged components.

8. Crop support and pruning

- Support tall crops using strings, stakes or trellises.
- Prune crops according to recommended practices.
- Remove diseased and damaged plant parts.
- Maintain suitable spacing and air circulation.

3.3 GRANARY

Meaning of a granary

A granary is a specially designed structure used for storing harvested grains and other dry agricultural produce under suitable conditions to protect them from moisture, pests, rodents, birds and other causes of deterioration.

Granaries are important in crop production because they help farmers preserve harvested produce for household consumption, seed purposes and sale.

In Kenya, granaries may be traditional or modern depending on the materials used, storage capacity, construction design and level of technology.

A. Types of granaries

1. Traditional granaries

These are storage structures constructed using locally available materials such as timber, poles, grass, reeds, stones, mud and thatching materials.

Characteristics

1. They are commonly constructed using locally available materials.

2. Some are raised above the ground using poles or supporting structures.
3. Many have walls made from woven materials, timber or other locally available materials.
4. They may have grass-thatched or other suitable roofs.
5. Some have ventilation openings to allow air movement.
6. Their storage capacity depends on their size and design.
7. They are commonly found in rural farming communities.

Advantages

- Materials may be locally available.
- Construction may be relatively inexpensive.
- They can be built using local skills.
- Some designs provide natural ventilation.
- They are suitable for small-scale storage when properly maintained.

Disadvantages

- Some materials deteriorate rapidly.
- Poorly constructed structures may allow entry of rodents and insects.
- Thatched roofs may be vulnerable to fire.
- Some structures may not provide adequate protection against moisture.
- They may have limited storage capacity.

2. Modern granaries

Modern granaries are constructed using durable materials such as metal, concrete, masonry and specialised storage materials.

They may include improved ventilation, moisture control, pest-proofing and mechanised grain-handling facilities.

Characteristics

1. They are constructed using durable materials.
2. They may have large storage capacities.
3. They can be designed to prevent water entry.
4. Some have systems for monitoring temperature and moisture.
5. They may have improved protection against rodents and insects.

6. Some use mechanical equipment for loading and unloading grains.
7. They may be suitable for commercial grain storage.

Advantages

- Durable when properly constructed and maintained.
- Can store large quantities of produce.
- May provide better protection against pests and weather.
- Easier to clean and maintain in suitable designs.
- Some allow efficient handling and monitoring of stored grains.

Disadvantages

- High initial construction costs.
- Some require specialised equipment.
- Metal structures may become hot if not properly designed and managed.
- Concrete structures require proper construction and moisture management.
- Some modern storage systems require electricity and technical skills.

3. Bag-storage granaries

These are storage buildings where dry grains are stored in bags or other suitable containers.

Characteristics

1. They have a roof and walls that protect produce from rain and direct sunlight.
2. They have a floor that should be dry and easy to clean.
3. Bags are placed on pallets to avoid direct contact with the floor.
4. They should have suitable ventilation.
5. They require regular inspection for pests and moisture.
6. Doors should close securely to reduce entry of rodents and other animals.

Uses

- Storage of maize.
- Storage of beans.
- Storage of sorghum.
- Storage of millet.

- Storage of rice.
- Storage of other dry agricultural products.

B. Main parts of a granary

1. Foundation

- Supports the weight of the granary.
- Transfers the load to the ground.
- Should be strong and stable.

2. Floor

- Provides the surface on which produce is stored.
- Should be dry, strong and easy to clean.
- In bag-storage buildings, pallets should be used to keep produce off the floor.

3. Walls

- Enclose and protect the stored produce.
- May be made from timber, stones, bricks, concrete blocks or metal.
- Should prevent the entry of rainwater and animals.

4. Roof

- Protects produce from rain and direct sunlight.
- Should be properly constructed to prevent leakage.
- May be made from iron sheets, tiles, thatch or other suitable materials.

5. Door

- Provides access for loading and removing produce.
- Should be strong and secure.
- Should fit properly to reduce entry by rodents.

6. Ventilation openings

- Allow air movement where the design requires ventilation.
- Help reduce the accumulation of excessive heat and moisture.
- Should be protected against pests and rain entry.

7. Raised platform or supporting posts

- Used in some traditional granaries to raise the storage area above the ground.
- Reduce direct contact with soil moisture.
- May make access by rodents more difficult when fitted with suitable rodent barriers.

8. Rodent guards

- Barriers fitted to supporting posts or other entry points.
- Prevent rodents from climbing into the storage structure.
- May be made from suitable smooth metal materials.

9. Drainage system

- Directs rainwater away from the building.
- Prevents water from accumulating around the foundation.

10. Storage containers or pallets

- Used to hold and organise stored produce.
- Include clean bags, bins, crates and pallets.
- Help prevent direct contact between produce and damp floors.

C. Characteristics of a good granary

A good granary should have the following characteristics:

1. It should be located on a well-drained site.
2. It should be constructed using strong and durable materials.
3. It should have a roof that does not leak.
4. It should have a dry floor.
5. It should be protected against rodents and birds.
6. It should have suitable ventilation.
7. It should have a secure door.
8. It should be easy to clean.
9. It should provide adequate storage space.
10. It should be accessible for loading and unloading produce.
11. It should be protected against flooding.
12. It should allow regular inspection of stored produce.

13. It should have suitable arrangements for controlling storage pests.
14. It should be designed to avoid excessive moisture accumulation.

D. Uses of granaries in crop production

1. Storing harvested maize.
2. Storing beans and other pulses.
3. Storing sorghum and millet.
4. Storing rice and other cereals.
5. Storing properly dried seeds for planting.
6. Preserving produce for household consumption.
7. Holding produce before sale.
8. Reducing losses caused by rain and other weather conditions.
9. Supporting food security at household and community levels.
10. Supporting commercial grain storage and marketing.

E. Advantages of granaries

1. Protection against rain: A good roof prevents rainwater from reaching stored produce.

2. Protection against rodents: Proper construction and rodent barriers reduce access by rats and mice.

3. Protection against birds: Secure walls and openings reduce contamination and grain losses.

4. Reduction of storage losses: Suitable storage conditions reduce spoilage and pest damage.

5. Food security: Farmers can preserve produce for use during periods when crops are not being harvested.

6. Improved marketing: Farmers may store produce and sell it when market conditions are favourable, provided quality is maintained.

7. Seed preservation: Properly dried and stored seeds can retain viability for planting, depending on crop and storage conditions.

8. Organisation of produce: Storage facilities allow farmers to keep harvested produce in one secure location.

9. Reduced contamination: A clean, well-designed structure protects produce from dirt, animals and other contaminants.

10. Improved farm management: Storage facilities help farmers plan the use and marketing of harvested produce.

F. Disadvantages of granaries

1. Construction requires money and materials.

2. Poor ventilation may encourage moisture accumulation.
3. Poorly dried grains may develop mould.
4. Storage pests may multiply if the granary is not properly managed.
5. Rodents may enter through poorly sealed openings.
6. Traditional structures may require frequent repairs.
7. Large granaries require adequate land and construction skills.
8. Improper storage may reduce seed viability.
9. Poorly designed metal granaries may experience excessive temperature changes.
10. Stored produce requires regular inspection and management.

G. Management of a granary

1. Cleaning before storage

- Remove old grain residues.
- Sweep and clean the floor.
- Remove cobwebs, dust and unwanted materials.
- Inspect corners and cracks where pests may hide.
- Ensure the structure is dry before loading produce.

2. Proper drying of produce

- Dry grains to the moisture content recommended for the crop and storage system.
- Avoid storing wet or poorly dried grains.
- Use clean drying surfaces.
- Protect produce from rain and contamination during drying.

3. Proper arrangement of produce

- Store produce in clean bags or suitable containers.
- Place bags on pallets.
- Leave adequate space for inspection and air movement.
- Avoid stacking bags against damp walls.
- Separate different types or batches of produce where necessary.

4. Pest control

- Inspect stored produce regularly.
- Look for insects, rodent droppings and damaged bags.
- Maintain good sanitation.
- Use approved storage pest-control products only where necessary.
- Follow label instructions and applicable safety requirements.

5. Moisture control

- Repair leaking roofs.
- Keep floors and walls dry.
- Maintain appropriate ventilation.
- Prevent water from entering the granary.
- Avoid placing produce directly on damp floors.

6. Rodent control

- Seal holes and openings.
- Fit suitable rodent guards.
- Keep the surrounding area clean.
- Use appropriate traps where necessary.
- Store feed and other materials securely.

7. Regular inspection

- Check for signs of insect infestation.
- Inspect the condition of stored bags.
- Monitor moisture and temperature where equipment is available.
- Remove and isolate infested produce appropriately.
- Maintain records of quantities stored and removed.

4. COMPARISON OF SHADE-NET HOUSES, GREENHOUSES AND GRANARIES

Feature	Shade-net house	Greenhouse	Granary
Main purpose	Provides shade and partial crop protection.	Provides a protected and more controllable growing environment.	Stores harvested grains and other dry produce.
Main covering	Shade netting.	Transparent or translucent	Roofing material such as

		covering.	iron sheets, tiles or thatch.
Main activities	Raising seedlings and growing selected crops.	Intensive crop production and raising seedlings.	Storage of harvested produce.
Light	Reduces sunlight intensity.	Allows sunlight to enter.	Light is generally not required for stored grains.
Temperature management	Limited control through shade and ventilation.	Greater control through ventilation, shading and other systems.	Designed to protect stored produce from unsuitable conditions.
Common materials	Posts, steel, timber, shade net and fasteners.	Steel, timber, greenhouse plastic, polycarbonate or glass.	Timber, metal, concrete, bricks, iron sheets and thatch.
Main benefit	Reduces excessive sunlight and provides partial protection.	Supports protected and intensive crop production.	Reduces storage losses.
Common challenge	Net damage and unsuitable shading levels.	High cost and technical management requirements.	Moisture and storage pest problems if poorly managed.

5. CONSTRUCTION MATERIALS USED IN CROP PRODUCTION STRUCTURES

Construction materials are the substances or products used to build different parts of crop production structures.

The selection of materials determines the strength, stability, durability, cost, safety and suitability of the structure.

Different structures require different materials depending on their purpose.

5.1 Types of construction materials

A. Timber

Timber is wood obtained from trees and processed for use in construction.

Uses

1. Construction of supporting posts.
2. Making greenhouse frames.
3. Constructing granary floors and walls.

4. Making doors and window frames.
5. Supporting roofs.
6. Constructing nursery benches.

Advantages

- Can be obtained locally.
- Easy to cut and shape.
- Can be joined using nails, screws and bolts.
- Suitable for small-scale structures.
- May be relatively affordable depending on availability.

Disadvantages

- May be attacked by termites and other wood-boring organisms.
- Can rot when exposed to moisture.
- May burn easily.
- Some timber is not strong enough for heavy structures.
- Requires proper treatment and maintenance.

Factors to consider when selecting timber

1. Strength.
2. Durability.
3. Resistance to termites.
4. Moisture content.
5. Availability.
6. Cost.
7. Intended use.

B. Steel and metal

Steel and other metals are used to construct strong supporting frameworks.

Uses

- Greenhouse frames.
- Shade-net house supports.

- Granary doors.
- Roofing supports.
- Storage silos.
- Fasteners and fittings.

Advantages

1. Strong and durable.
2. Suitable for supporting heavy loads.
3. Can be fabricated into different shapes.
4. Some forms are resistant to corrosion.
5. Suitable for large structures.

Disadvantages

1. May be expensive.
2. Some metals rust when exposed to moisture.
3. Require specialised cutting and joining tools.
4. May become hot under direct sunlight.
5. Some metal structures require regular protective coating.

C. Cement

Cement is a binding material used in construction. It hardens when mixed with water and other suitable materials.

Uses

1. Constructing foundations.
2. Making concrete floors.
3. Constructing granary walls.
4. Fixing supporting posts.
5. Building drainage channels.
6. Making concrete storage structures.

Advantages

- Provides strong construction when correctly mixed and cured.
- Durable when properly used.

- Suitable for foundations and floors.
- Resistant to termites.
- Can be used in different structural components.

Disadvantages

- Requires water and other materials.
- May be expensive.
- Requires construction skills.
- Can crack if poorly mixed or cured.
- May be difficult to transport to remote locations.

D. Sand

Sand is a granular material used in construction, especially in mortar and concrete.

Uses

- Making mortar.
- Mixing concrete.
- Plastering walls.
- Constructing floors.
- Preparing foundations.

Characteristics of good construction sand

1. Should be reasonably clean.
2. Should not contain excessive organic matter.
3. Should not contain harmful salts or contaminants.
4. Should have suitable particle sizes for the intended use.

E. Ballast or coarse aggregate

Ballast consists of coarse aggregates used in concrete production.

Uses

- Making concrete foundations.
- Constructing floors.
- Supporting structural bases.

- Making concrete pathways.

Advantages

- Contributes to the strength of concrete.
- Improves the stability of foundations.
- Suitable for heavy construction.

F. Stones

Stones are natural construction materials obtained from quarries or other approved sources.

Uses

1. Constructing foundations.
2. Building granary walls.
3. Constructing retaining walls.
4. Making drainage channels.
5. Constructing floors and pathways.

Advantages

- Durable.
- Strong.
- Resistant to termites.
- May be locally available.
- Suitable for foundations and walls.

Disadvantages

- Can be heavy to transport.
- May require skilled masonry.
- Cutting and shaping may be difficult.
- Cost may be high in areas far from quarries.

G. Bricks and concrete blocks

These are manufactured construction materials used for building walls and other structures.

Uses

- Granary walls.

- Storage rooms.
- Foundations.
- Partition walls.
- Other agricultural buildings.

Advantages

- Durable when properly constructed.
- Provide strong walls.
- Available in different sizes.
- Can be used to construct secure storage facilities.

Disadvantages

- Require mortar for joining.
- May be costly.
- Require labour and construction skills.
- Poor construction may lead to cracking.

H. Roofing materials

Roofing materials protect structures from rain, sunlight and other weather conditions.

Examples

1. Corrugated iron sheets.
2. Aluminium roofing sheets.
3. Roofing tiles.
4. Grass thatch.
5. Specialised greenhouse roofing sheets.

Factors to consider when selecting roofing materials

- Durability.
- Cost.
- Availability.
- Weight.
- Resistance to rain and wind.

- Suitability for the structure.
- Maintenance requirements.

I. Plastic materials

Plastic materials are widely used in modern agricultural structures.

Examples

1. Greenhouse plastic films.
2. Polycarbonate sheets.
3. PVC pipes.
4. HDPE pipes.
5. Plastic water tanks.
6. Plastic containers.
7. Plastic fittings.

Uses

- Covering greenhouses.
- Making irrigation systems.
- Constructing water storage facilities.
- Making seedling containers.
- Providing protective coverings.

Advantages

- Lightweight.
- Easy to transport.
- Available in different sizes and forms.
- Resistant to corrosion.
- Some types are flexible and easy to install.

Disadvantages

- Some plastics deteriorate under ultraviolet radiation.
- Some are easily damaged by sharp objects.

- Poor disposal causes environmental pollution.
- Quality varies according to the material used.

J. Shade nets and insect-proof nets

These are specialised netting materials used to cover agricultural structures.

Uses

- Covering shade-net houses.
- Protecting crops from birds.
- Reducing entry of selected insect pests.
- Providing shade for seedlings.
- Protecting nurseries.

Advantages

- Lightweight.
- Allow air circulation.
- Available in different mesh sizes.
- Can be installed on different frameworks.

Disadvantages

- Can tear.
- May deteriorate under prolonged sunlight.
- Require proper fixing.
- Unsuitable mesh sizes may allow pests to enter.

K. Nails, bolts, screws and binding wires

These are joining and fastening materials used to connect construction components.

Uses

1. Joining timber components.
2. Fixing roofing materials.
3. Attaching netting to supporting structures.
4. Connecting metal frames.

5. Securing doors and other fittings.

Factors to consider

- Size.
- Strength.
- Resistance to rust.
- Suitability for the material being joined.
- Cost and availability.

L. Paint and protective coatings

Paint and protective coatings are used to protect construction materials and improve their appearance.

Uses

- Protecting timber from weathering when the correct coating is selected.
- Protecting metal surfaces against corrosion.
- Improving visibility and appearance.
- Extending the service life of selected components.

Important: Use coatings suitable for agricultural structures and avoid applying products that may contaminate crops, water or stored produce.

6. FACTORS TO CONSIDER WHEN SELECTING CONSTRUCTION MATERIALS

A farmer should consider several factors before selecting materials for constructing a crop production structure.

6.1 Cost of materials

1. Materials should be affordable.
2. The farmer should prepare a realistic budget.
3. The cost of transportation should be included.
4. The cost of installation should be considered.
5. The farmer should compare the initial cost with expected long-term benefits.

6.2 Availability

1. Materials should be readily available.
2. Locally available materials may reduce transportation costs.
3. Availability of replacement materials should be considered.

4. The farmer should identify reliable suppliers.

6.3 Durability

1. Materials should withstand weather conditions.
2. They should resist wear and tear.
3. They should have a suitable lifespan.
4. Materials exposed to moisture should resist rotting and corrosion.
5. Materials should be suitable for the intended use.

6.4 Strength

1. Materials should support the weight of the structure.
2. They should withstand wind pressure.
3. Roofing materials should be adequately supported.
4. Foundations should be strong enough to carry the structural load.
5. Materials should not break easily during normal use.

6.5 Resistance to pests and diseases

1. Timber should be protected against termites and wood-boring organisms.
2. Storage structures should prevent rodent entry.
3. Materials should be easy to clean.
4. Surfaces should not encourage pest hiding places.
5. Stored produce should be protected from contamination.

6.6 Weather conditions

1. Materials should withstand local rainfall.
2. Roofing materials should resist strong winds.
3. Greenhouse coverings should withstand sunlight and temperature changes.
4. Structures should be suitable for the local climate.
5. Drainage materials should be suitable for the amount of rainfall received.

6.7 Weight of materials

1. Heavy materials require strong foundations.
2. Lightweight materials may be easier to transport.

3. Roofing materials should not overload the framework.
4. Materials should be selected according to the structural design.

6.8 Ease of construction

1. Materials should be easy to handle.
2. They should be compatible with available tools.
3. The farmer should consider the skills required.
4. Construction should be achievable using available labour.
5. Complex materials may require specialised technicians.

6.9 Environmental considerations

1. Use materials from legal and sustainable sources.
2. Reuse suitable materials where safe and practical.
3. Avoid materials that release harmful substances.
4. Reduce unnecessary plastic waste.
5. Dispose of damaged materials responsibly.
6. Consider the environmental effects of manufacturing and transporting materials.

6.10 Purpose of the structure

The selected materials should suit the function of the structure.

Examples

- A greenhouse requires materials that allow sufficient light transmission.
- A shade-net house requires suitable shade netting.
- A granary requires materials that protect stored produce from moisture and pests.
- A nursery requires materials that provide suitable shade and support for seedlings.

7. CONSTRUCTION OF CROP PRODUCTION STRUCTURES

Construction refers to the process of planning, designing, selecting materials and assembling components to form a usable structure.

Construction should follow a systematic procedure to ensure that the resulting structure is strong, safe, functional, affordable and suitable for its intended purpose.

7.1 General steps followed when constructing a crop production structure

Step 1: Identify the purpose of the structure

The farmer should establish why the structure is required.

Examples:

- A greenhouse for tomato production.
- A shade-net house for raising vegetable seedlings.
- A granary for storing harvested maize.
- A nursery structure for raising tree seedlings.

The purpose determines the design, size, location and materials required.

Step 2: Select a suitable site

The selected site should be appropriate for the structure.

Factors to consider

1. Accessibility: The site should be easy to reach for workers and transportation of materials and produce.

2. Drainage: It should be well drained to prevent waterlogging.

3. Topography: The land should be reasonably level or capable of being prepared safely.

4. Water supply: Structures used for crop production should be located where water can be supplied conveniently.

5. Sunlight: Greenhouses should be located where they can receive adequate sunlight.

6. Wind exposure: The structure should be protected from excessive wind where possible and designed to withstand local wind conditions.

7. Security: The site should be secure against theft and animal damage.

8. Space: Adequate room should be available for the structure and future expansion.

9. Soil condition: The ground should be suitable for the foundation and drainage requirements.

10. Distance from hazards: Avoid sites exposed to flooding, unstable ground or other environmental risks.

Step 3: Prepare a sketch design

A sketch design is a simple drawing showing the proposed structure and its main parts.

The design should indicate:

1. The shape of the structure.
2. Length and width.
3. Height.
4. Roof design.

5. Position of doors.
6. Position of windows or ventilation openings.
7. Foundation arrangements.
8. Supporting posts and beams.
9. Covering materials.
10. Drainage arrangements.

Importance of preparing a sketch design

1. Guides construction activities.
2. Helps determine the quantities of materials required.
3. Reduces wastage.
4. Helps estimate construction costs.
5. Communicates the intended design to workers.
6. Helps identify possible design weaknesses before construction.
7. Improves organisation and planning.

Step 4: Take measurements

Measurements should be taken according to the intended design.

Common measurements include:

- Length.
- Width.
- Height.
- Door dimensions.
- Roof dimensions.
- Spacing between supporting posts.
- Foundation depth and width, as determined by the design.

Importance of accurate measurements

1. Ensure correct fitting of materials.
2. Reduce construction errors.
3. Prevent unnecessary wastage.

4. Improve structural stability.
5. Help maintain the intended dimensions.

Step 5: Prepare a bill of quantities

A bill of quantities is a list showing the materials, estimated quantities and costs required for construction.

Example of a simple bill of quantities for a small shade-net structure

Material	Estimated quantity	Estimated cost (KSh)
Treated timber or metal posts	12 pieces	18,000
Shade net	1 roll	12,000
Binding wire and fasteners	1 lot	2,500
Cement	5 bags	3,500
Sand and ballast	1 lot	5,000
Nails, bolts and screws	1 lot	2,000
Door materials	1 set	3,000
Labour	1 lot	8,000
Estimated total		54,000

Illustrative figures only. Actual costs depend on dimensions, material quality, location, supplier prices and labour charges.

Step 6: Acquire the materials

1. Purchase materials according to the bill of quantities.
2. Inspect materials for quality.
3. Confirm that measurements and quantities are correct.
4. Transport materials safely.
5. Store them properly before construction.
6. Avoid purchasing unnecessary materials.

Step 7: Prepare the site

1. Clear unwanted vegetation.
2. Remove stones and debris where necessary.
3. Level the site according to the design.
4. Mark the structure boundaries.

5. Identify the positions of posts and foundations.
6. Prepare drainage channels where required.

Step 8: Construct the foundation

1. Mark the foundation positions.
2. Excavate holes or trenches according to the design.
3. Prepare concrete or other suitable foundation materials.
4. Position posts or foundation components correctly.
5. Check alignment and level.
6. Allow concrete to cure adequately where used.

Step 9: Assemble the framework

1. Fix supporting posts.
2. Install beams and rafters.
3. Connect the structural members.
4. Secure all joints.
5. Check the alignment.
6. Confirm that the framework is stable.
7. Inspect the structure before installing the covering.

Step 10: Install the roof and side coverings

The covering depends on the type of structure.

- Greenhouse: install greenhouse plastic, polycarbonate or glass as designed.
- Shade-net house: fix the shade net securely.
- Granary: install the selected roofing material.

The covering should be fitted properly to prevent unnecessary gaps, leakage or damage.

Step 11: Install doors, windows and ventilation facilities

1. Fix the doors securely.
2. Install windows or ventilation openings where required.
3. Fit insect-proof mesh where appropriate.
4. Ensure that doors open and close properly.

5. Ensure adequate air circulation.

Step 12: Install additional facilities

Depending on the purpose of the structure, install:

- Irrigation pipes.
- Water tanks.
- Drainage channels.
- Growing beds.
- Trellising systems.
- Storage shelves.
- Pallets.
- Rodent guards.
- Monitoring equipment.

Step 13: Inspect and test the structure

1. Check the strength of the framework.
2. Inspect all joints and connections.
3. Check the roof for leakage.
4. Check doors and openings.
5. Test irrigation systems where installed.
6. Confirm that drainage is effective.
7. Correct construction defects.
8. Ensure the structure is safe for use.

Step 14: Maintain the structure

1. Repair damaged parts.
2. Replace worn-out coverings.
3. Inspect foundations and supporting posts.
4. Clean the structure regularly.
5. Maintain drainage systems.
6. Replace faulty fittings.

7. Keep records of repairs and maintenance costs.

8. CONSTRUCTION OF SPECIFIC CROP PRODUCTION STRUCTURES

The construction process differs according to the purpose and design of the structure. Learners should understand the construction requirements of shade-net houses, greenhouses and granaries.

8.1 Construction of a shade-net house

Materials required

1. Treated timber posts or metal poles.
2. Shade net of the appropriate shade percentage.
3. Binding wire or suitable fixing clips.
4. Nails, screws or bolts.
5. Cement.
6. Sand and ballast where concrete foundations are required.
7. Suitable door materials.
8. Measuring tape.
9. Hammer.
10. Spade and digging tools.
11. Ladder and other appropriate working tools.

Construction procedure

1. Select a well-drained site with suitable access to water.
2. Clear and prepare the site.
3. Measure and mark the length and width of the proposed structure.
4. Mark the positions of the supporting posts.
5. Dig holes for the posts according to the design.
6. Position the posts and secure them firmly.
7. Allow concrete foundations to cure where used.
8. Connect the posts using horizontal beams.
9. Install the roof-supporting framework.
10. Check the framework for alignment and stability.
11. Fix the shade net over the roof.

12. Attach netting to the sides.
13. Secure the net using suitable clips, ties or wires.
14. Construct and fit the entrance.
15. Install drainage channels where necessary.
16. Inspect the completed structure for gaps, loose joints and damaged netting.

Precautions during construction

- Use treated timber to reduce termite attack and rotting.
- Anchor the structure properly against wind.
- Avoid sharp edges that may tear the netting.
- Select the appropriate shade percentage for the intended crop.
- Do not leave loose wires or dangerous protruding nails.
- Use safe working practices when handling tools and climbing ladders.

8.2 Construction of a greenhouse

Materials required

1. Galvanised steel pipes or suitable treated timber.
2. Greenhouse plastic film or other suitable covering.
3. Foundation materials.
4. Bolts, screws and connectors.
5. Insect-proof mesh.
6. Door materials.
7. Drip irrigation pipes.
8. Water tank and fittings.
9. Measuring tape.
10. Construction tools.
11. Trellising materials.

12. Drainage materials.

Construction procedure

1. Select a well-drained site with sufficient sunlight and a reliable water supply.
2. Prepare a sketch design showing the dimensions and main components.
3. Mark the greenhouse boundaries.
4. Prepare the foundation according to the design.
5. Install the supporting posts or arches.
6. Connect the framework using appropriate beams and fittings.
7. Install the roof-supporting members.
8. Check the structure for alignment and stability.
9. Install doors and ventilation openings.
10. Fit insect-proof mesh to the required openings.
11. Cover the roof and sides with greenhouse covering material.
12. Secure the covering without excessive stretching or leaving loose sections.
13. Install irrigation pipes, filters and drip lines.
14. Prepare growing beds or position growing containers.
15. Install trellising materials where necessary.
16. Construct drainage facilities.
17. Test irrigation and ventilation systems.
18. Inspect the greenhouse before introducing crops.

Important construction considerations

1. The framework must be strong enough to withstand local wind conditions.
2. The covering should allow adequate light transmission.
3. Ventilation openings should be adequate for the greenhouse size and crop.
4. The covering should be properly secured to prevent damage.
5. The structure should have effective drainage.
6. Irrigation facilities should be installed correctly.
7. The greenhouse should be accessible for crop management.

8. A suitable design should be selected according to the climate and production requirements.

Safety consideration: Large greenhouses and structures exposed to strong winds should be designed or checked by competent construction professionals. Learners should not attempt dangerous structural work or work at heights without proper supervision and safety equipment.

8.3 Construction of a granary

Materials required

1. Timber or treated poles.
2. Stones or concrete blocks.
3. Cement.
4. Sand.
5. Ballast.
6. Roofing sheets or suitable thatching materials.
7. Nails, bolts and screws.
8. Door materials.
9. Wire mesh where required.
10. Metal sheets for rodent guards.
11. Suitable floor materials.

Construction procedure

1. Select a well-drained site away from areas likely to flood.
2. Prepare a sketch design showing the storage capacity and dimensions.
3. Clear the construction site.
4. Mark the foundation boundaries.
5. Construct the foundation using suitable materials.
6. Prepare a strong and dry floor.
7. Construct the walls using the selected materials.
8. Install the roof-supporting framework.
9. Fix roofing materials securely.
10. Install a suitable door.
11. Provide ventilation openings where required by the storage design.

12. Fit suitable rodent guards or barriers.
13. Construct drainage channels around the building where necessary.
14. Clean the structure thoroughly.
15. Inspect it for openings that may allow entry of pests and rainwater.
16. Allow the structure to dry before storing produce.

Precautions

- The granary should be located away from flood-prone areas.
- The roof should not leak.
- The floor should remain dry.
- The structure should be protected against rodents.
- Stored produce should be properly dried before storage.
- The granary should be cleaned before introducing new produce.
- Pesticides should only be used in storage according to approved product labels and safety instructions.

9. CONSTRUCTION OF A MODEL CROP PRODUCTION STRUCTURE

Learners may not always have the resources to construct a full-size greenhouse, shade-net house or granary. They can demonstrate creativity by making scale models using locally available materials.

A model is a smaller representation of a real structure. It shows the shape, parts and arrangement of the actual structure.

9.1 Importance of constructing models

1. Helps learners understand the parts of crop production structures.
2. Develops creativity and imagination.
3. Improves practical construction skills.
4. Encourages problem-solving.
5. Helps learners understand measurements and proportions.
6. Promotes teamwork.
7. Encourages the use of locally available materials.
8. Provides an affordable alternative to full-scale construction.
9. Helps learners communicate design ideas.
10. Provides an opportunity to display and evaluate constructed models.

9.2 Materials used in making models

The materials depend on the structure being represented.

Examples include:

- Cardboard.
- Wooden sticks.
- Bamboo pieces.
- Transparent plastic.
- Small pieces of netting.
- String.
- Glue.
- Wire.
- Clay.
- Paper.
- Small containers.
- Recycled materials.
- Labels and markers.

9.3 Steps in making a greenhouse model

Procedure

1. Select a suitable greenhouse design.
2. Draw a sketch showing the shape and parts.
3. Determine the dimensions of the model.
4. Collect the required materials.
5. Prepare the base using cardboard or a suitable board.
6. Cut sticks or other materials to the required lengths.
7. Assemble the supporting framework.
8. Construct the roof and side supports.
9. Cover the framework with transparent plastic.
10. Make an entrance using suitable materials.

11. Add ventilation openings.
12. Add miniature growing beds and irrigation lines where possible.
13. Label the main parts.
14. Display the completed model.
15. Explain how the actual greenhouse is used in crop production.

9.4 Steps in making a shade-net house model

1. Select a suitable shade-net design.
2. Draw a sketch of the structure.
3. Prepare a base.
4. Collect sticks, netting and joining materials.
5. Construct the supporting posts.
6. Join the posts using horizontal supports.
7. Construct the roof framework.
8. Cover the roof and sides with suitable netting.
9. Construct an entrance.
10. Add a miniature growing area.
11. Label the parts.
12. Display the model and explain its functions.

9.5 Steps in making a granary model

1. Select a traditional or modern granary design.
2. Draw a sketch of the model.
3. Prepare a suitable base.
4. Collect cardboard, sticks, clay or other materials.
5. Construct the foundation or supporting posts.
6. Construct the floor.
7. Build the walls.
8. Add the roof.
9. Make a door.

10. Add ventilation openings where appropriate.
11. Include rodent guards in the model if the design requires them.
12. Label the parts.
13. Display the completed model and explain how it protects stored produce.

9.6 Qualities of a good model

A good model should:

1. Represent the actual structure accurately.
2. Show the main structural parts.
3. Have suitable proportions.
4. Be stable and properly assembled.
5. Use materials appropriate to the design.
6. Be neat and attractive.
7. Have clearly labelled parts.
8. Demonstrate the purpose of the structure.
9. Be safe to handle.
10. Be presented with an explanation of its use in crop production.

10. TOOLS AND EQUIPMENT USED IN CONSTRUCTING CROP PRODUCTION STRUCTURES

Different tools and equipment are required during the construction process.

Tool or equipment	Use
Hammer	Driving nails into timber and other suitable materials.
Saw	Cutting timber to the required lengths.
Measuring tape	Measuring dimensions and distances.
Spade	Digging and moving soil.
Hoe	Clearing vegetation and preparing the site.
Pliers	Holding, bending and cutting suitable wires.
Spirit level	Checking whether surfaces are level.
Builder's square	Checking right angles during construction.
Wheelbarrow	Transporting construction materials.

Trowel	Spreading and finishing mortar.
Shovel	Scooping and moving sand, ballast and soil.
Screwdriver	Tightening and loosening screws.
Drill	Making holes in suitable materials.
Ladder	Reaching elevated parts of a structure when used safely.
Spanner	Tightening and loosening nuts and bolts.
Hand saw	Cutting timber and other suitable materials.
Wire cutters	Cutting appropriate fastening wires.

10.1 Safety precautions when using construction tools

1. Use the correct tool for the task.
2. Inspect tools before use.
3. Keep cutting tools sharp and in good condition.
4. Wear suitable protective clothing.
5. Use gloves when handling materials that may cause injury.
6. Wear safety boots when working on construction sites.
7. Wear eye protection when cutting, drilling or hammering materials.
8. Keep tools in a safe storage place after use.
9. Do not leave sharp tools lying on the ground.
10. Avoid overcrowding the working area.
11. Do not use damaged electrical tools.
12. Ensure learners are supervised when using potentially dangerous tools.
13. Use ladders properly and avoid working at heights without appropriate protection.
14. Maintain a clean and organised working environment.

11. FACTORS TO CONSIDER WHEN SITING CROP PRODUCTION STRUCTURES

The location of a structure influences its effectiveness, durability, accessibility and cost of operation.

The following factors should be considered:

A. Soil drainage

- Select well-drained land.

- Avoid areas where water accumulates.
- Good drainage prevents flooding and waterlogging.
- It protects foundations from excessive moisture.

B. Water availability

- Greenhouses and shade-net houses require reliable water supplies.
- Water should be available for irrigation and cleaning.
- Storage facilities may require water for cleaning and sanitation.

C. Accessibility

- The structure should be easy to reach.
- Workers should be able to transport materials and produce conveniently.
- Access roads should be suitable for the intended farming activities.

D. Security

- The site should be protected against theft.
- It should be possible to control access.
- Storage structures should be secure against animals and unauthorised persons.

E. Wind direction and strength

- Consider prevailing wind direction.
- The structure should be designed to withstand local wind conditions.
- Proper anchoring is important.
- Natural windbreaks may offer protection where appropriate.

F. Sunlight

- Greenhouses require adequate sunlight.
- Avoid unnecessary shading from trees and buildings.
- Shade-net houses should receive sufficient light for the intended crops.

G. Land availability

- The site should accommodate the structure.
- Allow space for access, drainage and future expansion.

- Avoid interfering with other farm activities.

H. Distance from pollution sources

- Avoid sites exposed to harmful industrial emissions.
- Avoid areas where contaminated water may enter production facilities.
- Keep storage facilities away from materials that may contaminate food.

I. Proximity to markets

- Production structures should be reasonably accessible to markets.
- This reduces the cost of transporting perishable produce.
- It may improve the speed of delivering produce to buyers.

12. MAINTENANCE OF CROP PRODUCTION STRUCTURES

Maintenance refers to activities carried out to keep a structure in good working condition and extend its useful life.

12.1 Importance of maintenance

1. Extends the lifespan of structures.
2. Reduces the cost of major repairs.
3. Maintains structural stability.
4. Protects crops and stored produce.
5. Prevents unnecessary accidents.
6. Improves efficiency.
7. Reduces pest entry.
8. Maintains hygiene.
9. Protects the farmer's investment.
10. Ensures continuous use of the structure.

12.2 General maintenance practices

1. Inspect structures regularly.
2. Repair damaged sections immediately.
3. Replace worn-out materials.
4. Tighten loose joints and fasteners.
5. Clean floors, walls and other surfaces.

6. Maintain drainage channels.
7. Protect metal parts against corrosion.
8. Treat timber appropriately against pests and decay.
9. Maintain doors and ventilation openings.
10. Keep records of maintenance and repair costs.

12.3 Maintenance of specific structures

Structure	Maintenance activity
Shade-net house	Repair torn nets, tighten fittings and inspect supporting posts.
Greenhouse	Repair plastic coverings, maintain ventilation, check irrigation and clean drainage channels.
Granary	Clean regularly, inspect stored produce, seal rodent entry points and repair leaking roofs.

13. CHALLENGES EXPERIENCED IN THE USE OF CROP PRODUCTION STRUCTURES AND THEIR SOLUTIONS

Challenge	Explanation	Possible solution
High initial cost	Construction materials and equipment may be expensive.	Start with an affordable design and expand gradually.
Lack of technical skills	Farmers may not know how to construct or manage structures.	Provide training and seek technical guidance.
Strong winds	Wind may damage coverings and supporting frames.	Use suitable designs and proper anchoring.
Poor drainage	Water may accumulate around structures.	Construct appropriate drainage channels.
Material deterioration	Plastic, timber and metal may wear out.	Use suitable durable materials and carry out regular maintenance.
Pest infestation	Pests may enter and multiply inside structures.	Use suitable screens, sanitation and IPM.
High temperatures	Poor ventilation may cause overheating.	Provide adequate ventilation and shading.
Water shortages	Irrigation may be interrupted.	Install water-storage facilities and use efficient irrigation.
Poor construction	Weak foundations and joints may cause structural failure.	Follow proper designs and construction procedures.

Storage moisture	Poorly dried grains may deteriorate.	Dry produce adequately and manage storage conditions.
Theft	Materials and produce may be stolen.	Improve security and control access.
Market fluctuations	Produce prices may fall despite high production costs.	Plan production according to market demand and diversify enterprises.

PRACTICAL PROJECT

Project: Design and construct a model of a crop production structure

Project objective: To enable learners to demonstrate creativity, critical thinking, problem-solving, financial literacy and responsibility by designing and constructing a model of a crop production structure.

Possible structures

- Greenhouse.
- Shade-net house.
- Granary.

Project procedure

1. Form groups of learners.
2. Select one crop production structure.
3. Research the purpose and parts of the selected structure.
4. Visit a farm or observe photographs of similar structures.
5. Draw a labelled sketch.
6. Identify the construction materials.
7. Prepare a bill of quantities.
8. Estimate the cost of construction.
9. Collect suitable materials.
10. Assign duties to group members.
11. Construct the model.
12. Label the different parts.
13. Inspect the completed model.
14. Display the model to the class.
15. Explain its uses and benefits in crop production.
16. Evaluate the completed project.
17. Suggest improvements.

Expected project outcomes

At the end of the project, learners should be able to:

1. Identify different crop production structures.
2. Explain the functions of the structures.
3. Identify suitable construction materials.
4. Draw simple structural designs.
5. Estimate the cost of construction.
6. Use locally available materials creatively.
7. Construct a model.
8. Work responsibly in groups.
9. Present and explain their work.

10. Evaluate the effectiveness of the constructed model.

ASSESSMENT RUBRIC

The assessment should focus on the specific learning outcomes of this sub-strand. The following is a suggested rubric for assessing learners' ability to describe, design and construct crop production structures.

Assessment indicator	Exceeds expectations	Meets expectations	Approaches expectations	Below expectations
Ability to describe crop production structures	Accurately describes more than three structures, including their parts and uses.	Accurately describes three structures and their uses.	Describes two structures with some explanation.	Describes fewer than two structures or gives incomplete explanations.
Ability to identify construction materials	Identifies appropriate materials for three structures and explains their suitability.	Identifies suitable materials for two or three structures.	Identifies some materials but gives limited explanations.	Identifies few or unsuitable materials.
Ability to prepare a sketch design	Produces a clear, accurate and well-labelled design showing the main parts and dimensions.	Produces a clear design with most main parts labelled.	Produces a simple design with some missing details.	Produces an incomplete or unclear design.
Ability to estimate construction costs	Prepares an accurate bill of quantities and a realistic cost estimate.	Prepares a reasonable list of materials and cost estimate.	Prepares a partial materials list with some cost errors.	Unable to prepare a meaningful materials list or cost estimate.
Ability to construct a model or usable structure	Constructs a neat, stable and functional model or structure independently or with minimal guidance.	Constructs a suitable model or structure with minor support.	Constructs a partially complete model requiring considerable guidance.	Produces an incomplete or unstable model despite support.
Ability to apply safety measures	Consistently observes appropriate safety procedures and uses tools responsibly.	Observes most safety procedures.	Observes some safety procedures but requires reminders.	Frequently fails to observe safety procedures.
Ability to present the constructed model	Clearly explains the structure, its parts, materials and uses, and responds appropriately to questions.	Explains the main parts and uses of the structure.	Gives a limited explanation of the structure.	Cannot adequately explain the constructed model.

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives given.

1. Which one of the following structures is mainly used for raising seedlings under reduced sunlight intensity?

A. Granary
B. Shade-net house
C. Grain silo
D. Storage warehouse

2. A structure covered with transparent material that allows sunlight to enter is called a:

A. Granary
B. Shade-net house

C. Greenhouse
D. Drying rack

3. Which one of the following is the main purpose of a granary?

A. Raising seedlings
B. Growing vegetables
C. Storing harvested grains
D. Reducing sunlight intensity

4. Which material is commonly used to cover a greenhouse?

A. Greenhouse plastic film
B. Dry grass only
C. Loose soil
D. Untreated sand

5. Which one of the following materials is suitable for constructing greenhouse supporting frames?

A. Dry leaves
B. Galvanised steel
C. Paper
D. Fresh grass

6. Which part of a greenhouse allows air to move in and out?

A. Foundation
B. Ventilation opening
C. Floor
D. Growing bed

7. The base of a structure that supports its weight is called the:

A. Roof
B. Cladding
C. Foundation
D. Door

8. Which one of the following is an advantage of shade-net houses?

A. They completely control all weather conditions.
B. They reduce excessive sunlight reaching crops.
C. They prevent all pest attacks.
D. They eliminate the need for irrigation.

9. Which one of the following materials is commonly used to construct granary walls?

A. Concrete blocks
B. Cotton wool
C. Paper sheets
D. Dry leaves only

10. Which one of the following is a factor to consider when selecting a construction site?

A. Colour of the farmer's clothes
B. Soil drainage
C. Number of school learners
D. Shape of harvested maize grains

11. The document showing the materials, quantities and estimated costs required for construction is called a:

A. Farm diary
B. Bill of quantities
C. Crop rotation plan
D. Planting calendar

12. Which one of the following is a disadvantage of greenhouse production?

A. Improved control of growing conditions
B. Protection from direct rainfall
C. High initial construction cost
D. Efficient use of irrigation water

13. What is the main function of insect-proof netting in a greenhouse?

A. To increase soil fertility
B. To reduce entry of selected insect pests
C. To provide nutrients to crops
D. To increase the weight of the framework

14. Which one of the following is important when storing grains in a granary?

A. Storing wet grains
B. Keeping produce in contact with damp floors
C. Drying grains adequately before storage
D. Leaving the granary open to rodents

15. Which tool is used to measure the dimensions of a proposed structure?

A. Hammer
B. Measuring tape
C. Hoe
D. Trowel

16. Which one of the following is an appropriate way of maintaining a shade-net house?

A. Leaving torn nets unrepaired.
B. Removing all supporting posts.
C. Repairing damaged netting.
D. Blocking drainage channels.

17. Which one of the following is an advantage of preparing a sketch design before construction?

A. It increases material wastage.
B. It helps estimate materials and costs.
C. It prevents the need for measurements.
D. It eliminates the need for maintenance.

18. A granary should be constructed on well-drained land mainly to:

A. Encourage water accumulation.
B. Reduce the risk of moisture damage.
C. Increase insect multiplication.
D. Make the roof heavier.

19. Which one of the following is a suitable material for making a small model of a greenhouse?

A. Transparent plastic
B. Wet soil only
C. Fresh manure
D. Loose sand only

20. Which core competency is developed when learners design and construct original models of crop production structures?

A. Creativity and imagination
B. Memorisation only
C. Competition
D. Avoidance of teamwork

Section B: Structured questions

21.

a) Define the term crop production structure. (2 marks)

b) State four examples of structures used in crop production. (4 marks)

c) Explain six ways in which crop production structures improve agricultural production. (12 marks)

d) State two factors to consider when selecting a site for a greenhouse. (2 marks)

22.

a) Define a shade-net house. (2 marks)

b) Identify six main parts of a shade-net house. (6 marks)

c) Explain five uses of shade-net houses in crop production. (5 marks)

d) State four advantages of shade-net houses. (4 marks)

e) Explain three factors to consider when selecting shade netting. (3 marks)

23.

a) Define a greenhouse. (2 marks)

b) Describe six main parts of a greenhouse. (6 marks)

c) Explain six advantages of greenhouse production. (6 marks)

d) State four disadvantages of greenhouse production. (4 marks)

e) Name two crops that can be grown in a greenhouse. (2 marks)

24.

a) Define a granary. (2 marks)

b) Distinguish between traditional and modern granaries. (4 marks)

c) Identify six parts of a granary. (6 marks)

d) Explain four characteristics of a good granary. (4 marks)

e) Explain four management practices carried out in a granary. (4 marks)

25.

a) What are construction materials? (2 marks)

b) Identify six materials used in constructing crop production structures. (6 marks)

c) Explain five factors to consider when selecting construction materials. (10 marks)

d) State two advantages of using locally available construction materials. (2 marks)

26.

a) Outline eight steps followed when constructing a crop production structure. (8 marks)

b) Explain four reasons why a sketch design should be prepared before construction. (4 marks)

c) State four safety precautions observed when using construction tools. (4 marks)

d) Explain four ways of maintaining crop production structures. (4 marks)

KEY TERMS AND DEFINITIONS

Term	Meaning
Crop production structure	A facility constructed to support crop production, protection or storage.
Greenhouse	An enclosed structure covered with transparent or translucent material for protected crop production.
Shade-net house	A structure covered with netting to reduce sunlight intensity and provide partial crop protection.
Granary	A structure used for storing harvested grains and other dry produce.
Framework	The supporting skeleton of a structure.
Foundation	The base that supports a structure.
Cladding	Material used to cover the outside of a structure.
Ventilation	Movement of air into and out of a structure.
Insect-proof netting	Special mesh used to reduce entry of selected insect pests.
Bill of quantities	A list of materials, quantities and estimated costs required for construction.
Model	A smaller representation of an actual structure.
Durability	Ability of a material or structure to withstand wear and weathering.
Drainage	Removal or controlled movement of excess water.
Structural stability	Ability of a structure to remain firm and resist expected forces.
Maintenance	Activities carried out to keep a structure in good working condition.

SUMMARY OF THE SUB-STRAND

Crop production structures are important facilities that support modern agricultural production. They provide protection for crops, improve growing conditions, support intensive production and reduce post-harvest losses.

The three major structures studied in this sub-strand are:

1. Shade-net houses

- Covered with special netting.
- Reduce excessive sunlight.
- Protect crops from selected pests, birds and wind.
- Commonly used for nurseries and horticultural crops.

2. Greenhouses

- Covered with transparent or translucent materials.
- Allow sunlight to enter.
- Provide a more controlled growing environment.
- Used for tomatoes, capsicum, cucumbers, flowers and other horticultural crops.

3. Granaries

- Used for storing harvested grains.
- Protect produce from moisture, rodents and other storage hazards.
- May be traditional or modern.
- Require proper cleaning, drying, ventilation and pest management.

Construction materials include timber, steel, cement, sand, ballast, stones, bricks, roofing materials, plastics, shade nets, fasteners and protective coatings.

When selecting construction materials, farmers should consider cost, availability, durability, strength, weather conditions, safety and the purpose of the structure.

Construction involves identifying the purpose, selecting a site, preparing a sketch design, taking measurements, preparing a bill of quantities, acquiring materials, preparing the site, constructing the foundation and framework, installing coverings and carrying out final inspection.

Important points for learners to remember

1. Different crop production structures serve different agricultural purposes.
2. Greenhouses and shade-net houses support crop production, while granaries mainly support storage.
3. The choice of construction materials determines the cost, strength and durability of a structure.
4. A sketch design helps guide construction and estimate material requirements.
5. Construction should follow appropriate procedures and safety precautions.
6. Models help learners develop creativity, practical skills and problem-solving abilities.
7. Regular maintenance extends the lifespan and usefulness of agricultural structures.

STRAND 2.0: ANIMAL PRODUCTION

SUB-STRAND 2.1: DIGESTIVE SYSTEMS OF ANIMALS

Comprehensive learner's textbook notes | Competency-Based Education (CBE)

1.0 Introduction to animal digestive systems

Farm animals require food to obtain nutrients for growth, maintenance, reproduction and production. These nutrients include carbohydrates, proteins, fats, vitamins, minerals and water.

Most feeds contain complex substances that cannot be absorbed directly into the bloodstream. They must first be broken down into simpler substances through digestion.

Digestion is the process by which complex food substances are broken down mechanically and chemically into simple, soluble substances that can be absorbed and utilised by the body.

Farm animals have different digestive systems depending on their feeding habits and the nature of feeds they consume.

Examples include:

- Cattle: Have a ruminant digestive system adapted to digest fibrous plant materials such as grass, hay and crop residues.
- Pigs: Have a simple, single-chambered stomach adapted mainly to digest concentrated feeds and other easily digestible materials.
- Chickens: Have a specialised poultry digestive system with a crop, proventriculus and gizzard, which help in the digestion of grains, seeds and other feeds.

1.1 Importance of studying digestive systems of farm animals

Understanding animal digestive systems is important because it enables farmers to:

1. Select appropriate feeds: Different animals require different types of feeds depending on their digestive systems.
2. Improve animal productivity: Proper feeding promotes growth, milk production, egg production and meat production.
3. Reduce feeding costs: Farmers can use locally available feed materials efficiently.
4. Prevent digestive disorders: Knowledge of digestion helps farmers avoid inappropriate feeds and sudden changes in diet.
5. Formulate balanced rations: Farmers can combine different feed ingredients to provide all the required nutrients.
6. Promote animal welfare: Animals should receive feeds that their digestive systems can properly digest and utilise.
7. Reduce feed wastage: Appropriate feeding practices improve feed utilisation.
8. Improve farm profitability: Efficient digestion and nutrient utilisation improve production and reduce unnecessary expenditure.

1.2 Important terms used in animal digestion

Term	Meaning
Digestion	Breakdown of complex food substances into simple, soluble substances.
Ingestion	Taking food into the body through the mouth or beak.
Absorption	Movement of digested nutrients through the digestive tract into blood or lymph.
Assimilation	Utilisation of absorbed nutrients by body cells.
Egestion	Removal of undigested food materials from the body.
Ruminant	An animal with a specialised stomach divided into four compartments and which regurgitates cud.

Non-ruminant	An animal with a simple stomach, usually consisting of one main chamber.
Rumination	The process of regurgitating, rechewing and reswallowing partially digested feed.
Cud	Partially digested feed brought back from the rumen to the mouth for further chewing.
Peristalsis	Wave-like muscular contractions that move food along the digestive tract.
Enzymes	Biological substances that speed up chemical digestion.
Microorganisms	Tiny living organisms such as bacteria, protozoa and fungi that assist in digestion.
Fermentation	Breakdown of feed substances by microorganisms, often producing gases and organic acids.
Assimilable nutrients	Digested nutrients that can be absorbed and used by the body.

1.3 Processes involved in animal digestion

The digestive process involves several stages that work together to enable animals to obtain nutrients from feeds.

1. Ingestion

- This is the process of taking food into the digestive system.
- Different animals use different structures to obtain food.
- Cattle use their tongues and lower incisors against the dental pad to graze.
- Pigs use their mouths and snouts to pick up feeds.
- Chickens use their beaks to pick up grains, seeds and other feed materials.

2. Mechanical digestion

- This involves the physical breakdown of food into smaller particles.
- It does not change the chemical composition of food.
- It increases the surface area of food, allowing digestive enzymes to act more effectively.
- Examples include chewing by cattle and pigs and grinding of food in the chicken's gizzard.

3. Chemical digestion

- This involves the breakdown of complex food substances into simpler substances through digestive enzymes and other digestive secretions.
- It takes place in different parts of the digestive tract.
- Examples:
    - ✓ Starch is broken down into simpler sugars.

- ✓ Proteins are broken down into peptides and amino acids.
- ✓ Fats are broken down into fatty acids and monoglycerides.

4. Microbial digestion

- This is the breakdown of feed materials by microorganisms such as bacteria, protozoa and fungi.
- It is particularly important in ruminants.
- Microorganisms in the rumen break down cellulose and other components of fibrous plant materials.
- Microbial digestion also occurs in the hindgut of pigs and poultry, but it is less extensive than rumen fermentation.

5. Absorption

- This is the movement of digested nutrients through the walls of the digestive tract into the blood or lymph.
- Most absorption of digested nutrients takes place in the small intestine.
- Water and some mineral salts are also absorbed in the large intestine.

6. Assimilation

- Absorbed nutrients are transported to different body cells.
- They are used for:
  - ✓ Energy production.
  - ✓ Growth and development.
  - ✓ Repair of worn-out tissues.
  - ✓ Production of milk and eggs.
  - ✓ Formation of meat and body tissues.
  - ✓ Reproduction.

7. Egestion

- This is the removal of undigested and unabsorbed food materials from the body.
- In cattle and pigs, faeces are expelled through the anus.
- In poultry, digestive waste is expelled through the cloaca.

2.0 RUMINANT DIGESTIVE SYSTEM

2.1 Meaning of a ruminant

A ruminant is an animal that has a specialised stomach divided into four compartments and that regurgitates partially digested food from the rumen for further chewing.

This process is known as rumination.

Examples of ruminant farm animals include:

- Cattle.
- Sheep.
- Goats.
- Camels.
- Buffaloes.

Ruminants are particularly important in livestock production because they can utilise fibrous feeds that many other farm animals cannot digest efficiently.

Examples of fibrous feeds include:

- Napier grass.
- Rhodes grass.
- Hay.
- Maize stover.
- Bean haulms.
- Wheat straw.
- Pasture grasses.

2.2 Structure of the ruminant digestive system

The digestive system of cattle consists of the following main parts:

1. Mouth.
2. Oesophagus.
3. Rumen.
4. Reticulum.
5. Omasum.
6. Abomasum.
7. Small intestine.
8. Large intestine.
9. Rectum.

10. Anus.

Other important accessory digestive organs include the salivary glands, liver and pancreas.

A. Mouth

The mouth is the first part of the digestive system.

Functions of the mouth

1. Ingestion of food: It allows the animal to take feed into the digestive system.
2. Preliminary chewing: Teeth break feed into smaller particles.
3. Mixing with saliva: Saliva moistens food, making it easier to swallow.
4. Formation of a bolus: Chewed feed is mixed with saliva to form a soft mass that can be swallowed.
5. Taste: The tongue contains taste receptors that help the animal identify different feeds.

Special features of the cattle mouth

- Cattle have no upper front incisors.
- Instead, they possess a tough structure called the dental pad.
- The lower incisors press against the dental pad when grazing.
- The tongue is long and rough, enabling the animal to grasp and pull grass.

B. Salivary glands

Salivary glands produce saliva, which is released into the mouth.

Functions of saliva

1. Moistens feeds for easy swallowing.
2. Lubricates food as it passes through the oesophagus.
3. Helps maintain a suitable pH in the rumen through bicarbonate and phosphate buffering.
4. Supports the activities of rumen microorganisms.
5. Helps prevent excessive acidity in the rumen.

Importance of saliva in cattle

Cattle produce large quantities of saliva, especially during chewing and rumination. This is important because rumen microorganisms require a relatively stable environment to function effectively.

C. Oesophagus

The oesophagus is a muscular tube connecting the mouth to the stomach compartments.

Functions

1. Transports swallowed feed from the mouth to the rumen.
2. Transports cud from the rumen and reticulum back to the mouth during rumination.
3. Uses muscular contractions known as peristalsis to move food.

Special feature

In cattle, the oesophagus allows movement of food in both directions. This makes regurgitation of cud possible.

D. Rumen

Largest stomach compartment

The rumen is the largest compartment of the ruminant stomach. It acts as a fermentation chamber where microorganisms break down fibrous plant materials.

Characteristics of the rumen

- It occupies a large portion of the left side of the abdominal cavity.
- It contains millions of microorganisms.
- Its internal lining has small finger-like projections called papillae.
- It provides a suitable environment for microbial fermentation.
- It receives swallowed feed before it moves through the other stomach compartments.

Functions of the rumen

1. Storage of feed: It temporarily stores large quantities of swallowed feed.
2. Microbial fermentation: Bacteria, protozoa and fungi break down fibrous feed materials.
3. Cellulose digestion: Microorganisms produce enzymes that break down cellulose in plant cell walls.
4. Production of volatile fatty acids: Fermentation produces volatile fatty acids such as acetate, propionate and butyrate, which are absorbed and used as energy sources.
5. Microbial protein production: Microorganisms multiply and provide microbial protein when they pass into the lower digestive tract.
6. Vitamin synthesis: Some rumen microorganisms synthesise B-complex vitamins and vitamin K.
7. Gas production: Fermentation produces gases, mainly carbon dioxide and methane, which are removed mainly through eructation (belching).
8. Feed mixing: Rumen contractions mix feed with rumen fluid and microorganisms.

Examples of feed materials digested in the rumen

- Napier grass.
- Hay.
- Maize stover.
- Bean haulms.
- Rhodes grass.
- Pasture grasses.

E. Reticulum

The reticulum is the second compartment of the ruminant stomach. It is located near the rumen and has a honeycomb-like internal lining.

Characteristics

- It has a honeycomb appearance.
- It is closely connected with the rumen.
- It works together with the rumen during fermentation and rumination.

Functions of the reticulum

1. Sorting feed particles: It helps separate feed particles according to their size and density.
2. Rumination: It assists in bringing partially digested feed back to the mouth for rechewing.
3. Formation of cud: It helps collect and move suitable feed particles for regurgitation.
4. Movement of feed: It helps direct feed towards the omasum.
5. Foreign-body trapping: Heavy objects such as nails and pieces of wire may settle in the reticulum, sometimes causing traumatic reticulitis or traumatic reticuloperitonitis.

Importance of the reticulum

The reticulum is important in rumination and in controlling the movement of feed through the stomach.

F. Omasum

The omasum is the third compartment of the ruminant stomach. It contains numerous folds or muscular leaves that resemble the pages of a book.

Characteristics

- It has many internal folds.
- The folds increase its internal surface area.
- It is positioned between the reticulum and abomasum.

Functions of the omasum

1. Absorption of water: It absorbs much of the water from the digesta.
2. Absorption of minerals: It absorbs some mineral salts.
3. Reduction of particle size: It helps further reduce and process feed particles.
4. Regulation of feed movement: It controls the movement of digesta from the reticulum towards the abomasum.
5. Concentration of digesta: It reduces the water content of digesta before it enters the abomasum.

G. Abomasum

True stomach

The abomasum is the fourth compartment of the ruminant stomach. It is referred to as the true stomach because it performs digestion using acids and enzymes in a way similar to the stomach of non-ruminants.

Characteristics

- It has glandular walls.
- It secretes gastric juice.
- It contains hydrochloric acid and digestive enzymes.
- It is the last compartment before the small intestine.

Functions of the abomasum

1. Protein digestion: Pepsin breaks down proteins into smaller peptides.
2. Acid production: Hydrochloric acid creates an acidic environment suitable for pepsin activity.
3. Microbial digestion: It helps digest rumen microorganisms that pass from the rumen and other compartments.
4. Feed breakdown: It continues chemical digestion of feed materials.
5. Microorganism destruction: The acidic environment destroys many microorganisms entering from the rumen.

Importance of the abomasum

It enables the animal to digest both dietary proteins and microbial proteins produced in the rumen.

H. Small intestine

The small intestine is a long, narrow, coiled tube extending from the abomasum to the large intestine.

It consists of three main sections:

1. Duodenum.
2. Jejunum.

3. Ileum.

Functions of the small intestine

1. Completes the digestion of carbohydrates, proteins and fats.
2. Receives bile from the liver through the bile duct.
3. Receives pancreatic juice from the pancreas.
4. Absorbs digested nutrients into the blood and lymph.
5. Transports digested materials towards the large intestine.

Adaptations of the small intestine for absorption

- It is long, providing a large area for digestion and absorption.
- It has numerous folds.
- It contains tiny finger-like projections called villi.
- The villi have microvilli that further increase surface area.
- The walls are thin, allowing efficient absorption.
- It has a rich supply of blood capillaries and lymph vessels.

I. Large intestine

The large intestine is the part of the digestive tract extending from the small intestine to the rectum.

It includes the caecum, colon and rectum.

Functions

1. Absorbs water and electrolytes from undigested materials.
2. Contains microorganisms that ferment some remaining feed materials.
3. Forms and compacts faeces.
4. Temporarily stores faeces before elimination.

J. Rectum

The rectum is the final section of the large intestine.

Functions

1. Temporarily stores faeces.

2. Receives faeces from the colon.
3. Initiates the defaecation process when filled.

K. Anus

The anus is the external opening through which faeces are expelled.

Functions

1. Allows removal of faeces from the body.
2. Contains sphincter muscles that regulate the release of faeces.

2.3 Accessory digestive organs in cattle

Accessory digestive organs assist digestion even though food does not pass directly through them.

A. Liver

The liver is a large organ located in the abdominal cavity.

Functions

1. Produces bile, which helps emulsify fats.
2. Processes nutrients absorbed from the digestive tract.
3. Stores glycogen, iron and certain vitamins.
4. Detoxifies harmful substances.
5. Helps regulate blood glucose levels.
6. Metabolises proteins, carbohydrates and fats.

B. Gall bladder

The gall bladder is a small sac located beneath the liver.

Functions

1. Stores bile produced by the liver.
2. Concentrates bile.
3. Releases bile into the duodenum when required for fat digestion.

C. Pancreas

The pancreas is a gland located near the duodenum.

Functions

1. Produces pancreatic juice containing digestive enzymes.

2. Produces amylase for starch digestion.
3. Produces lipase for fat digestion.
4. Produces proteolytic enzymes for protein digestion.
5. Produces hormones such as insulin and glucagon, which regulate blood glucose.

2.4 The process of rumination in cattle

Rumination is the process by which partially digested feed is brought back from the rumen and reticulum to the mouth, rechewed, mixed with saliva and swallowed again.

It is commonly known as chewing the cud.

Stages of rumination

1. Ingestion

- The animal takes grass or other feed into the mouth.
- The feed is chewed briefly and mixed with saliva.
- It is swallowed through the oesophagus into the rumen and reticulum.

2. Regurgitation

- Partially digested feed is brought back from the reticulorumen to the mouth.
- The feed is returned as a bolus known as cud.

3. Rechewing

- The animal chews the cud thoroughly.
- The feed particles are broken into smaller pieces.
- This increases the surface area available for microbial digestion.

4. Resalivation

- More saliva is mixed with the cud.
- Saliva moistens the feed and helps buffer rumen acidity.

5. Reswallowing

- The animal swallows the rechewed cud.
- It passes into the rumen for further microbial fermentation.

6. Further digestion

- The feed moves through the digestive compartments.

- Nutrients are released, absorbed and utilised by the animal.

Importance of rumination

1. It reduces the size of feed particles.
2. It increases the surface area for microbial action.
3. It improves the digestion of fibrous feeds.
4. It stimulates saliva production.
5. It helps maintain a suitable rumen pH.
6. It improves the utilisation of roughages.
7. It enables cattle to digest plant materials that are difficult for non-ruminants to digest.

2.5 Microbial digestion in the rumen

Ruminants depend heavily on microorganisms in the rumen to digest fibrous feeds.

The major groups of microorganisms include:

- Bacteria.
- Protozoa.
- Fungi.

Roles of rumen microorganisms

Microorganism	Role in digestion
Bacteria	Break down cellulose, starch, proteins and other feed components.
Protozoa	Assist in the breakdown of starch and other feed materials and participate in rumen fermentation.
Fungi	Help break down tough plant materials, including fibrous plant cell walls.

Products of microbial fermentation

1. Volatile fatty acids (VFAs):

- Acetate, propionate and butyrate are produced.
- They are absorbed through the rumen wall.
- They provide a major source of energy for cattle.

2. Microbial protein:

- Microorganisms multiply using available nutrients.

- They pass into the abomasum and small intestine.
- They are digested to release amino acids.

3. B vitamins and vitamin K:

- Some rumen microorganisms synthesise these vitamins.

4. Gases:

- Carbon dioxide and methane are produced.
- They are mainly removed through eructation.

Importance of microbial digestion to farmers

- Enables cattle to use pasture and crop residues.
- Reduces dependence on expensive concentrated feeds.
- Converts low-quality fibrous materials into useful animal products.
- Supports milk and meat production when diets are properly balanced.

3.0 NON-RUMINANT DIGESTIVE SYSTEM

3.1 Meaning of a non-ruminant

A non-ruminant is an animal that has a simple stomach consisting of one main chamber and does not normally regurgitate and rechew cud.

Examples include:

- Pigs.
- Dogs.
- Cats.
- Rabbits (although rabbits practise caecotrophy, they are not ruminants).
- Horses (they are hindgut fermenters with an enlarged caecum and colon).

In this sub-strand, the pig is used as the main example of a non-ruminant farm animal.

Pigs mainly depend on enzymatic digestion in the stomach and small intestine. They can digest starch, proteins and fats efficiently, but they cannot utilise large quantities of cellulose as effectively as cattle.

3.2 Structure of the pig digestive system

The main parts of the pig digestive system are:

1. Mouth.
2. Oesophagus.
3. Stomach.
4. Small intestine.
5. Caecum.
6. Large intestine or colon.
7. Rectum.
8. Anus.

Accessory organs include the liver, gall bladder and pancreas.

A. Mouth

The mouth is the entry point of food into the pig's digestive system.

Functions

1. Ingestion of feeds.
2. Mechanical breakdown of food through chewing.
3. Mixing food with saliva.
4. Formation of a bolus for swallowing.
5. Taste and selection of feeds.

Features of the pig mouth

- Pigs have different types of teeth, including incisors, canines, premolars and molars.
- The teeth help in cutting, tearing and grinding feed.
- The tongue assists in moving food during chewing and swallowing.

B. Salivary glands

Salivary glands produce saliva that enters the mouth.

Functions

1. Moistens food.
2. Lubricates food for swallowing.

3. Helps form a bolus.
4. Contains salivary amylase, which may begin starch digestion.
5. Helps maintain oral health.

C. Oesophagus

The oesophagus is a muscular tube connecting the mouth to the stomach.

Functions

1. Transports swallowed food to the stomach.
2. Uses peristaltic movements to push food forward.
3. Prevents food from remaining in the mouth.

D. Stomach

Single-chambered stomach

The pig has a simple stomach consisting of one main chamber.

Characteristics

- It is a muscular sac.
- It has glandular regions that secrete gastric juice.
- It stores food temporarily.
- It mixes food with gastric juice.
- It provides an acidic environment for protein digestion.

Functions of the stomach

1. Temporary food storage: It holds food before it enters the small intestine.
2. Mechanical mixing: Muscular contractions mix food with gastric juice.
3. Protein digestion: Pepsin breaks down proteins into smaller peptides.
4. Acid production: Hydrochloric acid provides an acidic environment for pepsin action.
5. Microorganism control: The acidic environment helps destroy many harmful microorganisms.
6. Controlled release: It gradually releases partially digested food into the duodenum.

Important secretions of the stomach

- Hydrochloric acid.
- Pepsinogen, which is activated to pepsin.

- Gastric mucus, which protects the stomach lining.

E. Small intestine

The small intestine is a long, coiled tube where most enzymatic digestion and absorption take place.

It consists of:

1. Duodenum.
2. Jejunum.
3. Ileum.

Functions

1. Completes digestion of carbohydrates.
2. Completes digestion of proteins.
3. Digests fats with the help of bile and pancreatic lipase.
4. Absorbs amino acids, glucose, fatty acids, vitamins and minerals.
5. Transports digested materials into the blood and lymph.

Role of the three sections

Section	Main function
Duodenum	Receives bile and pancreatic juice; major site of chemical digestion.
Jejunum	Major site of absorption of digested nutrients.
Ileum	Absorbs remaining nutrients and passes digesta into the large intestine.

F. Caecum

The caecum is a pouch-like structure located at the junction of the small and large intestines.

Functions

1. Provides a site for limited microbial fermentation.
2. Supports the activity of microorganisms that digest some fibrous materials.
3. Allows further breakdown of some undigested feed components.

Important point: The pig's caecum is relatively small compared with the enlarged fermentation compartments of specialised hindgut fermenters such as horses. Therefore, pigs do not digest large quantities of fibrous feed as efficiently as cattle.

G. Large intestine

The large intestine includes the colon and rectum.

Functions

1. Absorbs water from undigested materials.
2. Absorbs some electrolytes.
3. Supports limited microbial fermentation.
4. Forms and compacts faeces.
5. Moves faeces towards the rectum.

H. Rectum

The rectum is the final section of the large intestine.

Functions

1. Temporarily stores faeces.
2. Receives faecal materials from the colon.
3. Initiates the defaecation reflex.

I. Anus

The anus is the opening through which faeces leave the body.

Functions

1. Allows egestion of faeces.
2. Controls the release of faeces through sphincter muscles.

3.3 Accessory digestive organs of pigs

A. Liver

Functions

1. Produces bile for fat emulsification.
2. Processes absorbed nutrients.
3. Stores glycogen and some vitamins and minerals.

4. Detoxifies harmful substances.
5. Helps regulate blood glucose.
6. Participates in metabolism of carbohydrates, proteins and fats.

B. Gall bladder

Functions

1. Stores bile produced by the liver.
2. Concentrates bile.
3. Releases bile into the duodenum during digestion.

C. Pancreas

Functions

1. Produces pancreatic amylase for starch digestion.
2. Produces pancreatic lipase for fat digestion.
3. Produces proteases for protein digestion.
4. Releases pancreatic juice into the duodenum.
5. Produces insulin and glucagon for blood glucose regulation.

4.0 POULTRY DIGESTIVE SYSTEM

4.1 Meaning of poultry

Poultry refers to domesticated birds kept for meat, eggs, feathers and other products.

Examples include:

- Chicken.
- Ducks.
- Turkeys.
- Geese.
- Guinea fowl.
- Quails.

The chicken is used as the main example in this sub-strand.

Poultry have a specialised digestive system adapted to their feeding habits. They do not have teeth; therefore, they use the beak to pick up food and the gizzard to grind it.

4.2 Main parts of the chicken digestive system

The digestive system of chicken consists of:

1. Beak and mouth.
2. Oesophagus.
3. Crop.
4. Proventriculus.
5. Gizzard.
6. Small intestine.
7. Caeca.
8. Large intestine.
9. Cloaca.
10. Vent.

Accessory organs include the liver and pancreas.

A. Beak and mouth

The beak is the external structure used by poultry to pick up food.

Functions

1. Picks up grains, seeds, insects and other feed materials.
2. Helps in selecting food.
3. Breaks larger feed materials into smaller pieces through pecking.
4. Assists in swallowing food.
5. Helps poultry drink water.

Special features

- Chickens do not have teeth.
- They use the beak to pick up feed.

- Food is swallowed with little chewing.
- Mechanical grinding takes place mainly in the gizzard.

B. Oesophagus

The oesophagus is a muscular tube connecting the mouth to the crop and proventriculus.

Functions

1. Transports swallowed food.
2. Moves feed towards the crop.
3. Allows movement of food through muscular contractions.

C. Crop

Temporary food storage

The crop is an enlarged pouch-like part of the oesophagus located at the base of the neck.

Characteristics

- It is expandable.
- It temporarily stores food.
- It softens feed before it enters the stomach.
- It allows birds to consume food quickly and digest it gradually.

Functions of the crop

1. Food storage: Temporarily stores swallowed food.
2. Softening of feed: Moistens and softens dry feed materials.
3. Regulation of food movement: Releases feed gradually into the proventriculus.
4. Limited fermentation: Some microbial activity may occur, but it is not the main site of digestion.

Importance of the crop

It enables poultry to collect food quickly and process it gradually, which is useful under natural feeding conditions.

D. Proventriculus

Glandular stomach

The proventriculus is the glandular part of the chicken's stomach. It is located between the crop and the gizzard.

Characteristics

- It has glandular walls.
- It secretes gastric juice.
- It produces hydrochloric acid and pepsinogen.
- It begins chemical digestion of proteins.

Functions

1. Secretes hydrochloric acid.
2. Releases pepsinogen, which is activated into pepsin.
3. Initiates protein digestion.
4. Mixes food with gastric secretions.
5. Prepares feed for further mechanical digestion in the gizzard.

E. Gizzard

Mechanical grinding organ

The gizzard is a strong, muscular organ located after the proventriculus.

It is also known as the muscular stomach.

Characteristics

- It has thick, powerful muscular walls.
- It has a tough inner lining.
- It contains grit or small stones when available in the diet.
- It performs mechanical grinding of feed.

Functions of the gizzard

1. Grinding feed: Crushes grains and other hard feed materials into smaller particles.
2. Mechanical digestion: Breaks down feed without changing its chemical composition.
3. Mixing: Mixes food with digestive juices.
4. Increasing surface area: Produces smaller particles that are easier for enzymes to digest.
5. Improving digestion: Helps poultry utilise grains and seeds effectively.

Importance of grit in poultry digestion

Grit consists of small hard particles that poultry swallow. These particles assist in grinding hard feed materials in the gizzard.

Examples include suitable small stones and insoluble grit.

Important distinction

- The proventriculus is mainly responsible for chemical digestion.
- The gizzard is mainly responsible for mechanical digestion.

F. Small intestine

The small intestine is a long, coiled tube where most enzymatic digestion and absorption take place.

It consists of the duodenum, jejunum and ileum.

Functions

1. Completes digestion of carbohydrates.
2. Completes digestion of proteins.
3. Digests fats.
4. Absorbs glucose and other simple sugars.
5. Absorbs amino acids.
6. Absorbs fatty acids and other fat digestion products.
7. Absorbs vitamins and minerals.

Special feature

The duodenum forms a loop around the pancreas, allowing pancreatic juice to enter the digestive tract.

G. Caeca

The caeca are two blind-ended pouches located at the junction of the small and large intestines.

Functions

1. Support microbial fermentation.
2. Assist in the breakdown of some fibrous feed materials.
3. Absorb some water and fermentation products.
4. Support the activity of beneficial microorganisms.

Importance

The caeca help poultry utilise some fibrous materials, although their ability to digest fibre is much lower than that of ruminants.

H. Large intestine

The large intestine in chickens is relatively short.

Functions

1. Absorbs water and electrolytes.
2. Moves undigested materials towards the cloaca.
3. Supports the final stages of faecal formation.

I. Cloaca

The cloaca is a common chamber into which the digestive, urinary and reproductive tracts open.

Functions

1. Receives faecal materials from the digestive tract.
2. Receives urinary waste from the urinary system.
3. Receives reproductive products during reproduction.
4. Provides a common passage for elimination of waste and release of eggs.

J. Vent

The vent is the external opening of the cloaca.

Functions

1. Allows the discharge of faecal and urinary waste.
2. Allows the passage of eggs during laying.
3. Provides an external opening for the reproductive and excretory systems.

4.3 Accessory digestive organs of poultry

A. Liver

Functions

1. Produces bile for fat emulsification.
2. Processes absorbed nutrients.
3. Stores glycogen and some vitamins and minerals.
4. Helps detoxify harmful substances.
5. Participates in metabolism.

B. Pancreas

Functions

1. Produces amylase for starch digestion.

2. Produces lipase for fat digestion.
3. Produces proteases for protein digestion.
4. Releases pancreatic juice into the duodenum.
5. Produces hormones that regulate blood glucose.

5.0 COMPARISON OF THE DIGESTIVE SYSTEMS OF CATTLE, PIGS AND CHICKENS

Farm animals have different digestive systems because they consume different feeds and have different methods of extracting nutrients.

Feature	Cattle	Pigs	Chickens
Type of digestive system	Ruminant	Non-ruminant	Poultry digestive system
Stomach	Four compartments	One main chamber	Proventriculus and gizzard
Main fermentation site	Rumen	Limited hindgut fermentation	Caeca
Teeth	Present	Present	Absent
Special structure	Rumen and reticulum	Simple stomach	Crop and gizzard
Rumination	Present	Absent	Absent
Main feed type	Roughages and concentrates	Concentrates and suitable mixed feeds	Grains, protein sources and balanced poultry feeds
Cellulose digestion	Efficient due to rumen microorganisms	Limited	Limited
Food grinding	Teeth	Teeth	Gizzard
Main site of absorption	Small intestine	Small intestine	Small intestine

5.1 Differences between ruminants and non-ruminants

Ruminants	Non-ruminants
Have a specialised four-compartment stomach.	Have one main stomach chamber.
Regurgitate and rechew cud.	Do not normally regurgitate and rechew cud.
Have extensive microbial fermentation in the rumen.	Have limited microbial fermentation in the hindgut.
Digest fibrous feeds efficiently.	Have limited ability to digest fibrous feeds.

Can obtain energy from microbial fermentation products.	Obtain much of their energy through enzymatic digestion of carbohydrates and fats.
Microorganisms contribute microbial protein.	Most dietary protein is digested by the animal's own enzymes.
Examples include cattle, sheep and goats.	Examples include pigs, dogs and cats.

5.2 Differences between pig and poultry digestive systems

Pig	Chicken
Has teeth for chewing and grinding food.	Has a beak and no teeth.
Has a single-chambered stomach.	Has a proventriculus and gizzard.
Food is chewed in the mouth.	Food is swallowed with little chewing.
Does not have a crop.	Has a crop for temporary food storage.
Has a caecum, usually relatively small.	Has paired caeca.
Faeces leave through the anus.	Waste leaves through the cloaca and vent.
Digestion occurs through stomach and intestinal enzymes.	Digestion occurs through gastric and intestinal enzymes, with grinding in the gizzard.

6.0 RELATIONSHIP BETWEEN DIGESTIVE SYSTEMS AND ANIMAL FEEDS

Different farm animals require different feeds because their digestive systems have different capacities for breaking down food materials.

The type of feed given to an animal should be appropriate to its digestive system, age, body size, production purpose and physiological condition.

6.1 Appropriate feeds for cattle

Cattle are ruminants and can digest fibrous feeds through microbial fermentation in the rumen.

A. Roughages

Roughages are bulky feeds that contain relatively high amounts of fibre.

Examples include:

1. Napier grass.
2. Rhodes grass.

3. Hay.
4. Maize stover.
5. Bean haulms.
6. Wheat straw.
7. Pasture grasses.
8. Silage.

Importance of roughages in cattle feeding

- Supply fibre required for normal rumen function.
- Stimulate rumination.
- Encourage saliva production.
- Provide energy through microbial fermentation.
- Help maintain normal digestive activity.

B. Concentrates

Concentrates are feeds that contain relatively high amounts of energy or protein and lower fibre levels than roughages.

Examples include:

- Maize germ.
- Wheat bran.
- Cottonseed cake.
- Sunflower seed cake.
- Soybean meal.
- Commercial dairy meal.

Importance of concentrates

1. Supply additional energy.
2. Supply protein for growth and milk production.
3. Supplement nutrients that may be inadequate in roughages.
4. Improve production when properly balanced with roughages.

C. Mineral supplements

Examples include:

- Mineral licks.
- Calcium supplements.
- Phosphorus supplements.
- Salt.

Importance

- Support bone and teeth formation.
- Maintain normal body functions.
- Support reproduction and milk production.
- Prevent mineral deficiencies.

D. Water

Clean drinking water should always be available.

Water is required for:

- Digestion.
- Nutrient transport.
- Temperature regulation.
- Milk production.
- Removal of metabolic waste.

6.2 Appropriate feeds for pigs

Pigs are non-ruminants. They depend mainly on enzymatic digestion, so their feeds should contain readily digestible nutrients.

A. Energy feeds

Examples:

- Maize.
- Wheat.
- Sorghum.
- Cassava meal.
- Rice bran.

Importance

- Supply energy for body activities.

- Support growth and weight gain.
- Support fat deposition and production.

B. Protein feeds

Examples:

- Soybean meal.
- Fish meal where suitable and permitted.
- Sunflower seed cake.
- Other approved protein sources.

Importance

- Support muscle development.
- Support tissue repair.
- Promote growth.
- Support reproduction and lactation.

C. Mineral and vitamin supplements

Examples:

- Calcium.
- Phosphorus.
- Salt.
- Vitamin premixes.

Importance

- Support bone development.
- Maintain body functions.
- Support immunity and reproduction.
- Prevent nutrient deficiencies.

D. Water

Pigs require adequate clean water for digestion, metabolism, temperature regulation and growth.

Important feeding consideration

Pigs can consume some vegetable materials and crop by-products. However, excessive fibrous materials may reduce digestibility and growth performance. Feed should therefore be properly processed, balanced and suitable for the animal's age and production stage.

6.3 Appropriate feeds for poultry

Poultry require balanced feeds containing energy, protein, vitamins, minerals and water.

A. Energy feeds

Examples:

- Maize.
- Wheat.
- Sorghum.
- Millet.
- Suitable cereal by-products.

Importance

- Provide energy for movement and body functions.
- Support growth.
- Support egg production.

B. Protein feeds

Examples:

- Soybean meal.
- Sunflower seed cake.
- Approved fish meal.
- Other suitable protein sources.

Importance

- Support muscle development.
- Promote feather growth.
- Support egg formation.
- Support tissue repair.

C. Mineral supplements

Examples:

- Calcium sources such as limestone.
- Phosphorus sources.
- Salt.
- Appropriate mineral premixes.

Importance

- Calcium supports eggshell formation in laying birds.
- Calcium and phosphorus support bone development.
- Minerals maintain normal physiological functions.

D. Vitamin supplements

Examples include vitamins A, D, E and K, as well as B-complex vitamins.

Importance

- Support growth and immunity.
- Maintain normal body functions.
- Support reproduction.
- Prevent deficiency disorders.

E. Grit

Grit is made up of small hard particles swallowed by poultry.

Importance

- Helps grind hard feed materials in the gizzard.
- Improves mechanical breakdown of grains and seeds.

Note: Grit is different from soluble calcium supplements. Grit helps grinding, while calcium sources provide calcium for bone and eggshell formation.

F. Water

Poultry require clean water at all times.

Water supports:

- Digestion.
- Nutrient absorption.
- Body temperature regulation.
- Egg production.

- Metabolism.

7.0 EFFECTIVENESS OF CATTLE, PIGS AND CHICKENS IN DIGESTING VEGETATIVE FEEDS

Vegetative feeds are plant materials such as grass, leaves, stems and crop residues.

Examples include:

- Napier grass.
- Maize stover.
- Bean haulms.
- Lucerne.
- Hay.
- Pasture grasses.

Different animals digest these feeds with varying levels of efficiency.

7.1 Why cattle digest vegetative feeds more efficiently

Cattle possess a specialised rumen containing microorganisms capable of fermenting cellulose and other plant fibre components.

The microorganisms produce enzymes that break down plant cell walls.

The products of fermentation provide energy to the animal.

Cattle can therefore utilise many fibrous feed materials that pigs and chickens cannot digest efficiently.

7.2 Why pigs are less efficient at digesting vegetative feeds

- Pigs have a simple stomach.
- They lack a rumen containing large populations of cellulose-digesting microorganisms.
- Their digestive enzymes efficiently digest starch, proteins and fats.
- They have limited microbial fermentation in the hindgut.
- They cannot utilise large amounts of roughage as efficiently as cattle.

7.3 Why chickens are less efficient at digesting vegetative feeds

- Chickens do not have a rumen.
- Their digestive tract is relatively short.
- They have paired caeca where limited microbial fermentation occurs.
- They can digest some plant materials but cannot efficiently utilise large quantities of highly fibrous feed.
- Excessive fibre may reduce feed intake and nutrient utilisation.

7.4 Comparison of the three animals when fed on similar vegetative feeds

Animal	Ability to digest vegetative feeds	Explanation
Cattle	High for suitable fibrous feeds	Rumen microorganisms digest cellulose and ferment plant materials.
Pigs	Limited	Simple stomach and limited hindgut fermentation.
Chickens	Limited	No rumen; only limited fermentation occurs in the paired caeca.

7.5 Effects of feeding similar vegetative feeds to cattle, pigs and chickens

If cattle, pigs and chickens are all fed on the same highly fibrous feed, their productivity is likely to differ.

A. Effects on cattle

- Cattle can utilise the fibrous material through rumen fermentation.
- They obtain energy from volatile fatty acids.
- Their maintenance and production needs may be met if the feed is of adequate quality and is properly supplemented.
- Poor-quality forage alone may still result in low milk production or slow growth.

B. Effects on pigs

- Pigs may digest only a limited proportion of the fibrous material.
- They may obtain inadequate energy and protein.
- Growth rate may reduce.
- Feed conversion may become poor.
- Excessive fibre may reduce digestibility and production efficiency.

C. Effects on chickens

- Chickens may not digest highly fibrous feeds efficiently.
- Nutrient availability may be low.
- Growth rate and egg production may decline.
- Feed intake may be affected.
- Excessive fibre may reduce the overall energy and nutrient density of the diet.

Conclusion: Cattle are generally better adapted to utilising fibrous vegetative feeds than pigs and chickens. However, all animals require balanced diets suitable for their production needs.

8.0 IMPORTANCE OF APPROPRIATE FEEDING IN ANIMAL PRODUCTION

Appropriate feeding is essential for successful livestock production.

1. Promotes growth

- Provides nutrients required for body development.
- Supports muscle and bone formation.
- Improves body weight gain.

2. Improves milk production

- Supplies energy and protein for milk synthesis.
- Supports the nutritional requirements of lactating animals.
- Helps maintain body condition.

3. Improves egg production

- Provides nutrients for egg formation.
- Calcium supports eggshell formation.
- Protein supports albumen and yolk development.

4. Improves reproduction

- Supports fertility.
- Promotes normal reproductive functions.
- Helps maintain healthy breeding animals.

5. Improves disease resistance

- Vitamins and minerals support immunity.
- Balanced nutrition improves the animal's ability to withstand disease challenges.

6. Reduces production costs

- Appropriate feed selection reduces wastage.
- Locally available feeds can be used efficiently.
- Balanced rations improve feed utilisation.

7. Promotes animal welfare

- Prevents starvation and malnutrition.
- Reduces the risk of digestive disorders.
- Supports normal growth and behaviour.

- Ensures access to adequate clean water.

9.0 FACTORS TO CONSIDER WHEN SELECTING FEEDS FOR FARM ANIMALS

1. Type of digestive system: Feeds should be appropriate for the animal's digestive capacity.
2. Age: Young animals require feeds suitable for their developing digestive systems.
3. Production purpose: Dairy cattle, beef cattle, layers, broilers and breeding pigs have different nutritional requirements.
4. Nutrient composition: Feeds should provide adequate energy, protein, vitamins and minerals.
5. Availability: Locally available feeds may reduce production costs.
6. Cost: The farmer should select feeds that provide good nutritional value at a reasonable cost.
7. Palatability: Feeds should be acceptable to the animals.
8. Digestibility: Feeds should contain nutrients that the animal can digest and absorb.
9. Safety: Feeds should be free from harmful contaminants, toxins and moulds.
10. Water availability: Adequate clean water must accompany feeding.
11. Health condition: Sick animals may require special feeding management.
12. Environmental conditions: Feed requirements may change under heat stress, cold conditions and other environmental challenges.

COMMON DIGESTIVE DISORDERS RELATED TO FEEDING

Improper feeding can cause digestive problems in farm animals.

Disorder	Animal	Description and possible causes
Bloat	Cattle	Excessive gas accumulation in the rumen, sometimes associated with lush legumes or other rapidly fermentable feeds.
Acidosis	Cattle	Excessive acidity in the rumen, often associated with sudden consumption of large amounts of rapidly fermentable carbohydrates.
Impaction	Cattle	Accumulation of poorly digested material in the digestive tract.
Diarrhoea	Cattle, pigs and poultry	Passing loose or watery faeces due to several possible causes, including infections, feed changes and poor-quality water.
Constipation	Cattle and pigs	Difficulty passing faeces, sometimes associated with inadequate water or unsuitable feeding.

Sour crop	Poultry	Abnormal retention and fermentation of crop contents, sometimes associated with digestive dysfunction or infection.

Preventive measures

- Provide balanced rations.
- Avoid sudden changes in feed.
- Introduce new feeds gradually.
- Provide adequate clean drinking water.
- Avoid mouldy and contaminated feeds.
- Maintain proper feeding hygiene.
- Seek veterinary advice when animals show signs of digestive illness.

PRACTICAL LEARNING ACTIVITIES

Activity 1: Observing digestive systems of farm animals

Objective: To identify the main parts of the digestive systems of cattle, pigs and chickens.

Requirements:

- Textbooks.
- Charts.
- Models.
- Digital videos.
- Animal anatomy diagrams.

Procedure:

1. Study diagrams of cattle, pig and chicken digestive systems.

2. Identify the main digestive organs.
3. Label the different parts.
4. Discuss the functions of each organ.
5. Compare the three digestive systems.
6. Present findings to the class.

Expected learning outcome:

The learner should be able to identify and describe the main parts of the digestive systems of farm animals.

Activity 2: Comparing digestion of vegetative feeds

Objective: To investigate why cattle digest fibrous feeds more efficiently than pigs and chickens.

Procedure:

1. Form groups.
2. Identify common vegetative feeds such as Napier grass, hay and maize stover.
3. Study the digestive systems of cattle, pigs and chickens.
4. Discuss the role of rumen microorganisms.
5. Compare the ability of the three animals to digest fibrous materials.
6. Present the findings.

Expected outcome:

The learner should explain the relationship between digestive structure and feeding habits.

Activity 3: Investigating suitable feeds for farm animals

Procedure:

1. Collect samples or pictures of different animal feeds.
2. Classify them into roughages, energy feeds, protein feeds and mineral supplements.
3. Identify animals that can efficiently utilise each feed.
4. Discuss the importance of balanced feeding.
5. Present the findings.

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives provided.

1. Which one of the following farm animals has a ruminant digestive system?

A. Pig

B. Chicken

C. Cattle

D. Rabbit

2. The largest compartment of the ruminant stomach is the

A. Abomasum.

B. Rumen.

C. Omasum.

D. Reticulum.

3. Which compartment of the ruminant stomach is referred to as the true stomach?

A. Rumen.

B. Reticulum.

C. Omasum.

D. Abomasum.

4. The honeycomb-like structure in the ruminant stomach is the

A. Rumen.

B. Reticulum.

C. Omasum.

D. Abomasum.

5. Which one of the following is the main function of the omasum?

A. Production of saliva.

B. Absorption of water and minerals.

C. Storage of cud.

D. Production of bile.

6. The process of bringing partially digested food back to the mouth for rechewing is known as

A. Absorption.

B. Assimilation.

C. Rumination.

D. Egestion.

7. Which microorganisms are mainly responsible for the breakdown of cellulose in cattle?

A. Bacteria, protozoa and fungi.

B. Viruses and algae.

C. Worms and insects.

D. Yeasts only.

8. Which one of the following animals has a simple stomach?

A. Sheep.

B. Goat.

C. Cattle.

D. Pig.

9. The main site of nutrient absorption in pigs is the

A. Stomach.

B. Small intestine.

C. Oesophagus.

D. Rectum.

10. The crop in poultry is mainly responsible for

A. Absorption of amino acids.

B. Temporary storage and softening of food.

C. Production of bile.

D. Removal of faeces.

11. The glandular stomach of poultry is called the

A. Crop.

B. Gizzard.

C. Proventriculus.

D. Caecum.

12. Which poultry organ is mainly responsible for grinding feed?

A. Crop.

B. Gizzard.

C. Cloaca.

D. Oesophagus.

13. The paired caeca in chickens assist in

A. Egg formation.

B. Limited microbial fermentation.

C. Production of saliva.

D. Grinding grains.

14. Which one of the following animals is most efficient at digesting fibrous plant materials?

A. Chicken.

B. Pig.

C. Cattle.

D. Dog.

15. The main energy products of rumen fermentation are

A. Volatile fatty acids.

B. Amino acids only.

C. Vitamins only.

D. Mineral salts.

16. Which one of the following is an accessory digestive organ?

A. Oesophagus.

B. Rumen.

C. Liver.

D. Rectum.

17. Which one of the following is a major function of bile?

A. Digestion of cellulose.

B. Emulsification of fats.

C. Breakdown of proteins.

D. Absorption of glucose.

18. The cloaca in poultry serves as

A. A temporary food storage organ.

B. A common chamber for digestive, urinary and reproductive tracts.

C. A grinding organ.

D. A site of rumination.

19. Which one of the following feeds is most suitable as a roughage for dairy cattle?

A. Napier grass.

B. Fish meal.

C. Mineral premix.

D. Wheat flour.

20. Why should pigs not be fed exclusively on highly fibrous feeds?

A. They lack a digestive system.

B. They cannot swallow roughages.

C. Their simple stomach and limited hindgut fermentation make fibre digestion less efficient.

D. They do not require energy.

Section B: Structured questions

21.
a) Define the term digestion. (2 marks)

b) State four processes involved in digestion. (4 marks)

c) Explain four functions of the digestive system in farm animals. (8 marks)

22.
a) Name the four compartments of the ruminant stomach. (4 marks)

b) Explain the functions of each compartment. (12 marks)

c) State two advantages of rumination in cattle. (4 marks)

23.
a) Describe the process of rumination in cattle. (8 marks)

b) Explain four roles of microorganisms in the rumen. (8 marks)

c) State two examples of fibrous feeds that can be utilised by cattle. (2 marks)

24.
a) Name six parts of the pig digestive system. (6 marks)

b) Explain the functions of the following parts:
i. Stomach. (3 marks)
ii. Small intestine. (3 marks)
iii. Large intestine. (3 marks)

c) State five examples of feeds suitable for pigs. (5 marks)

25.
a) Name six parts of the chicken digestive system. (6 marks)

b) Explain the functions of:
i. Crop. (3 marks)
ii. Proventriculus. (3 marks)
iii. Gizzard. (3 marks)
iv. Caeca. (3 marks)

c) Explain two reasons why poultry require grit. (2 marks)

26.
a) Differentiate between ruminant and non-ruminant digestive systems. (6 marks)

b) Explain why cattle digest vegetative feeds more efficiently than pigs and chickens. (6 marks)

c) Discuss four effects of feeding pigs and chickens on highly fibrous feeds. (8 marks)

14.0 SUMMARY OF THE SUB-STRAND

- Digestion is the breakdown of complex food substances into simple, soluble substances.
- Cattle have a ruminant digestive system with four stomach compartments: rumen, reticulum, omasum and abomasum.
- Rumen microorganisms help cattle digest cellulose and other fibrous materials.
- Rumination involves regurgitation, rechewing, resalivation and reswallowing of cud.
- Pigs have a simple, single-chambered stomach and depend mainly on enzymatic digestion.
- Chickens have a specialised digestive system consisting of the crop, proventriculus and gizzard, among other structures.
- The crop stores and softens feed, while the proventriculus performs chemical digestion and the gizzard grinds food.
- Cattle are more efficient at digesting fibrous vegetative feeds than pigs and chickens.
- Appropriate feeding improves animal growth, health, reproduction and productivity.

- Farmers should select feeds according to the digestive system, age and production purpose of each animal.

STRAND 2.0: ANIMAL PRODUCTION

SUB-STRAND 2.2: ANIMAL HEALTH – PARASITE CONTROL

1.0 Introduction to parasites in animal production

Animal health is an important factor in successful livestock production. Healthy animals grow well, reproduce effectively and produce quality products such as meat, milk and eggs. However, animal production is affected by various diseases and parasites that reduce productivity and may cause death.

Parasites are organisms that live in or on another living organism, known as the host, and obtain nourishment or shelter at the host's expense. Parasites may cause injury, irritation, blood loss, poor growth, reduced production and transmission of diseases.

In Kenya, parasites are a major challenge in livestock production, particularly where animals graze in infested pastures, share watering points or are kept under unhygienic conditions.

Examples of parasites affecting farm animals include:

- Internal parasites: Tapeworms, roundworms and liver flukes.
- External parasites: Ticks, fleas, tsetse flies, keds and mites.

1.1 Meaning of important terms

Parasite: An organism that lives in or on another organism and obtains nourishment or other benefits at the host's expense.

Host: An animal or other organism that provides food, shelter or a suitable environment for a parasite.

Infestation: The presence of parasites, especially external parasites, on or in an animal or its environment.

Infection: The entry and establishment of disease-causing organisms, including certain internal parasites, in the body of an animal.

Life cycle: The series of developmental stages through which a parasite passes from one stage to another until it reaches maturity and reproduces.

Intermediate host: An organism in which a parasite undergoes some developmental stages but does not usually reach sexual maturity.

Definitive host: The host in which a parasite reaches sexual maturity or undergoes sexual reproduction.

Vector: An organism that transmits disease-causing organisms or parasites from one host to another.

Ectoparasite: A parasite that lives on the external surface of its host.

Endoparasite: A parasite that lives inside the body of its host.

Deworming: The administration of suitable anthelmintic medicines to control or remove internal parasitic worms.

Dipping: Immersing livestock, usually cattle, in an approved acaricide solution to control external parasites such as ticks.

Drenching: Giving an animal liquid medicine orally, commonly to control internal parasites.

1.2 Categories of parasites affecting farm animals

Parasites affecting farm animals are broadly classified into two main categories:

1. Internal parasites (endoparasites).
2. External parasites (ectoparasites).

A. Internal parasites (Endoparasites)

Internal parasites are organisms that live inside the body of an animal and obtain nutrients from the host.

They may be found in:

- Stomach.
- Small intestine.
- Large intestine.
- Liver.

- Lungs.
- Blood.
- Other internal tissues and organs.

Examples include:

1. Tapeworms.
2. Roundworms.
3. Liver flukes.

Characteristics of internal parasites

- They live inside the host's body.
- They obtain nutrients from the host or its body fluids.
- Some have complex life cycles involving intermediate hosts.
- They may damage internal organs.
- They may cause anaemia, diarrhoea, poor growth and loss of body condition.
- Some produce eggs that leave the host through faeces.
- Their control may involve appropriate deworming, sanitation and pasture management.

B. External parasites (Ectoparasites)

External parasites are organisms that live on the external surface of an animal and obtain nourishment from its blood, skin, feathers or other tissues.

They may be found on:

- Skin.
- Hair.
- Feathers.
- Ears.
- Body folds.
- Other external body surfaces.

Examples include:

1. Ticks.
2. Fleas.

3. Tsetse flies.
4. Keds.
5. Mites.

Characteristics of external parasites

- They live on the body surface of animals.
- Some suck blood while others feed on skin debris or tissues.
- They may cause irritation, wounds and inflammation.
- Some transmit disease-causing organisms.
- They may cause animals to scratch, rub themselves or become restless.
- They can reduce the quality of hides, skins, wool and feathers.
- They are controlled through appropriate acaricides, insecticides, hygiene and environmental management.

Differences between internal and external parasites

Internal parasites	**External parasites**
Live inside the host's body.	Live on the external surface of the host.
May affect the digestive tract, liver, lungs or blood.	Commonly affect skin, hair, feathers and ears.
Examples include tapeworms, roundworms and liver flukes.	Examples include ticks, fleas, keds, mites and tsetse flies.
May cause internal organ damage and nutrient loss.	May cause skin irritation, wounds and blood loss.
Often controlled using appropriate anthelmintics.	Often controlled using appropriate acaricides or insecticides and other measures.
Eggs or larvae may be passed in faeces.	Some reproduce on the host or in its environment.

1.3 Importance of studying parasites in animal production

Knowledge of parasites enables farmers to:

1. Identify parasites affecting their animals.
2. Recognise signs of parasitic infestation.
3. Understand how parasites spread from one animal to another.
4. Select appropriate parasite control measures.
5. Reduce livestock deaths and production losses.
6. Improve animal growth and body condition.
7. Improve milk, meat and egg production.
8. Reduce the cost of veterinary treatment.
9. Protect animals from parasite-transmitted diseases.
10. Promote animal welfare and good livestock management.

2.0 INTERNAL PARASITES AFFECTING FARM ANIMALS

Internal parasites live within the body of animals. They obtain nourishment from the host and may interfere with normal body functions.

The main internal parasites covered in this sub-strand are:

1. Tapeworms.
2. Roundworms.
3. Liver flukes.

2.1 Tapeworms

Meaning of tapeworms

Tapeworms are long, flat, ribbon-like internal parasitic worms that live mainly in the intestines of their hosts.

They belong to the class Cestoda.

Examples include:

- Taenia solium – pork tapeworm.
- Taenia saginata – beef tapeworm.
- Other tapeworm species affecting different livestock and animal hosts.

2.1.1 Characteristics of tapeworms

1. Flat and ribbon-like body: Their bodies are long, flattened and segmented.
2. Segmentation: Their bodies consist of many segments called proglottids.

3. Scolex: The head region is called the scolex. It has suckers and, in some species, hooks for attachment to the intestinal wall.
4. Neck: A short region behind the scolex produces new segments.
5. No complete digestive system: Tapeworms absorb already digested nutrients through their body surface.
6. Hermaphroditic segments: Many tapeworm segments contain both male and female reproductive organs.
7. High egg production: Mature segments contain eggs and may detach from the adult worm.
8. Complex life cycles: Many tapeworms require an intermediate host to complete their development.

2.1.2 Animals affected by tapeworms

Tapeworm species affect different animal hosts.

Examples include:

- Pigs.
- Cattle.
- Sheep.
- Goats.
- Dogs.
- Humans, depending on the tapeworm species.

Important examples

- The larval stage of Taenia solium develops in pig tissues. Humans can develop intestinal taeniasis by eating inadequately cooked infected pork. Humans may also develop cysticercosis by ingesting T. solium eggs through faecal contamination.
- Taenia saginata uses cattle as an intermediate host, while humans are its definitive host.

2.1.3 Effects of tapeworms on animals

1. Nutrient competition: Tapeworms absorb nutrients from the host's digestive tract.
2. Poor growth: Infected young animals may grow slowly.
3. Weight loss: Heavy infestations may contribute to loss of body condition.
4. Digestive disturbances: Some animals may develop diarrhoea or other digestive problems.
5. Intestinal irritation: Attachment of parasites may irritate the intestinal lining.
6. Reduced productivity: Infected animals may produce less meat, milk or other livestock products.

7. Organ damage: Larval cysts of certain tapeworms may develop in muscles and other tissues.

2.1.4 Life cycle of the pork tapeworm (Taenia solium)

The pork tapeworm has a life cycle involving two main hosts:

- Human beings – definitive host.
- Pigs – intermediate host.

Stages in the life cycle

1. Adult tapeworm in the human intestine

- The adult pork tapeworm lives in the small intestine of a human being.
- Mature segments produce eggs.
- Eggs or egg-containing segments leave the body through faeces.

2. Contamination of the environment

- Human faeces containing tapeworm eggs contaminate soil, pasture, water or animal feeds.
- Poor sanitation increases the likelihood of environmental contamination.

3. Ingestion of eggs by pigs

- Pigs may swallow the eggs when feeding in contaminated areas.
- The eggs hatch in the pig's digestive tract.

4. Development of larvae

- The larvae penetrate the intestinal wall.
- They enter the bloodstream and are carried to different body tissues, especially muscles.

5. Formation of cysticerci

- The larvae develop into bladder-like structures called cysticerci.
- These may be found in muscles and other tissues.

6. Infection of humans

- A human being may acquire intestinal taeniasis by eating raw or inadequately cooked pork containing viable cysticerci.

7. Development of adult tapeworm

- The cysticercus develops into an adult tapeworm in the human small intestine.
- The life cycle is completed.

Important public-health distinction: Human cysticercosis occurs when a person ingests T. solium eggs through faecal contamination. It is not acquired simply by eating pork containing cysticerci. Eating infected, inadequately cooked pork causes intestinal taeniasis.

2.1.5 Control of pork tapeworm

- Keep pig housing clean.
- Prevent pigs from accessing human faeces.
- Provide properly constructed toilets and latrines.
- Prevent open defaecation.
- Feed pigs in clean troughs.
- Provide safe drinking water.
- Have pork inspected by authorised meat inspectors.
- Cook pork thoroughly before consumption.
- Ensure proper disposal of infected meat.
- Deworm animals when advised by a qualified animal-health professional.
- Educate farmers and communities on the importance of sanitation.

2.2 Roundworms

Meaning of roundworms

Roundworms are elongated, cylindrical, unsegmented parasitic worms that commonly live in the digestive tract or other tissues of animals.

They belong to a group of worms called nematodes.

Examples include:

- Ascaris suum – pig roundworm.
- Haemonchus contortus – barber's pole worm of sheep and goats.
- Toxocara vitulorum – roundworm affecting calves.
- Oesophagostomum species – nodular worms affecting livestock.

2.2.1 Characteristics of roundworms

1. Cylindrical bodies: Their bodies are long, round and slender.
2. Unsegmented: Their bodies do not have the segments found in tapeworms.
3. Tapered ends: Most have pointed or tapered ends.
4. Separate sexes: Male and female worms are usually separate individuals.
5. Digestive system present: They have a complete digestive tract with a mouth and anus.
6. Reproduction: Females produce eggs that may be passed out in faeces.
7. Different habitats: They may live in the stomach, intestines, lungs or other body tissues.
8. Different life cycles: Some complete their life cycles in one host, while others use intermediate hosts.

2.2.2 Animals affected by roundworms

Roundworms affect many farm animals, including:

- Cattle.
- Sheep.
- Goats.
- Pigs.
- Poultry.
- Dogs and cats.

Different roundworm species are adapted to particular hosts.

2.2.3 Effects of roundworms on farm animals

1. Nutrient loss: They compete with the host for nutrients.
2. Anaemia: Blood-sucking worms such as Haemonchus contortus cause blood loss.
3. Diarrhoea: Heavy infestations may interfere with normal digestion.
4. Poor growth: Young animals may fail to attain expected body weight.
5. Reduced productivity: Milk and meat production may decline.
6. Poor body condition: Infected animals may become thin and weak.
7. Intestinal blockage: Heavy infections, especially with large roundworms, may cause obstruction.
8. Organ damage: Migrating larvae may damage tissues such as the liver and lungs.
9. Death: Severe infestations may cause death, especially in young or poorly nourished animals.

2.2.4 Life cycle of a typical roundworm

The following is a simplified direct life cycle of a typical livestock roundworm whose eggs develop into infective larvae in the environment. Different roundworm species have different life cycles.

Stages in the life cycle

1. Adult worms in the host

- Mature male and female worms live in the digestive tract.
- They reproduce and produce eggs.

2. Eggs passed out

- Eggs leave the host's body through faeces.
- They contaminate pasture, soil, water and animal housing.

3. Development in the environment

- Under suitable conditions of moisture and temperature, eggs develop into larvae.
- Some larvae develop further into infective stages.

4. Ingestion by another animal

- Animals swallow infective eggs or larvae while grazing or feeding.
- Contaminated water and feed may also transmit infection.

5. Development in the host

- The parasites develop into immature stages.
- Depending on the species, larvae may migrate through organs or develop in the intestine.

6. Maturation

- Immature worms develop into adults.
- They reproduce and produce more eggs.

7. Continuation of the cycle

- Eggs are passed out through faeces.
- The cycle continues when another susceptible animal ingests infective stages.

2.2.5 Control of roundworms

- Deworm animals using suitable veterinary-approved anthelmintics.
- Follow veterinary guidance on drug selection and timing.
- Avoid unnecessary repeated use of the same drug class because it can encourage drug resistance.
- Keep animal houses clean and dry.

- Dispose of animal faeces properly.
- Avoid overcrowding.
- Rotate grazing areas where appropriate.
- Avoid grazing young animals on heavily contaminated pastures.
- Provide adequate nutrition.
- Separate severely affected animals for assessment and treatment.
- Conduct regular monitoring of parasite burdens where veterinary services are available.

2.3 Liver flukes

Meaning of liver flukes

Liver flukes are flat, leaf-shaped internal parasitic worms that mainly affect the liver and bile ducts of livestock.

A common species is Fasciola hepatica. Another important species is Fasciola gigantica, which occurs in many tropical and subtropical regions.

They mainly affect:

- Cattle.
- Sheep.
- Goats.
- Other grazing animals.

2.3.1 Characteristics of liver flukes

1. Flat body: They have flattened, leaf-shaped bodies.
2. Unsegmented: Their bodies are not divided into segments.
3. Suckers: They have suckers that assist in attachment.
4. Internal parasites: They live inside the host's body.
5. Liver habitat: Adult flukes mainly inhabit the bile ducts.
6. Complex life cycle: They require a freshwater snail as an intermediate host.
7. Egg production: Adult flukes produce eggs that leave the host through faeces.
8. Migration: Immature flukes migrate through liver tissues, causing damage.

2.3.2 Effects of liver flukes on farm animals

1. Liver damage: Migrating immature flukes damage liver tissues.

2. Anaemia: Blood loss and tissue damage may contribute to anaemia.
3. Weight loss: Animals may lose body condition.
4. Reduced milk production: Infected dairy animals may produce less milk.
5. Poor growth: Young animals may grow slowly.
6. Swelling under the jaw: Severe infections may cause fluid accumulation under the jaw, commonly called bottle jaw.
7. Reduced fertility: Poor body condition may affect reproductive performance.
8. Liver condemnation: Infected livers may be rejected during meat inspection.
9. Death: Severe infections may result in death, especially in sheep.

2.3.3 Life cycle of the liver fluke (Fasciola species)

The liver fluke has an indirect life cycle involving a freshwater snail as an intermediate host.

Stages in the life cycle

1. Adult liver fluke in the bile ducts

- Mature flukes live in the bile ducts of infected animals.
- They reproduce and produce eggs.

2. Eggs leave the host

- Eggs pass from the bile ducts into the intestine.
- They leave the animal's body through faeces.

3. Egg development in water

- Eggs reach wet environments or water.
- Under suitable conditions, they develop and hatch into free-swimming larvae called miracidia.

4. Infection of the snail

- Miracidia penetrate a suitable freshwater snail.
- The snail acts as the intermediate host.

5. Development inside the snail

- The parasite undergoes several developmental stages:
  - ✓ Sporocyst.
  - ✓ Redia.
  - ✓ Cercaria.

- Cercariae leave the snail.

6. Encystment on vegetation

- Cercariae attach to aquatic plants or other suitable wet surfaces.
- They form protective cysts called metacercariae.
- Metacercariae are the infective stage for grazing livestock.

7. Infection of livestock

- Cattle, sheep or goats ingest metacercariae when grazing on contaminated wet vegetation or drinking contaminated water.

8. Migration to the liver

- The young flukes emerge in the digestive tract.
- They penetrate the intestinal wall and migrate through the abdominal cavity into the liver.
- They move through liver tissues before reaching the bile ducts.

9. Maturation

- The flukes mature in the bile ducts.
- They produce eggs, and the cycle begins again.

2.3.4 Control of liver flukes

- Avoid grazing animals in heavily infested swampy and marshy areas.
- Improve drainage in waterlogged grazing areas where practical.
- Provide clean drinking water.
- Use veterinary-approved flukicides appropriate to the parasite's developmental stage.
- Follow veterinary guidance on treatment timing.
- Monitor animals grazing in areas where liver flukes are common.
- Manage snail habitats where environmentally appropriate and legally permitted.
- Avoid uncontrolled use of chemicals in wetlands because they may harm other organisms and contaminate water.
- Conduct regular veterinary examinations.
- Practise proper pasture management.

Important: Not all dewormers control liver flukes. Farmers should use medicines specifically approved for the parasite and follow the product label and veterinary advice.

3.0 EXTERNAL PARASITES AFFECTING FARM ANIMALS

External parasites live on the body surface of animals. They may feed on blood, skin tissues, feathers or skin debris.

The main external parasites covered in this sub-strand are:

1. Ticks.
2. Fleas.
3. Tsetse flies.
4. Keds.
5. Mites.

3.1 Ticks

Meaning of ticks

Ticks are blood-sucking external parasites belonging to the group of arachnids. They attach to the skin of animals and feed on blood.

They commonly affect:

- Cattle.
- Sheep.
- Goats.
- Dogs.
- Other domestic animals.

3.1.1 Characteristics of ticks

1. They have four pairs of legs in the nymph and adult stages.
2. Their bodies are generally oval-shaped.
3. They have specialised mouthparts for piercing skin and sucking blood.
4. They attach firmly to the host during feeding.
5. Their bodies may enlarge after taking a blood meal.
6. They may transmit disease-causing organisms.
7. Their life cycles vary according to species.

3.1.2 Types of ticks

Ticks are broadly divided into two main groups:

A. Hard ticks

- They belong to the family Ixodidae.
- They possess a hard shield called a scutum.
- Their mouthparts are usually visible when viewed from above.
- Many species are important livestock parasites.
- Examples include Rhipicephalus, Amblyomma and Hyalomma species.

B. Soft ticks

- They belong to the family Argasidae.
- They lack the hard dorsal shield found in hard ticks.
- Their bodies are generally leathery.
- They are commonly associated with shelters, cracks and crevices.
- Some species affect poultry and other animals.

3.1.3 Effects of ticks on livestock

1. Blood loss: Heavy infestations may cause anaemia.
2. Skin damage: Bites cause wounds and irritation.
3. Reduced productivity: Infested animals may produce less milk and meat.
4. Disease transmission: Some ticks transmit organisms responsible for diseases such as East Coast fever, babesiosis and anaplasmosis.
5. Secondary infections: Tick wounds may become infected by bacteria.
6. Poor body condition: Heavy infestations may weaken animals.
7. Hide damage: Tick bites reduce the quality and value of hides and skins.
8. Restlessness: Animals may scratch, rub against objects and feed poorly.

3.1.4 Life cycle of a one-host tick

A one-host tick completes most of its parasitic development on one animal host.

The main stages are:

1. Egg.
2. Larva.
3. Nymph.
4. Adult.

Stages in the life cycle

1. Egg stage

- The engorged female tick drops from the animal.
- She lays many eggs in a suitable environment.
- The female dies after laying eggs.

2. Larval stage

- Eggs hatch into larvae, commonly called seed ticks.
- The larvae have three pairs of legs.
- They climb onto vegetation and attach to a suitable host.

3. Nymph stage

- Larvae feed on the host's blood.
- They moult into nymphs while remaining on the same host.
- Nymphs have four pairs of legs.

4. Adult stage

- Nymphs moult into adult ticks.
- Adult males and females feed and mate on the same host.
- The engorged female eventually drops to the ground.

5. Egg laying

- The female lays eggs in the environment.
- The cycle begins again.

Key feature: In a one-host tick, the larva, nymph and adult stages remain on the same animal host. The female drops off to lay eggs.

3.1.5 Control of ticks

- Dip cattle in properly maintained acaricide solutions where dipping is practised.
- Spray animals using approved acaricides.
- Use pour-on tick-control products according to label instructions.
- Inspect animals regularly, particularly around the ears, neck, udder, tail and between the legs.
- Practise strategic tick control based on local tick populations and veterinary guidance.
- Maintain clean livestock housing.

- Control vegetation around animal resting areas where practical.
- Avoid under-dosing or incorrect dilution of acaricides.
- Rotate acaricide classes only under a suitable resistance-management plan.
- Seek veterinary assistance where tick-borne diseases are suspected.

3.2 Fleas

Meaning of fleas

Fleas are small, wingless, blood-sucking insects that live on the bodies of animals and move by jumping.

They commonly affect:

- Dogs.
- Cats.
- Pigs.
- Poultry.
- Other domestic animals.

3.2.1 Characteristics of fleas

1. They are small, wingless insects.
2. Their bodies are flattened from side to side.
3. They have strong hind legs for jumping.
4. They possess piercing and sucking mouthparts.
5. They feed on blood.
6. Their bodies are covered with a hard outer covering.
7. Their life cycle includes egg, larva, pupa and adult stages.

3.2.2 Effects of fleas on farm animals

1. Cause itching and skin irritation.
2. Cause restlessness and discomfort.
3. Lead to excessive scratching and skin wounds.
4. May cause anaemia in young animals when infestation is severe.
5. Reduce animal growth and performance.
6. May transmit certain disease-causing organisms.

7. Reduce the quality of skins due to scratching and wounds.

3.2.3 Life cycle of a flea

Fleas undergo complete metamorphosis.

Stages in the life cycle

1. Egg

- Adult female fleas lay eggs on the host.
- Eggs commonly fall into bedding, cracks, litter or the surrounding environment.

2. Larva

- Eggs hatch into worm-like larvae.
- Larvae live in the environment rather than remaining on the host.
- They feed on organic debris and flea dirt.

3. Pupa

- Larvae develop into pupae within protective cocoons.
- The pupal stage may remain in the environment until conditions favour emergence.

4. Adult

- Adult fleas emerge from pupae.
- They jump onto a suitable host.
- They feed on blood and reproduce.

5. Reproduction

- Female fleas lay more eggs.
- The life cycle continues.

3.2.4 Control of fleas

- Treat affected animals using approved veterinary flea-control products.
- Clean and disinfect animal housing appropriately.
- Wash animal bedding regularly.
- Remove accumulated litter and organic debris.
- Vacuum or thoroughly clean areas where animals rest, where appropriate.
- Control fleas on all susceptible animals in the household or farm as advised.

- Prevent overcrowding.
- Maintain good hygiene in animal houses.
- Follow product instructions and observe withdrawal periods where applicable.

3.3 Tsetse flies

Meaning of tsetse flies

Tsetse flies are blood-sucking insects belonging to the genus Glossina. They feed on the blood of animals and can transmit trypanosomes, which cause trypanosomiasis.

They are important in livestock production in areas where suitable tsetse habitats occur.

3.3.1 Characteristics of tsetse flies

1. They are blood-sucking insects.
2. Both male and female tsetse flies feed on blood.
3. They have piercing and sucking mouthparts.
4. Their wings overlap when resting.
5. They have a characteristic hatchet-shaped cell in the wing.
6. They reproduce by giving birth to a mature larva rather than laying eggs.
7. The larva develops into a pupa in the soil.

3.3.2 Effects of tsetse flies on livestock

1. Cause painful bites and irritation.
2. Cause blood loss.
3. Transmit trypanosomes that cause trypanosomiasis.
4. Cause anaemia in infected animals.
5. Lead to weight loss and poor body condition.
6. Reduce milk and meat production.
7. May cause reproductive problems.
8. Severe infection may cause death.

3.3.3 Life cycle of a tsetse fly

Stages in the life cycle

1. Adult mating

- Male and female tsetse flies mate.
- Fertilisation takes place inside the female.

2. Development inside the female

- The fertilised egg develops inside the female's reproductive system.
- The larva is nourished by special milk glands.

3. Larval deposition

- The female deposits a fully developed larva in suitable soil.
- The larva burrows into the soil.

4. Pupal stage

- The larva develops into a pupa.
- Development takes place within a protective pupal case.

5. Adult emergence

- An adult tsetse fly emerges from the pupa.
- It begins feeding on blood.

6. Reproduction

- The adult mates and the female continues producing larvae.

3.3.4 Control of tsetse flies

- Use insecticide-treated targets and traps.
- Apply approved insecticides to suitable target surfaces.
- Use insecticide-treated cattle where recommended.
- Clear or manage suitable vegetation strategically where appropriate and environmentally acceptable.
- Conduct coordinated community-based tsetse control programmes.
- Monitor tsetse populations.
- Seek veterinary treatment for animals suspected of trypanosomiasis.
- Avoid indiscriminate destruction of vegetation because it may harm the environment.

3.4 Keds

Meaning of keds

Keds are wingless, blood-sucking flies that live on the bodies of animals. The sheep ked, Melophagus ovinus, is an important parasite of sheep.

3.4.1 Characteristics of keds

1. They are wingless insects.
2. They have flattened bodies.
3. They possess strong legs for clinging to wool and hair.
4. They feed on blood.
5. They spend most of their lives on the host.
6. Female sheep keds deposit mature larvae, which quickly form pupae in the wool.

3.4.2 Effects of keds on animals

1. Cause itching and irritation.
2. Cause animals to scratch and rub against objects.
3. Damage wool through contamination and rubbing.
4. Cause blood loss.
5. May cause anaemia in heavy infestations.
6. Reduce the quality and market value of wool.
7. Cause restlessness and reduced feeding.

3.4.3 Life cycle of sheep ked

1. Adult male and female keds live on sheep.
2. They feed on blood.
3. The female develops a larva internally.
4. A mature larva is deposited in the sheep's wool.
5. The larva forms a pupa.
6. An adult ked emerges from the pupa.
7. The adult attaches to the sheep, feeds and reproduces.

3.4.4 Control of keds

- Treat affected sheep using approved veterinary products.
- Shear sheep where appropriate as part of an integrated control programme.

- Treat animals according to veterinary advice, including consideration of newly shorn animals.
- Quarantine and inspect newly introduced sheep.
- Clean and maintain sheep housing.
- Avoid sharing contaminated equipment without proper cleaning.
- Monitor flocks regularly.

3.5 Mites

Meaning of mites

Mites are tiny, usually microscopic or barely visible arthropods that may live on the skin or within its superficial layers. Some cause mange, scabies or other skin conditions in farm animals.

Examples include:

- Sarcoptes species.
- Psoroptes species.
- Demodex species.
- Poultry red mite, Dermanyssus gallinae.

3.5.1 Characteristics of mites

1. They are very small organisms.
2. They have four pairs of legs in the nymph and adult stages.
3. Some burrow into the skin.
4. Others live on the skin surface or in feathers.
5. Some feed on skin debris, while others feed on blood or tissue fluids.
6. They may spread through direct contact between animals.
7. Some survive for a period in the environment.

3.5.2 Effects of mites on farm animals

1. Cause severe itching.
2. Cause skin inflammation.
3. Lead to hair or wool loss.
4. Cause thickening and crusting of the skin.
5. Cause wounds due to scratching.
6. May result in secondary bacterial infections.

7. Reduce animal growth and productivity.
8. Reduce hide, skin and wool quality.
9. Cause restlessness and discomfort.

3.5.3 Life cycle of a typical mange mite

Stages in the life cycle

1. Egg stage

- The female lays eggs on or within the skin, depending on the mite species.

2. Larval stage

- Eggs hatch into larvae.
- Larvae have three pairs of legs.

3. Nymph stage

- Larvae moult into nymphs.
- Nymphs have four pairs of legs.

4. Adult stage

- Nymphs develop into adult males and females.
- Adults mate and reproduce.

5. Continuation

- Females lay more eggs.
- The cycle continues.

3.5.4 Control of mites

- Treat affected animals using appropriate veterinary-approved acaricides.
- Seek veterinary diagnosis because different mites require different treatment approaches.
- Isolate heavily affected animals where necessary.
- Clean and disinfect animal houses and equipment appropriately.
- Wash or replace contaminated bedding.
- Reduce overcrowding.
- Inspect animals regularly.
- Quarantine newly introduced animals.

- Treat affected groups as advised by a veterinarian, since some mites spread easily.

4.0 SUMMARY OF THE LIFE CYCLES OF PARASITES

Parasites undergo different developmental stages before becoming mature and reproducing. Understanding their life cycles helps farmers identify how infections occur and where control measures should be applied.

4.1 Comparison of the life cycles

Parasite	Main life cycle stages	Host requirements
Pork tapeworm	Egg → oncosphere → cysticercus → adult	Pig is intermediate host; human is definitive host.
Roundworm	Egg → larva → immature worm → adult	Depends on species; some require only one host.
Liver fluke	Egg → miracidium → sporocyst → redia → cercaria → metacercaria → adult	Requires a suitable freshwater snail as intermediate host.
One-host tick	Egg → larva → nymph → adult	Larva, nymph and adult stages feed on the same host.
Flea	Egg → larva → pupa → adult	Adult feeds on the host; immature stages develop mainly in the environment.
Tsetse fly	Egg develops internally → larva → pupa → adult	No intermediate host is required.
Sheep ked	Egg develops internally → larva deposited → pupa → adult	Most developmental stages occur on the sheep or in its wool.
Mange mite	Egg → larva → nymph → adult	Usually develops on or in the skin of the host.

4.2 Importance of understanding parasite life cycles

1. Identifying infection stages: Farmers can understand the stages at which parasites infect animals.
2. Timing of treatment: Appropriate control measures can be applied when parasites are most vulnerable.
3. Breaking transmission: Farmers can interrupt parasite development by removing contaminated faeces, controlling intermediate hosts and improving hygiene.
4. Preventing reinfection: Understanding where immature parasites develop helps farmers reduce exposure.
5. Reducing production losses: Effective interruption of parasite life cycles reduces infestation and disease.
6. Improving animal health: Control of parasites promotes growth, reproduction and productivity.

5.0 CONTROL OF PARASITES IN ANIMAL PRODUCTION

Parasite control refers to the practices and methods used to prevent, reduce or eliminate parasites affecting farm animals.

Effective parasite control is important because parasites reduce productivity, cause suffering and may transmit serious diseases.

Parasite control should combine several methods rather than depending on one treatment alone.

5.1 General methods of controlling internal parasites

1. Deworming

Deworming involves administering suitable anthelmintic medicines to control internal parasitic worms.

Importance of deworming

- Reduces worm burdens.
- Improves nutrient utilisation.
- Promotes growth and body condition.
- Helps reduce production losses.
- Protects young and vulnerable animals when properly planned.

Important considerations

- Use products approved for the particular animal species.
- Select medicines that are effective against the suspected parasite.
- Follow veterinary advice and product instructions.
- Observe meat and milk withdrawal periods.
- Avoid unnecessary frequent treatment.
- Use parasite monitoring, such as faecal egg counts, where available.
- Follow anthelmintic resistance-management practices.

2. Proper disposal of animal faeces

- Remove accumulated faeces from animal houses.
- Dispose of manure safely.
- Avoid contaminating animal feeds and water.
- Prevent animals from grazing on heavily contaminated areas.
- Compost manure appropriately before using it in crop production.

Importance: Proper manure management reduces the number of parasite eggs and larvae in the environment.

3. Rotational grazing

Rotational grazing involves moving animals between different grazing paddocks according to a planned grazing programme.

Benefits

1. Reduces continuous exposure to contaminated pasture.
2. Allows pasture to recover.
3. Helps reduce some parasite populations.
4. Supports better pasture management.
5. Improves grazing efficiency.

Important note: Rotational grazing does not automatically eliminate parasites. Some parasite eggs and larvae can survive for long periods, and grazing management should be combined with other control measures.

4. Avoiding overcrowding

- Provide adequate space for animals.
- Avoid keeping too many animals in a small area.
- Reduce contamination of pasture and housing.
- Improve cleanliness and ventilation.
- Reduce contact with contaminated faeces and bedding.

5. Providing clean water and feeds

- Supply clean drinking water.
- Store feeds in clean and dry places.
- Prevent contamination by faeces.
- Use clean feeding troughs.
- Avoid feeding animals on contaminated ground.

6. Quarantine of new animals

Quarantine involves keeping newly purchased or introduced animals separate from the main herd or flock for an appropriate period.

Importance

- Allows observation for signs of parasitic infestation.
- Reduces introduction of new parasites.

- Allows veterinary examination.
- Enables appropriate testing and treatment before animals join the herd.

7. Good animal nutrition

- Provide balanced rations.
- Supply adequate protein and energy.
- Provide essential vitamins and minerals.
- Ensure adequate clean water.
- Give special nutritional attention to young, pregnant and lactating animals.

Well-nourished animals are generally better able to withstand the effects of parasitic infestation.

5.2 General methods of controlling external parasites

1. Dipping

Dipping involves passing livestock through a specially designed dip containing an approved acaricide solution.

Animals commonly dipped

- Cattle.
- Sheep.
- Goats, where suitable facilities and products are available.

Importance of dipping

1. Kills or reduces ticks on animals.
2. Helps control other susceptible external parasites.
3. Reduces the risk of some tick-borne diseases.
4. Protects hides and skins from excessive tick damage.
5. Improves animal comfort.

Precautions during dipping

- Use only approved acaricides.
- Prepare the dip according to the manufacturer's instructions.
- Maintain the correct concentration.
- Ensure animals are dipped appropriately.
- Avoid dipping severely sick or unsuitable animals without veterinary guidance.

- Prevent contamination of water sources.
- Observe relevant withdrawal periods.
- Maintain dipping facilities properly.

2. Spraying

Spraying involves applying an approved parasite-control solution onto the animal's body using suitable spraying equipment.

Importance

- Controls ticks and other susceptible external parasites.
- Allows treatment of animals that cannot be dipped.
- Can target areas where parasites commonly attach.

Precautions

- Use the correct product and dilution.
- Wear protective clothing.
- Avoid spraying against strong winds.
- Prevent contamination of feed and drinking water.
- Follow label instructions.
- Use equipment that produces appropriate coverage.

3. Pour-on treatment

Pour-on treatment involves applying a veterinary-approved liquid preparation along the animal's back or another specified body area.

Importance

1. Helps control ticks and other susceptible parasites.
2. Is relatively easy to apply.
3. Can be useful where dipping facilities are unavailable.
4. Reduces the need for extensive spraying equipment.

Precautions

- Apply the correct amount for the animal's weight as directed.
- Use products approved for the animal species.

- Follow the manufacturer's instructions.
- Avoid applying products to unintended areas.

4. Dusting

Dusting involves applying approved powdered insecticides or acaricides to the animal or its environment.

Importance

- Helps control certain external parasites.
- Can be useful in poultry housing.
- May control parasites in bedding and other approved treatment areas.

5. Environmental sanitation

- Clean animal houses regularly.
- Remove accumulated manure.
- Replace contaminated bedding.
- Clean cracks and crevices where parasites hide.
- Maintain proper drainage.
- Keep feeding and watering equipment clean.

6. Traps and targets

These are especially useful in controlling tsetse flies.

Functions

- Attract and capture tsetse flies.
- Reduce the number of flies in affected areas.
- Help interrupt transmission of trypanosomiasis.

7. Hand removal and inspection

- Inspect animals regularly.
- Remove visible ticks using appropriate tick-removal tools.

- Avoid crushing attached ticks against the animal's skin.
- Dispose of removed ticks safely.
- Seek treatment if wounds become infected.

8. Shearing

Shearing involves removing wool from sheep.

Importance in parasite control

- Reduces the wool environment in which some external parasites hide.
- Makes inspection of the skin easier.
- Can support the control of sheep keds and other wool-associated parasites.
- Makes application of suitable treatments easier where recommended.

9. Isolation of infested animals

- Separate heavily infested animals where appropriate.
- Prevent unnecessary contact with healthy animals.
- Treat affected animals using suitable veterinary products.
- Clean and disinfect the affected housing and equipment.

6.0 INTEGRATED PARASITE CONTROL

Integrated parasite control is the use of a combination of appropriate methods to prevent and manage parasites in livestock.

It is more sustainable than depending entirely on chemical treatment.

6.1 Components of integrated parasite control

1. Regular inspection: Examine animals for signs of internal and external parasites.
2. Strategic treatment: Treat animals according to veterinary advice and parasite risk.
3. Pasture management: Use grazing practices that reduce exposure to infective larvae.
4. Housing hygiene: Keep animal houses clean, dry and well ventilated.
5. Nutrition: Provide balanced feeds to maintain good body condition.
6. Quarantine: Examine newly introduced animals before mixing them with existing stock.
7. Parasite monitoring: Use appropriate diagnostic tests where available.
8. Resistance management: Avoid unnecessary repeated use of the same class of parasite-control medicine.

9. Environmental management: Reduce breeding and survival sites for external parasites.
10. Record keeping: Maintain records of treatments, infestations and animal responses.

6.2 Advantages of integrated parasite control

- Reduces parasite burdens.
- Reduces unnecessary use of chemicals.
- Helps delay the development of drug resistance.
- Improves animal productivity.
- Reduces treatment expenses over time.
- Protects the environment.
- Promotes animal welfare.
- Supports sustainable livestock production.

7.0 HARMFUL EFFECTS OF PARASITES ON ANIMAL PRODUCTION

Parasites affect animal production directly and indirectly. They may reduce growth, cause disease, damage organs and increase the cost of livestock management.

7.1 Reduced growth rate

- Parasites compete with animals for nutrients.
- Infected animals may eat less due to discomfort or illness.
- Nutrients that should support growth may be lost.
- Young animals may fail to attain their expected body weight.

Example: Calves infected with heavy roundworm burdens may grow more slowly than healthy calves.

7.2 Reduced milk production

- Internal parasites may reduce nutrient absorption.
- External parasites cause irritation and discomfort.
- Sick animals may eat less.
- Reduced feed intake lowers nutrients available for milk production.

Example: Dairy cattle suffering from heavy tick infestation and associated illness may produce less milk.

7.3 Reduced meat production

- Parasites reduce growth and body condition.
- Some cause anaemia and weakness.

- Infected animals may take longer to reach market weight.
- Infected organs or carcass portions may be condemned during meat inspection.

7.4 Reduced egg production

- Parasites affect nutrient utilisation.
- Heavy infestations may cause anaemia and weakness.
- Poultry may reduce feed intake.
- Egg production and egg quality may decline.

7.5 Anaemia

Anaemia is a condition in which the blood has reduced oxygen-carrying capacity, commonly due to a reduction in red blood cells or haemoglobin.

How parasites cause anaemia

- Blood-sucking worms remove blood from the digestive tract.
- Ticks and fleas feed on blood.
- Some parasites damage blood cells.
- Severe infestations may cause substantial blood loss.

Signs of anaemia in animals

- Pale mucous membranes.
- Weakness.
- Reduced activity.
- Poor appetite.
- Rapid breathing in severe cases.
- Poor growth and body condition.

7.6 Damage to internal organs

- Liver flukes damage the liver.
- Some roundworm larvae migrate through the lungs and liver.
- Certain tapeworm larvae form cysts in muscles and other tissues.
- Intestinal parasites may damage the intestinal lining.

7.7 Transmission of diseases

Some parasites transmit disease-causing organisms.

Examples:

Parasite/vector	Disease or organism transmitted
Certain ticks	East Coast fever, babesiosis and anaplasmosis
Tsetse flies	Trypanosomiasis
Some biting flies	May mechanically transmit disease-causing organisms
Certain mites	Cause mange and associated skin damage

7.8 Reduced reproductive performance

- Poor body condition may interfere with normal reproduction.
- Severe parasitic infestation may reduce fertility.
- Weak animals may have poor reproductive performance.
- Pregnant animals in poor health may experience complications.

7.9 Damage to hides, skins and wool

- Tick bites cause skin wounds.
- Mange mites cause thickening and scarring of the skin.
- Keds cause wool contamination and damage.
- Excessive scratching causes wounds and hair loss.

7.10 Increased production costs

Farmers incur additional costs through:

- Purchase of veterinary medicines.
- Payment for veterinary services.
- Labour required for parasite control.
- Replacement of dead animals.
- Cleaning and disinfection of animal houses.
- Loss of production during illness.

7.11 Death of animals

Severe parasitic infestations may lead to death due to:

- Severe anaemia.
- Extensive organ damage.
- Severe blood loss.
- Complications arising from parasite-transmitted diseases.
- Failure to feed and maintain body condition.

8.0 SIGNS OF PARASITIC INFESTATION IN FARM ANIMALS

Farmers should regularly observe their animals for signs that may indicate parasitic infestation.

Sign	Possible explanation
Weight loss	Nutrient loss or reduced feed intake.
Pale eyes and gums	Possible anaemia.
Diarrhoea	Intestinal irritation or parasitic infection.
Rough coat	Poor nutrition or chronic illness.
Excessive scratching	External parasites such as mites or fleas.
Hair or wool loss	Skin irritation and parasite damage.
Swelling under the jaw	May indicate severe liver fluke infection or other conditions.
Reduced milk production	Poor health and reduced nutrient utilisation.
Poor growth	Heavy parasitic burden or inadequate feeding.
Restlessness	Irritation and discomfort caused by external parasites.
Coughing	May occur with certain lungworm infections.
Visible worms in faeces	Possible intestinal worm infestation.

Important: These signs are not proof of parasitic infection. Other diseases and nutritional problems may cause similar signs. Diagnosis should be confirmed through appropriate veterinary examination and laboratory tests where necessary.

9.0 PREVENTION OF PARASITIC INFESTATION THROUGH GOOD FARM MANAGEMENT

Prevention is often more economical and sustainable than treating severe infestations.

9.1 Proper housing

- Construct well-drained animal houses.
- Maintain good ventilation.

- Avoid overcrowding.
- Repair cracks and crevices where parasites may hide.
- Provide clean and dry bedding.
- Clean houses regularly.

9.2 Proper feeding

- Provide balanced rations.
- Avoid contaminated feeds.
- Use clean feeding troughs.
- Store feeds in dry, hygienic places.
- Prevent access to contaminated pasture and water.

9.3 Proper watering

- Provide clean drinking water.
- Clean watering troughs regularly.
- Avoid using contaminated water sources.
- Protect water points from faecal contamination.

9.4 Proper pasture management

- Avoid continuous grazing on heavily contaminated pastures.
- Use rotational grazing where suitable.
- Avoid grazing animals in high-risk wet areas where liver flukes occur.
- Maintain suitable pasture height and quality.
- Provide alternative grazing areas where possible.

9.5 Regular veterinary examination

- Examine animals regularly.
- Conduct faecal examinations where appropriate.
- Seek advice on parasite-control programmes.
- Keep treatment records.
- Investigate unexplained weight loss and reduced productivity.

10.0 SAFETY AND PRECAUTIONS WHEN CONTROLLING PARASITES

Parasite-control products may be harmful if mishandled. Farmers should follow proper safety procedures.

1. Read and follow product labels.
2. Use only veterinary-approved medicines and chemicals.
3. Wear protective clothing, gloves and other recommended protective equipment.
4. Avoid inhaling sprays and dusts.
5. Avoid direct contact with concentrated chemicals.
6. Store chemicals away from children, animals, food and water.
7. Do not mix different chemicals unless specifically instructed.
8. Avoid contaminating rivers, dams, wells and other water sources.
9. Observe meat and milk withdrawal periods.
10. Dispose of empty containers according to label instructions and local regulations.
11. Seek veterinary advice where animals show severe reactions.
12. Do not use human medicines or household chemicals as substitutes for approved animal treatments.

10.1 Meaning of withdrawal period

A withdrawal period is the minimum period that must pass between the last administration of a veterinary medicine and the use of animal products such as meat or milk for human consumption.

Importance

- Prevents harmful medicine residues in food.
- Protects consumers.
- Promotes food safety.
- Ensures compliance with veterinary product instructions.

11.0 PRACTICAL LEARNING ACTIVITIES

Activity 1: Observation of internal and external parasites

Objective: To identify common parasites affecting farm animals.

Requirements:

- Pictures of tapeworms.
- Roundworm specimens or images.
- Liver fluke specimens or images.
- Tick specimens.

- Flea and mite images.
- Charts and textbooks.

Procedure:

1. Observe the specimens or pictures provided.
2. Identify each parasite.
3. Classify the parasites into internal and external categories.
4. Identify the animals affected.
5. Discuss their harmful effects.
6. Record the findings in a table.
7. Present the findings to the class.

Expected learning outcome: The learner should be able to describe and classify parasites affecting animal production.

Activity 2: Illustration of parasite life cycles

Objective: To demonstrate the life cycles of selected parasites.

Procedure:

1. Form groups.
2. Select one parasite from the following:
    - ✓ One-host tick.
    - ✓ Pork tapeworm.
    - ✓ Liver fluke.
3. Research its life cycle using approved learning resources.
4. Draw and label the different stages.
5. Use arrows to show the direction of development.
6. Identify the host or intermediate host at each stage.
7. Present the chart to the class.

Expected learning outcome: The learner should be able to illustrate and explain parasite life cycles.

Activity 3: Demonstration of parasite-control measures

Objective: To understand appropriate parasite-control methods.

Procedure:

1. Observe a demonstration of safe livestock inspection.
2. Identify areas where ticks commonly attach.
3. Observe appropriate cleaning of animal housing.
4. Discuss deworming and tick-control programmes.
5. Identify safety precautions when handling veterinary products.
6. Present findings.

Expected learning outcome: The learner should be able to select suitable parasite-control measures while observing animal welfare and safety.

12.0 COMPETENCY-BASED EDUCATION INTEGRATION

A. Core competence: Creativity and imagination

The learner develops this competence through:

1. Creating diagrams of parasite life cycles.
2. Designing charts showing parasite developmental stages.
3. Preparing visual presentations on parasite control.
4. Developing innovative ways of explaining parasite transmission.
5. Constructing learning models showing parasite life cycles.

B. Value: Respect

The learner develops respect by:

1. Appreciating the contributions of other learners.
2. Listening to different opinions during group discussions.
3. Respecting other people's work.
4. Working cooperatively during parasite-control demonstrations.
5. Handling specimens and animals responsibly.

C. Pertinent and Contemporary Issue: Animal welfare

The learner promotes animal welfare by:

1. Recognising signs of parasitic infestation.
2. Providing appropriate parasite-control measures.
3. Avoiding unnecessary suffering.
4. Providing clean water and balanced feeds.

5. Maintaining hygienic animal housing.
6. Seeking veterinary attention when necessary.
7. Using medicines responsibly.
8. Observing withdrawal periods to promote food safety.

D. Key inquiry questions

1. How do parasites affect animal production?
2. How are parasites controlled in animal production?

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives provided.

1. An organism that lives in or on another organism and obtains nourishment at its expense is called a

A. Host.

B. Parasite.

C. Vector.

D. Predator.

2. Which one of the following is an internal parasite?

A. Tick.

B. Flea.

C. Roundworm.

D. Ked.

3. The head region of a tapeworm is called the

A. Scolex.

B. Proglottid.

C. Larva.

D. Cyst.

4. Which one of the following animals acts as an intermediate host for the pork tapeworm?

A. Cattle.

B. Pig.

C. Sheep.

D. Goat.

5. The intermediate host of the liver fluke is a

A. Housefly.

B. Freshwater snail.

C. Tick.

D. Flea.

6. Which one of the following is the infective stage of the liver fluke to grazing livestock?

A. Egg.

B. Miracidium.

C. Metacercaria.

D. Redia.

7. Which one of the following parasites has a cylindrical, unsegmented body?

A. Tapeworm.

B. Roundworm.

C. Liver fluke.

D. Sheep ked.

8. Which one of the following is an external parasite?

A. Liver fluke.

B. Tapeworm.

C. Roundworm.

D. Tick.

9. A one-host tick completes its larval, nymphal and adult feeding stages on

A. One host.

B. Two hosts.

C. Three hosts.

D. Four hosts.

10. Which one of the following parasites transmits trypanosomiasis?

A. Flea.

B. Tsetse fly.

C. Sheep ked.

D. Liver fluke.

11. The sheep ked mainly affects

A. Cattle.

B. Pigs.

C. Sheep.

D. Chickens.

12. Which one of the following parasites causes mange?

A. Mite.

B. Tapeworm.

C. Liver fluke.

D. Roundworm.

13. The main purpose of deworming is to control

A. External parasites.

B. Internal parasitic worms.

C. Bacterial diseases.

D. Viral diseases.

14. Which one of the following practices helps control liver flukes?

A. Grazing animals in swampy areas.

B. Allowing animals to drink contaminated water.

C. Avoiding heavily infested wet grazing areas.

D. Feeding animals on contaminated vegetation.

15. Which one of the following is a major harmful effect of heavy tick infestation?

A. Improved milk production.

B. Anaemia.

C. Increased fertility.

D. Improved growth.

16. The developmental stage of a flea that forms a protective cocoon is the

A. Egg.

B. Larva.

C. Pupa.

D. Adult.

17. Which one of the following is an important method of controlling tsetse flies?

A. Dipping only.

B. Insecticide-treated traps and targets.

C. Deworming.

D. Shearing.

18. The process of immersing livestock in an acaricide solution is called

A. Drenching.

B. Spraying.

C. Dipping.

D. Dusting.

19. The period that must pass between the last administration of a veterinary medicine and the use of animal products for human consumption is called

A. Incubation period.

B. Withdrawal period.

C. Gestation period.

D. Quarantine period.

20. Which one of the following is an advantage of integrated parasite control?

A. Encourages drug resistance.

B. Increases parasite transmission.

C. Reduces reliance on chemical treatment alone.

D. Increases animal suffering.

Section B: Structured questions

21.
a) Define the term parasite. (2 marks)

b) Distinguish between internal and external parasites. (4 marks)

c) Give four examples of internal parasites affecting farm animals. (4 marks)

d) State five harmful effects of parasites on animal production. (5 marks)

22.
a) Describe five characteristics of tapeworms. (5 marks)

b) Explain the life cycle of the pork tapeworm. (10 marks)

c) State five measures used to control pork tapeworm infection. (5 marks)

23.
a) Describe five characteristics of roundworms. (5 marks)

b) Explain the harmful effects of roundworms on farm animals. (7 marks)

c) State four measures used to control roundworms. (4 marks)

d) Name two animals commonly affected by roundworms. (2 marks)

24.
a) Describe the characteristics of liver flukes. (5 marks)

b) Explain the life cycle of liver flukes. (10 marks)

c) State five measures used to control liver flukes. (5 marks)

25.
a) Distinguish between hard ticks and soft ticks. (4 marks)

b) Describe the life cycle of a one-host tick. (8 marks)

c) Explain four harmful effects of ticks on livestock. (8 marks)

26.
a) Describe the life cycle of a flea. (6 marks)

b) Explain four harmful effects of fleas on farm animals. (4 marks)

c) State five measures used to control fleas. (5 marks)

d) Give five characteristics of tsetse flies. (5 marks)

27.
a) Explain the meaning of the term integrated parasite control. (2 marks)

b) Discuss six methods used to control external parasites in livestock. (12 marks)

c) State three safety precautions to observe when using acaricides and insecticides. (3 marks)

d) Explain one reason why withdrawal periods are important. (3 marks)

28.
a) Explain six harmful effects of parasites on animal production. (12 marks)

b) Discuss four management practices that farmers can adopt to prevent parasitic infestation. (8 marks)

KEY TERMS FOR REVISION

Term	Meaning
Parasite	Organism that lives in or on another organism and benefits at its expense.
Host	Organism that provides food or shelter to a parasite.
Endoparasite	Parasite that lives inside the host.
Ectoparasite	Parasite that lives on the external surface of the host.
Intermediate host	Host in which a parasite undergoes some developmental stages.
Definitive host	Host in which a parasite reaches sexual maturity or reproduces sexually.
Vector	Organism that transmits disease-causing organisms.

Life cycle	Developmental stages through which a parasite passes.
Deworming	Administration of suitable medicines to control internal worms.
Dipping	Immersing livestock in an approved acaricide solution.
Drenching	Giving liquid medicine orally.
Acaricide	Chemical product used to control mites and ticks.
Insecticide	Chemical product used to control insects.
Flukicide	Medicine used to control liver flukes and other susceptible flukes.
Anthelmintic	Medicine used to control parasitic worms.
Infestation	Presence of parasites on or in an animal or its environment.
Withdrawal period	Time required after treatment before animal products can be used for human consumption.
Integrated parasite control	Combining different methods to prevent and control parasites.
Quarantine	Keeping new or potentially infected animals separate for observation and assessment.

SUMMARY

Parasites are organisms that live in or on other organisms and obtain nourishment at their expense. They are classified into internal and external parasites.

Internal parasites include:

- Tapeworms.
- Roundworms.
- Liver flukes.

External parasites include:

- Ticks.
- Fleas.

- Tsetse flies.
- Keds.
- Mites.

Parasites undergo different life cycles. Some require intermediate hosts, while others complete their development without an intermediate host.

Parasites cause several harmful effects, including anaemia, poor growth, reduced milk and egg production, organ damage, disease transmission and death.

Parasites can be controlled through:

- Deworming.
- Dipping.
- Spraying.
- Pour-on treatment.
- Dusting.
- Proper sanitation.
- Rotational grazing.
- Quarantine.
- Environmental management.
- Integrated parasite control.

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STRAND 2.0: ANIMAL PRODUCTION

SUB-STRAND 2.3: STRUCTURES IN LIVESTOCK PRODUCTION

1.0 Introduction to structures in livestock production

Livestock production structures are physical facilities, buildings and installations constructed on a farm to provide suitable conditions for keeping, feeding, watering, breeding, handling and protecting farm animals.

They are designed to promote animal welfare, improve production, make farm operations easier and protect livestock from harsh weather, predators, theft and diseases.

Livestock structures vary depending on:

1. The type of livestock kept.
2. The number of animals on the farm.

3. The production system used.
4. The age and purpose of the animals.
5. The climatic conditions of the area.
6. The available construction materials.
7. The financial resources of the farmer.

Examples of livestock production structures

- Fences and animal enclosures.
- Zero-grazing units for dairy cattle.
- Poultry houses.
- Rabbit hutches.
- Pigsties.
- Goat and sheep pens.
- Calf pens.
- Milking parlours.
- Feed stores.
- Water troughs.
- Loading ramps and handling races.
- Dipping facilities.

2.0 Structures used in livestock production

Livestock production structures can be classified according to their purpose and the animals they accommodate.

2.1 Fences

A fence is a physical barrier constructed around a farm or a particular section of the farm to restrict the movement of animals and people.

Fences are made using materials such as timber posts, wire, chain-link, live plants, stones, concrete posts and metal poles.

Types of fences used in livestock production

1. Barbed-wire fence

- Constructed using strands of barbed wire attached to strong posts.

- Commonly used to enclose large grazing areas and farm boundaries.
- Helps prevent cattle and other large livestock from straying.
- It should be properly maintained to minimise injuries to animals and people.

2. Plain-wire fence

- Made using smooth strands of wire fixed to wooden or concrete posts.
- Suitable for controlling the movement of livestock.
- It is less likely to cause cuts than poorly maintained barbed-wire fences.
- It requires proper tensioning and regular maintenance.

3. Chain-link fence

- Made from interwoven galvanised steel wires.
- Commonly used around poultry units, calf areas and other restricted sections.
- Provides security and helps prevent entry of unwanted animals.
- It is relatively expensive compared with some traditional fencing materials.

4. Electric fence

- Consists of electrically charged wires supported by insulated posts.
- Produces a short, controlled electric pulse when an animal touches the wire.
- Helps control livestock movement and protects selected farm areas.
- Requires a reliable energiser, warning signs and regular maintenance.
- It must be installed and used safely.

5. Live fence

- Established using closely planted trees, shrubs or thorny plants.
- Examples include kei apple, sisal and other suitable locally available plants.
- Provides a physical barrier while improving the appearance of the farm.
- Some live fences also provide shade, wind protection and useful biomass.
- They take time to grow and require regular trimming.

6. Stone fence

- Constructed by arranging stones to form a boundary.
- Suitable in areas where stones are readily available.

- Can be durable and requires relatively little maintenance once properly built.
- Construction may require considerable labour.

Importance of fences in livestock production

- Prevent livestock from straying and getting lost.
- Protect animals from predators and thieves.
- Separate different species and groups of livestock.
- Facilitate rotational grazing by dividing pasture into paddocks.
- Prevent unauthorised access to livestock units.
- Reduce unnecessary mixing of animals from different herds.
- Protect crops from damage by roaming livestock.
- Make livestock management easier.

2.2 Zero-grazing structures

A zero-grazing structure is a livestock housing facility in which animals, particularly dairy cattle, are confined within a designated unit and provided with feed and water instead of being allowed to graze freely.

It is commonly used where land is limited or where farmers want to control feeding and animal management.

Main parts of a zero-grazing unit

1. Cubicles or resting area

- Provides a comfortable place for cattle to lie down and rest.
- Should be spacious enough for the animal to stand, lie down and rise comfortably.
- Bedding may be provided to improve comfort and cleanliness.

2. Feeding trough

- A structure where fodder and other feeds are placed.
- Should be accessible to all animals.
- Its design should minimise feed wastage and contamination.

3. Water trough

- Provides clean drinking water.
- Should be easy to clean and refill.
- Adequate water supply supports digestion, milk production and temperature regulation.

4. Exercise yard

- An open area where animals can move around.
- Allows exercise and exposure to fresh air.
- Should have a suitable surface that does not become excessively muddy or slippery.

5. Milking area

- A clean and convenient place where cows are milked.
- Should have good drainage and be protected from dust and contamination.
- Makes milking easier and more hygienic.

6. Calf pen

- A separate area for keeping young calves.
- Protects calves from injury and competition from adult animals.
- Makes feeding, observation and health management easier.

7. Manure collection area

- A designated place for collecting animal waste.
- Helps maintain cleanliness around the unit.
- Manure can be composted and used to improve soil fertility.

8. Drainage channel

- Carries away wastewater, urine and cleaning water.
- Prevents water accumulation and unpleasant smells.
- Reduces conditions that encourage disease-causing organisms.

Features of a good zero-grazing unit

- Strong and durable construction.
- Adequate ventilation and natural lighting.
- Sufficient space for each animal.
- Non-slippery floor.
- Proper drainage.
- Clean feeding and watering facilities.
- Protection from rain, strong winds and excessive sunlight.
- Easy access for cleaning and manure removal.

- Convenient location for feeding and milking operations.

Importance of a zero-grazing unit

- Enables farmers to keep dairy cattle on small pieces of land.
- Allows controlled feeding using harvested fodder.
- Makes it easier to monitor the health of individual animals.
- Reduces energy lost through long-distance movement in search of pasture.
- Makes collection of manure easier.
- Helps protect cattle from theft and some predators.
- Facilitates controlled breeding and record keeping.

2.3 Poultry houses

A poultry house is a building or enclosed structure designed to provide suitable conditions for keeping domestic birds such as chickens, ducks, turkeys and geese.

It protects birds from harsh weather, predators and theft while providing a suitable environment for feeding, watering, laying eggs and resting.

Types of poultry houses

1. Deep-litter poultry house

This is a poultry house in which birds are kept on a floor covered with a layer of absorbent bedding material called litter.

Examples of litter materials include:

- Wood shavings.
- Rice husks.
- Chopped straw.
- Dry grass.
- Coffee husks where suitable and safe.

Characteristics

- Has a solid floor, often concrete or another easily cleaned material.
- The floor is covered with suitable dry litter.
- Contains feeders and drinkers.
- Has adequate ventilation.
- Provides enough floor space for the birds.

- Litter is managed to prevent excessive moisture and caking.

Advantages

- Birds can move freely within the house.
- Allows natural scratching and dust-bathing behaviour.
- Can be used for broilers and some types of layers.
- Litter mixed with poultry droppings can be composted into manure.
- Construction and management can be relatively simple.

Disadvantages

- Wet litter encourages disease-causing organisms and ammonia accumulation.
- Poor litter management may encourage coccidiosis and other health problems.
- Litter requires regular inspection, turning or replacement.
- Birds may waste feed if feeders are poorly positioned.

2. Battery-cage poultry house

This is a poultry housing system in which birds, mainly laying hens, are kept in specially designed cages.

Characteristics

- Uses cages made from wire mesh or other suitable materials.
- Provides separate compartments for groups of birds.
- May have automatic feeding and watering systems.
- Eggs can be collected through specially designed systems.

Advantages

- Makes egg collection easier in suitable systems.
- Allows close monitoring of feed consumption.
- Reduces direct contact with droppings when manure is properly managed.
- Can use floor space efficiently.

Disadvantages

- Poorly designed cages restrict natural movement and behaviour.
- Requires careful attention to bird welfare.
- Initial construction and equipment costs may be high.

- Requires proper manure management.

3. Free-range poultry house

This is a poultry housing system where birds are provided with a shelter but are also allowed access to an outdoor run or designated ranging area.

Characteristics

- Has an enclosed shelter for resting and protection.
- Provides access to an outdoor area.
- May include perches, nests, feeders and drinkers.
- Requires protection against predators and escape.

Advantages

- Allows birds to express natural behaviours such as scratching and foraging.
- Can reduce pressure on indoor housing space.
- Birds may obtain some natural feed from the environment.
- May support diversified small-scale poultry production.

Disadvantages

- Birds may be exposed to predators and infectious diseases.
- Production can be affected by weather.
- Requires secure fencing and proper supervision.

Main parts of a deep-litter poultry house

- Roof: Protects birds from rain and excessive sunlight.
- Walls or side curtains: Help control wind, rain and ventilation.
- Floor: Provides a firm, dry surface for litter.
- Litter: Absorbs moisture and provides a comfortable surface.
- Feeders: Hold poultry feed.
- Drinkers: Supply clean drinking water.
- Perches: Provide raised resting places for birds that naturally perch.
- Nest boxes: Provide suitable laying places for hens.
- Ventilation openings: Allow fresh air to enter and stale air to escape.
- Doors: Allow entry for feeding, cleaning and inspection.

Factors to consider when managing a poultry house

- Avoid overcrowding.
- Maintain dry litter.
- Provide adequate feeders and drinkers.
- Ensure continuous access to clean water.
- Maintain good ventilation without exposing birds to harmful draughts.
- Control rodents, wild birds and other disease carriers.
- Clean and disinfect the house between production cycles where appropriate.

2.4 Rabbit hutches

A rabbit hutch is a specially designed housing structure used to keep rabbits safely and comfortably.

It may be constructed using timber, wire mesh, metal or other suitable materials.

Features of a good rabbit hutch

1. Raised floor

- Keeps rabbits away from damp ground.
- Helps reduce contamination by faeces and urine.
- Makes cleaning and waste collection easier.
- The floor must be designed to prevent foot injuries; provide suitable resting surfaces.

2. Wire-mesh sides

- Allow adequate ventilation.
- Make observation of rabbits easier.
- Help maintain a clean and dry environment.
- Mesh openings should be appropriately sized to prevent injuries and escape.

3. Roof

- Protects rabbits from rain and direct sunlight.
- Should be waterproof and durable.
- Should provide adequate shade.

4. Feeding trough

- Holds feed such as pellets, hay and suitable green fodder.

- Should be firmly fixed to minimise spillage and contamination.

5. Water container

- Provides clean drinking water.
- Should be easy to refill and clean.

6. Nest box

- Provides a safe place for a doe to kindle and nurse her young.
- Should be clean, dry and appropriately sized.
- It is particularly important during breeding.

7. Droppings collection tray

- Collects faeces and some spilled feed.
- Makes waste removal easier.
- Helps maintain hygiene around the hutch.

Types of rabbit hutches

- Single-compartment hutch: Keeps one rabbit or a small compatible group.
- Multi-compartment hutch: Has separate compartments for different rabbits.
- Breeding hutch: Includes a nest box for a breeding doe.
- Grower hutch: Designed for young rabbits after weaning.

Importance of rabbit hutches

- Protect rabbits from predators.
- Prevent escape and uncontrolled movement.
- Make feeding and watering easier.
- Facilitate breeding and separation of animals.
- Make observation and health monitoring easier.
- Support hygienic management of rabbit waste.

2.5 Pigsties

A pigsty is a structure designed for housing pigs. It provides shelter, feeding and watering facilities, resting space and an area for managing pigs at different stages of production.

Types of pig pens

1. Boar pen

- Used for keeping a mature male pig.
- Should be strong and secure.
- Provides enough space for movement and resting.
- Should allow safe handling during breeding management.

2. Farrowing pen

- Used for keeping a sow during farrowing and nursing.
- Provides space for the sow and her piglets.
- May include a protective creep area where piglets can rest safely.
- Should be warm, clean and free from draughts.

3. Weaner pen

- Used for keeping piglets after separation from the sow.
- Should provide warmth, clean water and suitable feed.
- Helps farmers monitor growth and health.

4. Grower pen

- Used for keeping pigs as they increase in body weight.
- Requires sufficient space, ventilation and feeding facilities.

5. Fattening pen

- Used for pigs being prepared for the market.
- Should allow adequate feeding, watering and resting.

6. Sow pen

- Used for keeping breeding females.
- Should provide safe resting and feeding facilities.

Features of a good pigsty

- Strong walls and partitions.
- Durable, non-slippery floor.
- Proper drainage.
- Adequate ventilation.
- Reliable clean-water supply.

- Suitable feeding troughs.
- Roof that protects pigs from rain and excessive heat.
- Separate pens for pigs of different ages and production stages.
- A cleanable waste-management system.

Importance of a pigsty

- Protects pigs from harsh weather.
- Prevents pigs from straying.
- Facilitates controlled feeding and watering.
- Makes breeding and farrowing management easier.
- Helps separate sick pigs from healthy ones.
- Makes cleaning and manure collection easier.
- Reduces injuries caused by uncontrolled mixing.

2.6 Goat and sheep pens

A goat or sheep pen is an enclosed structure used to house small ruminants. It provides shelter, protection, feeding and resting facilities.

Features of a good goat or sheep pen

- Strong walls and fencing.
- Adequate ventilation.
- A roof that protects animals from rain and direct sunlight.
- A dry resting area.
- Feeding and watering facilities.
- Proper drainage.
- Sufficient space to prevent overcrowding.
- Separate areas for young animals, breeding males and sick animals where necessary.

Types of goat and sheep housing

1. Ground-floor pen

- Constructed directly on a well-drained ground surface.
- May have a concrete or compacted floor.
- Requires regular removal of manure and wet bedding.

2. Raised slatted-floor pen

- Constructed above ground level.
- Uses wooden or suitable slatted flooring.
- Allows droppings and urine to fall through spaces between slats.
- Helps keep animals dry when properly designed.
- Slats must be smooth and correctly spaced to prevent foot injuries.

3. Open-sided shed

- Has a roof and partial walls.
- Allows free movement of air.
- Provides protection from rain and direct sunlight.
- Suitable where the climate and management system permit.

Importance of goat and sheep pens

- Protect animals from predators and theft.
- Provide shelter from harsh weather.
- Facilitate feeding and watering.
- Make breeding management easier.
- Help prevent uncontrolled mixing of animals.
- Make manure collection easier.
- Support disease monitoring and treatment.

2.7 Calf pens

A calf pen is a structure designed for housing young cattle, particularly calves that require special care during early growth.

Features of a good calf pen

- Clean and dry floor.
- Adequate ventilation.
- Protection from rain and strong winds.
- Sufficient space for movement.
- Clean feeding and watering containers.
- Easy access for inspection and cleaning.

- Protection from adult animals and possible injuries.

Importance of calf pens

- Help protect calves from injury.
- Facilitate individual feeding and observation.
- Make it easier to monitor calf growth.
- Support hygiene and disease prevention.
- Allow sick calves to be separated when necessary.

2.8 Milking parlours

A milking parlour is a specially designed facility where dairy animals are milked under hygienic and organised conditions.

Main features

- Non-slippery floor.
- Adequate lighting.
- Clean water supply.
- Proper drainage.
- Milking equipment or facilities.
- Safe entry and exit routes for animals.
- Cleanable walls and surfaces.
- Milk-handling area protected from dust and contamination.

Importance

- Promotes hygienic milk production.
- Makes milking more efficient.
- Reduces contamination of milk.
- Allows observation of udder health.
- Makes handling of dairy animals easier.

2.9 Feed stores

A feed store is a building or enclosed facility used for storing livestock feeds such as hay, silage, concentrates, mineral supplements and other feed ingredients.

Features of a good feed store

1. Dry floor

- Prevents moisture from entering stored feeds.
- Helps prevent mould growth and feed spoilage.

2. Waterproof roof

- Protects feed from rain and excessive moisture.
- Reduces losses caused by weather damage.

3. Adequate ventilation

- Allows air circulation.
- Helps reduce moisture accumulation and unpleasant smells.

4. Raised pallets

- Keep feed bags off the floor.
- Reduce contact with moisture and make cleaning easier.

5. Secure doors and windows

- Prevent entry of rodents, birds and other pests.
- Help protect feeds from theft and contamination.

6. Separate storage sections

- Allow different feed types to be stored separately.
- Prevent mixing of feeds and reduce contamination risks.

Importance of feed stores

- Prevent wastage and spoilage of livestock feeds.
- Ensure feed is available during dry seasons.
- Protect feeds from rodents and other pests.
- Make feed distribution easier.
- Help farmers maintain a consistent feeding programme.
- Allow bulk purchasing and storage when feed is available.

2.10 Water troughs and watering facilities

Water troughs are containers or structures used to provide drinking water to livestock.

Types of watering facilities

- Concrete water troughs.
- Metal water troughs.
- Plastic drinking containers.
- Automatic drinkers.
- Nipple drinkers for poultry.
- Float-valve watering systems.

Characteristics of a good watering facility

- Provides clean and safe drinking water.
- Is easy to clean and refill.
- Is strong and durable.
- Has no sharp edges that may injure animals.
- Is positioned where animals can access it easily.
- Prevents unnecessary water wastage.
- Is designed to minimise contamination by faeces, feed and soil.

Importance of watering facilities

- Ensure animals have access to sufficient drinking water.
- Support digestion and nutrient absorption.
- Help regulate body temperature.
- Support milk, meat and egg production.
- Reduce competition for drinking water.
- Make water provision easier and more organised.

2.11 Livestock handling structures

Livestock handling structures are facilities designed to restrain, guide, examine, treat, weigh, sort and load animals safely.

Examples of livestock handling structures

1. Handling race

- A narrow passage through which animals move in single file.
- Guides animals towards a crush, treatment area or loading point.
- Reduces unnecessary movement and makes handling more orderly.

2. Cattle crush

- A strong restraining structure used to hold cattle during examination or treatment.
- Helps prevent sudden movement.
- Makes activities such as vaccination, deworming, ear tagging and hoof examination safer.

3. Loading ramp

- A raised sloping structure used when loading and offloading animals from vehicles.
- Reduces the difficulty of moving livestock into transport vehicles.
- Should have a non-slippery surface and suitable side barriers.

4. Weighing scale

- Used to determine the body weight of livestock.
- Helps farmers monitor growth and estimate market value.
- Supports accurate calculation of feed requirements and veterinary treatment under professional guidance.

5. Sorting pen

- An enclosure used to separate animals according to age, size, sex, health or production purpose.
- Makes selection and management easier.

6. Dipping facility

- A specially designed facility used to expose livestock to an approved acaricide solution for the control of external parasites such as ticks.
- Requires correct chemical handling, supervision and safe disposal of waste.

Importance of livestock handling structures

- Improve the safety of animals and handlers.
- Reduce stress during handling.
- Make vaccination and treatment easier.
- Support weighing and selection.
- Facilitate loading and transportation.
- Improve farm management and record keeping.

3.0 Siting of livestock production structures

Siting refers to the selection of a suitable location on a farm where a livestock production structure will be constructed.

The location selected affects the health, comfort, productivity and safety of animals. It also influences construction costs, ease of management and environmental protection.

A suitable site should provide a healthy environment for animals and allow the farmer to carry out daily activities conveniently.

3.1 Factors to consider when siting livestock production structures

1. Topography of the land

Topography refers to the physical features and shape of the land, including its slope and elevation.

- A gently sloping site is generally suitable for livestock structures.
- It allows rainwater and wastewater to drain away.
- Very steep land increases construction costs.
- Low-lying areas may become waterlogged during rainy seasons.
- Extremely uneven land may require expensive levelling before construction.

2. Drainage of the site

Drainage refers to the removal of excess water from an area.

- The site should have good natural drainage.
- It should not collect stagnant water.
- Good drainage keeps animal resting areas dry.
- It reduces the development of muddy conditions.
- It helps minimise breeding places for mosquitoes and other pests.
- It reduces the risk of some diseases associated with wet and dirty environments.

3. Availability of water

- The site should be near a reliable source of clean water.
- Livestock require water for drinking, cleaning and other farm operations.
- A nearby water supply reduces the cost of transporting water.
- Water should be sufficient throughout the year.
- The source should be protected from contamination by animal waste, chemicals and other pollutants.

4. Accessibility

Accessibility refers to how easily people, animals, vehicles and farm supplies can reach the structure.

- The site should be accessible throughout the year.

- Roads or paths should allow movement of feed, construction materials and farm equipment.
- It should allow easy transportation of livestock and livestock products.
- Good access makes veterinary visits and emergency response easier.
- However, the structure should not be placed where unnecessary public traffic disturbs animals.

5. Wind direction

- The direction of prevailing winds should be considered when positioning livestock structures.
- Proper orientation can improve natural ventilation.
- It can help reduce the movement of unpleasant smells towards homes and public areas.
- Poultry houses should be positioned to avoid harmful draughts while maintaining adequate air movement.
- The design should also protect animals from strong cold winds.

6. Sunlight and shade

- The site should receive suitable natural lighting.
- Excessive direct sunlight may cause heat stress.
- Trees or suitable shade structures can help protect animals from excessive heat.
- Sunlight can help keep some surfaces dry.
- Poultry houses should be designed to provide adequate light without exposing birds to excessive heat.

7. Soil type and stability

- The soil should be firm enough to support the weight of the structure.
- Stable soil reduces the risk of uneven settlement and structural failure.
- Very loose or expansive soils may require special foundations.
- Waterlogged soils are unsuitable unless properly improved.
- Soil conditions influence the type and cost of foundation required.

8. Distance from residential houses

- Livestock structures should be located at a reasonable distance from homes.
- This helps minimise noise, odours and disturbance.
- It reduces direct contact between household activities and animal waste.
- It improves comfort for both people and animals.
- The distance should comply with applicable local public-health and planning requirements.

9. Distance from other livestock units

- Structures should be arranged to reduce unnecessary mixing of different livestock groups.
- Poultry houses should be managed to reduce the risk of disease transmission.
- Sick-animal isolation areas should be separate from healthy stock.
- Separation of units can improve biosecurity.
- The layout should allow easy cleaning and movement between facilities without spreading contamination.

10. Availability of construction materials

- The site should be reasonably accessible to materials such as timber, stones, sand, cement, roofing sheets and wire mesh.
- Locally available materials can reduce transportation costs.
- Materials should be strong, safe and suitable for the intended structure.
- Reusable materials may reduce construction costs if they are clean, sound and safe for livestock.

11. Security

- The site should be secure against theft and predators.
- It should allow the farmer to monitor livestock easily.
- Fencing and controlled entry points improve security.
- Lighting may be installed where necessary.
- The site should not be unnecessarily exposed to unauthorised access.

12. Availability of space for future expansion

- The farmer should consider possible future increases in livestock numbers.
- Adequate space should be left for additional pens, stores or handling facilities.
- The site should allow future improvements without disrupting existing operations.
- Expansion should not compromise animal welfare or environmental safety.

13. Environmental protection

- The site should not expose rivers, streams, wells and other water sources to contamination.
- Animal waste should be managed safely.
- Wastewater should not flow into neighbouring farms or public areas.

- The site should comply with relevant environmental and public-health requirements.
- Existing trees and vegetation should be retained where practical.

14. Cost of land preparation

- The farmer should consider the cost of clearing, levelling and preparing the site.
- A site requiring extensive excavation may increase construction costs.
- Areas with stable soil and good natural drainage may reduce preparation expenses.
- The total cost should be considered before construction begins.

15. Neighbourhood and community considerations

- The site should not cause unnecessary inconvenience to neighbours.
- Noise, odours and waste disposal should be managed.
- The farmer should consider local land-use requirements.
- Community safety and environmental cleanliness should be maintained.

3.2 Summary of factors considered when siting livestock structures

Factor	Reason for consideration
Topography	Ensures suitable land slope and reduces construction costs
Drainage	Prevents waterlogging and muddy conditions
Water supply	Ensures reliable water for livestock and cleaning
Accessibility	Makes transport and daily management easier
Wind direction	Promotes ventilation and reduces nuisance from odours
Sunlight	Provides suitable lighting and helps manage heat
Soil type	Ensures a stable foundation
Distance from homes	Reduces noise, odours and disturbance
Security	Protects livestock from theft and predators
Space	Allows future expansion
Construction materials	Reduces transport and construction costs
Environment	Prevents pollution and protects natural resources

3.3 Siting considerations for specific livestock structures

Different livestock structures have different requirements. The farmer should therefore select a site according to the purpose of the structure.

Structure	Important siting considerations
Poultry house	Good drainage, ventilation, security and separation from other poultry units
Zero-grazing unit	Reliable water supply, access to fodder, good drainage and convenient manure handling
Pigsty	Good drainage, water availability, secure location and proper waste management
Rabbit hutch	Dry, well-ventilated, shaded and secure location
Goat pen	Dry ground, adequate ventilation, access to feed and water
Feed store	Dry, secure, accessible and protected from flooding
Milking parlour	Close to dairy housing, clean water, good drainage and easy milk handling
Loading ramp	Accessible to transport vehicles and connected to a suitable handling area

Application: A farmer planning to construct a poultry house should avoid a low-lying, waterlogged location. Such a site may make the house damp and encourage the development of disease-causing organisms. A well-drained, secure and accessible site is more suitable.

4.0 Construction of livestock production structures

Construction refers to the process of putting together materials to make a structure for a specified purpose.

Livestock structures should be designed and constructed to provide safety, comfort, durability, hygiene and convenience.

The construction process involves planning, site selection, designing, selecting materials, preparing the site, building and finishing the structure.

4.1 Steps followed when constructing livestock production structures

Step 1: Identify the purpose of the structure

- Determine the type of livestock to be housed.
- Identify the main activity the structure will support.
- Decide whether it is for housing, feeding, breeding, storage, handling or treatment.
- Establish the number and type of animals to be accommodated.
- Consider the production system to be used.

Example: A farmer intending to keep 100 laying hens needs a poultry house designed for layers, with appropriate nesting facilities, perches where suitable, feeders, drinkers and adequate ventilation.

Step 2: Select a suitable site

- Assess the available land.
- Check drainage and soil stability.
- Consider water supply and accessibility.
- Examine the direction of prevailing winds.
- Consider security and environmental protection.
- Ensure that the site meets relevant local requirements.

Step 3: Prepare a sketch design

A sketch design is a simple drawing showing the proposed structure and its main parts.

It helps the farmer plan the construction before spending money on materials.

A good sketch should show:

- The shape and general appearance of the structure.

- The approximate dimensions.
- The position of doors and windows.
- The roof design.
- Feeding and watering facilities.
- Drainage channels.
- Internal partitions where required.
- The materials to be used.

Step 4: Estimate the materials and costs

- Prepare a list of materials required.
- Estimate the quantities needed.
- Find out the prices of the materials.
- Estimate labour and transportation costs.
- Identify materials that can be safely reused.
- Prepare a realistic construction budget.

Step 5: Clear and prepare the site

- Remove bushes, rubbish and unwanted vegetation.
- Remove obstacles from the construction area.
- Level the site where necessary.
- Mark the position of the structure.
- Provide for drainage.
- Store construction materials safely.

Step 6: Lay the foundation

A foundation is the lowest supporting part of a building that transfers the weight of the structure to the ground.

- Excavate the foundation trenches according to the design.
- Prepare the base.
- Use suitable construction materials.
- Ensure the foundation is stable and level.
- Allow concrete or other materials to set properly where applicable.

The foundation should be appropriate to the soil conditions, size and intended use of the structure.

Step 7: Construct the floor

- Prepare a firm and stable floor base.
- Use suitable materials such as concrete, compacted earth or timber, depending on the structure.
- Ensure the surface is safe and easy to clean.
- Provide a suitable slope where drainage is required.
- Avoid slippery surfaces that may cause animal injuries.
- For poultry deep-litter houses, provide a suitable solid floor on which dry litter can be spread.

Step 8: Construct walls and partitions

- Use suitable materials such as timber, bricks, blocks, stones or wire mesh.
- Ensure walls are strong and stable.
- Provide openings for ventilation.
- Construct internal partitions where animals need separation.
- Avoid sharp edges and protruding objects that may injure animals.

Step 9: Construct the roof

- Install the roof framework securely.
- Fix suitable roofing materials.
- Ensure the roof protects animals from rain and excessive sunlight.
- Provide sufficient roof height and ventilation openings.
- Ensure rainwater is directed away from the structure.

Step 10: Install doors, windows and ventilation openings

- Install doors of suitable size.
- Provide windows or other ventilation openings.
- Use mesh where necessary to prevent entry of predators and wild birds.
- Ensure the structure can be accessed easily for cleaning and management.
- Provide suitable protection against strong winds and rain.

Step 11: Install internal facilities

Depending on the structure, install:

- Feed troughs.
- Water troughs.
- Nest boxes.
- Perches.
- Resting cubicles.
- Calf pens.
- Manure collection trays.
- Drainage channels.
- Handling equipment.

Step 12: Finish and inspect the structure

- Remove construction waste.
- Smooth or cover sharp edges.
- Check the strength of the structure.
- Check the drainage system.
- Confirm that the structure is well ventilated.
- Ensure all facilities are safe for animals.
- Clean and disinfect where appropriate before introducing livestock.

Step 13: Maintain the structure

- Repair damaged roofs and walls.
- Replace broken fencing and wire mesh.
- Clean floors, troughs and drinkers.
- Remove manure and waste regularly.
- Repair drainage channels.
- Replace worn-out fittings.
- Inspect the structure regularly for safety.

5.0 Construction of selected livestock production structures

The following examples show how the construction principles are applied to different livestock structures.

5.1 Construction of a simple deep-litter poultry house

A deep-litter poultry house should provide adequate space, ventilation, protection and easy access for cleaning and feeding.

Materials required

- Timber or metal poles.
- Roofing sheets.
- Wire mesh.
- Nails and screws.
- Cement, sand and ballast where a concrete floor is used.
- Door materials and hinges.
- Suitable litter material.
- Feeders and drinkers.

Construction procedure

1. Select a dry, well-drained and secure site.
2. Prepare a sketch showing the dimensions, doors, windows and ventilation openings.
3. Clear and level the construction site.
4. Mark the foundation and construct the floor base.
5. Construct the floor using suitable materials.
6. Erect the supporting posts and wall framework.
7. Fix wire mesh and suitable wall materials.
8. Install the roof and provide adequate overhang to protect the walls from rain.
9. Fit doors and ventilation openings.
10. Install feeders and drinkers at suitable positions.
11. Spread clean, dry litter on the floor.
12. Inspect the house to ensure that it is safe and ready for birds.

Important considerations

- The house should not be overcrowded.
- The litter should remain dry and well managed.
- The house should be protected from predators.
- Adequate ventilation should be provided.

- The floor should be easy to clean and disinfect.

5.2 Construction of a simple rabbit hutch

Materials required

- Timber.
- Wire mesh.
- Roofing sheets.
- Nails and screws.
- Hinges and door fasteners.
- Feeding containers.
- Water containers.
- Nest box materials.
- Droppings collection tray.

Construction procedure

1. Select a dry, shaded and secure location.
2. Prepare a sketch showing the compartments and dimensions.
3. Cut timber to the required measurements.
4. Assemble the frame.
5. Raise the hutch above the ground using strong supports.
6. Fix suitable wire mesh to the sides.
7. Construct a floor that is safe and comfortable for rabbit feet.
8. Install the roof to protect the rabbits from rain and sunlight.
9. Construct doors that allow easy access for cleaning and handling.
10. Fit feeding and watering containers.
11. Install a nest box in the breeding compartment.
12. Fit a droppings collection tray where appropriate.
13. Inspect the hutch for sharp edges, weak joints and gaps through which rabbits may escape.

Important considerations

- The hutch should be well ventilated.

- Rabbits should be protected from direct rain and excessive heat.
- The floor should not injure the animals' feet.
- Each rabbit should have sufficient space.
- The hutch should be easy to clean.

5.3 Construction of a simple pigsty

Materials required

- Stones, bricks or concrete blocks.
- Cement, sand and ballast.
- Timber or metal roofing supports.
- Roofing sheets.
- Strong doors and gates.
- Water pipes or suitable drinkers.
- Feeding troughs.
- Drainage materials.

Construction procedure

1. Select a secure site with good drainage and access to water.
2. Prepare a sketch showing the number of pens and their intended uses.
3. Clear and mark the site.
4. Construct a suitable foundation.
5. Build the floor and provide appropriate drainage.
6. Construct strong walls and internal partitions.
7. Install the roof.
8. Fix secure doors and gates.
9. Install feeding troughs and drinking facilities.
10. Provide a suitable waste collection and disposal system.
11. Smooth sharp surfaces and inspect the structure.
12. Clean and prepare the pigsty before introducing pigs.

Important considerations

- The floor should be non-slippery.
- Drainage should prevent accumulation of wastewater.
- Pens should be spacious enough for the pigs.
- Piglets should be protected from crushing and cold conditions.
- Different groups of pigs should be housed appropriately.

5.4 Construction of a simple goat pen

Materials required

- Timber poles.
- Timber planks or suitable slats.
- Roofing sheets.
- Nails and screws.
- Wire mesh where necessary.
- Water and feed containers.

Construction procedure

1. Select a dry site with good drainage.
2. Prepare a sketch showing the floor, roof, walls and partitions.
3. Clear and mark the site.
4. Install strong supporting posts.
5. Construct a raised floor if using a raised-floor design.
6. Fix smooth slats with safe spacing.
7. Construct walls or side barriers.
8. Install the roof.
9. Construct feeding and watering facilities.
10. Provide suitable access for goats and workers.
11. Inspect the pen to ensure there are no sharp or unsafe surfaces.

Important considerations

- The pen should provide protection from rain and strong winds.
- The floor should be dry and safe.

- The structure should be easy to clean.
- Separate areas may be provided for kids and breeding animals.
- Feed and water should be accessible without unnecessary wastage.

6.0 Selection of materials for constructing livestock structures

Construction materials are substances used to build and finish livestock production facilities.

The choice of materials depends on the purpose of the structure, cost, availability, durability, safety and environmental conditions.

6.1 Common construction materials and their uses

Material	Uses in livestock structures
Timber	Frames, doors, partitions, roofs and rabbit hutches
Stones	Foundations, walls and floors
Bricks	Walls and partitions
Cement	Floors, foundations, troughs and drainage channels
Sand	Preparation of mortar and concrete
Ballast	Preparation of concrete
Roofing sheets	Roof covering
Wire mesh	Poultry houses, rabbit hutches and ventilation openings
Nails and screws	Joining timber and other components
Metal pipes	Water supply and structural supports
Plastic containers	Feeders and drinkers
Recycled timber	Suitable frames and partitions
Reused drums	Water storage or other safe farm uses

6.2 Factors to consider when selecting construction materials

1. Availability

- Materials that are locally available may reduce transportation costs.
- Availability also makes repairs easier.

2. Cost

- Materials should be affordable and fit the farmer's budget.
- The farmer should consider both initial cost and long-term maintenance cost.

3. Durability

- Materials should withstand weather conditions and regular use.
- Durable materials reduce frequent repairs and replacement.

4. Strength

- Materials should support the weight and pressure expected in the structure.
- Strong materials are particularly important for pig pens, cattle handling facilities and boundary fences.

5. Safety to animals

- Materials should not have sharp edges, poisonous coatings or loose parts.
- Surfaces should not cause injuries.

6. Ease of cleaning

- Materials should allow effective cleaning and disinfection where required.
- Smooth, non-porous surfaces are useful in areas requiring high standards of hygiene.

7. Resistance to weather

- Roofing and wall materials should withstand rain, sunlight and wind.
- Materials should not deteriorate rapidly in the local climate.

8. Environmental friendliness

- Materials should be selected with consideration for the environment.
- Safe reuse and recycling can reduce waste.

9. Ease of repair

- Materials that can be repaired or replaced easily are useful in farm construction.
- Common local materials may simplify maintenance.

6.3 Re-use of materials in livestock structure construction

Re-use involves using materials that have already served another purpose to make a new structure or improve an existing one.

Examples

- Re-using sound timber to make poultry-house partitions.
- Using clean, suitable containers as feeders or drinkers.
- Using suitable stones from the farm for foundations.
- Re-using intact roofing sheets.
- Using safe recycled metal for gates and supports.
- Using clean plastic containers for water storage.

Benefits of re-using materials

- Reduces construction costs.
- Minimises waste on the farm.
- Conserves natural resources.

- Encourages creativity and innovation.
- Promotes environmental awareness.
- Makes use of locally available resources.

Precautions when re-using materials

- Do not use containers that previously held toxic chemicals for animal feed or water.
- Avoid rotten timber and rusted materials that may cause injuries.
- Ensure reused materials are clean and safe.
- Remove protruding nails, sharp wires and broken edges.
- Ensure reused materials are strong enough for their intended purpose.

7.0 Importance of livestock production structures

Livestock production structures play an important role in improving the management, health, welfare and productivity of farm animals.

7.1 Protection of livestock

- Structures protect animals from rain, excessive sunlight and strong winds.
- Fences and secure housing protect animals from predators.
- Proper housing reduces exposure to theft and accidents.
- Calf pens protect young animals from unnecessary disturbance and injury.

7.2 Improvement of animal welfare

- Provide animals with suitable resting areas.
- Protect animals from extreme weather conditions.
- Allow access to clean feed and drinking water.
- Provide space for movement and normal animal behaviour.
- Reduce stress caused by poor housing conditions.
- Facilitate separation of sick or injured animals.

7.3 Disease control and prevention

- Properly designed structures make cleaning easier.
- Separate pens reduce unnecessary mixing of livestock groups.
- Good drainage reduces wet and dirty conditions.
- Quarantine facilities help isolate newly introduced animals.

- Well-managed poultry houses reduce exposure to contaminated litter.
- Suitable ventilation helps maintain good air quality.

7.4 Improvement of livestock productivity

- Comfortable animals are more likely to maintain good production.
- Suitable dairy housing supports milk production and hygienic milking.
- Good poultry housing supports egg and meat production.
- Proper pig housing supports growth and reproduction.
- Suitable feeding and watering facilities improve access to resources.

7.5 Ease of feeding and watering

- Feeding troughs make feed distribution easier.
- Water troughs provide convenient access to drinking water.
- Properly positioned facilities reduce feed and water wastage.
- Farmers can monitor the feeding behaviour of animals more easily.

7.6 Ease of handling and management

- Handling races and crushes make animal examination easier.
- Loading ramps simplify transportation.
- Sorting pens facilitate grouping of animals.
- Milking parlours improve the organisation of milking activities.
- Structures make routine farm operations more efficient.

7.7 Proper manure management

- Manure collection areas make waste removal easier.
- Collected manure can be composted.
- Properly managed manure can be used as organic fertiliser.
- Waste management helps maintain cleanliness around livestock units.
- Appropriate disposal reduces environmental pollution.

7.8 Efficient use of land

- Zero-grazing units allow farmers to keep dairy cattle where grazing land is limited.
- Poultry houses accommodate birds in a managed space.

- Rabbit hutches use relatively little land.
- Properly arranged pens make better use of available farm space.

7.9 Reduction of production costs

- Durable structures reduce frequent repair expenses.
- Proper housing can reduce losses caused by theft, predators and injuries.
- Feed stores reduce wastage caused by rain, rodents and spoilage.
- Suitable handling facilities reduce labour and handling difficulties.

7.10 Improvement of farm security

- Fences restrict uncontrolled movement of livestock.
- Strong doors and gates help prevent theft.
- Secure pens protect young animals.
- Enclosed poultry houses reduce attacks by predators.

7.11 Facilitation of breeding and reproduction

- Separate breeding pens allow controlled mating.
- Farrowing pens provide a suitable environment for sows and piglets.
- Calving areas allow observation of cows during parturition.
- Nest boxes provide suitable places for breeding rabbits to kindle.

7.12 Improvement of farm organisation

- Different structures provide specific areas for different farm activities.
- Feed stores, animal houses and handling facilities make work systematic.
- Separate units make record keeping and monitoring easier.
- A well-planned farm layout reduces unnecessary movement of animals and workers.

8.0 Maintenance of livestock production structures

Maintenance refers to the regular inspection, cleaning, repair and improvement of livestock structures to keep them safe and functional.

8.1 Routine maintenance practices

1. Cleaning

- Remove manure, leftover feed and other waste.
- Clean feeders and drinkers regularly.

- Remove dirty bedding and replace it where necessary.

2. Repairing damaged parts

- Replace broken timber.
- Repair leaking roofs.
- Fix loose doors and gates.
- Replace damaged wire mesh.

3. Maintaining drainage

- Clear blocked drainage channels.
- Repair damaged drainage systems.
- Prevent stagnant water around livestock units.

4. Disinfection

- Clean surfaces before applying suitable disinfectants.
- Follow instructions on approved disinfectant products.
- Observe the required safety precautions.

5. Maintaining fences

- Replace broken posts.
- Tighten loose wires.
- Repair damaged gates.
- Remove vegetation that may weaken or conceal the fence.

6. Checking ventilation

- Ensure ventilation openings are not blocked.
- Repair damaged windows and curtains.
- Maintain suitable air circulation.

7. Checking water and feeding facilities

- Repair leaking pipes and troughs.
- Remove feed residues.
- Ensure containers are stable and safe.

8. Controlling pests

- Prevent rodents from accessing stored feed.
- Remove waste that may attract pests.
- Maintain cleanliness around the structures.

8.2 Importance of maintaining livestock structures

- Extends the useful life of structures.
- Reduces repair and replacement costs.
- Improves animal comfort and safety.
- Promotes hygiene.
- Helps prevent injuries.
- Reduces the risk of disease transmission.
- Maintains efficient farm operations.

9.0 Challenges associated with livestock production structures

Farmers may experience various challenges when constructing and managing livestock structures.

1. High construction costs

- Quality construction materials may be expensive.
- Skilled labour may increase the total cost.
- Transporting materials to remote farms may be costly.

2. Limited land

- Small farms may lack sufficient space for all the required structures.
- Farmers may need to design compact but comfortable facilities.

3. Shortage of suitable materials

- Some construction materials may not be locally available.
- This may delay construction or increase costs.

4. Poor workmanship

- Weak foundations and poorly joined materials may cause structures to collapse.
- Poorly designed floors may cause injuries.
- Poor roofing may allow rainwater to enter.

5. Poor site selection

- Structures built in waterlogged areas may become damp.
- Poor accessibility may make transportation of feed and livestock difficult.
- Inappropriate positioning may expose animals to excessive wind or heat.

6. Inadequate maintenance

- Failure to repair damaged structures may expose animals to injury.
- Blocked drainage may cause water accumulation.
- Broken fences may allow animals to escape.

7. Environmental pollution

- Poor disposal of manure and wastewater may contaminate water sources.
- Uncontrolled runoff may affect neighbouring farms.
- Poor waste management may produce unpleasant smells.

8. Disease transmission

- Overcrowded structures may encourage the spread of diseases.
- Poor ventilation and dirty housing may affect animal health.
- Mixing newly introduced animals with existing stock without appropriate precautions may introduce diseases.

Ways of overcoming the challenges

- Prepare a realistic construction budget.
- Use locally available and safe materials.
- Seek technical advice when designing structures.
- Select sites carefully.
- Construct structures according to animal welfare requirements.
- Carry out regular inspection and maintenance.
- Adopt appropriate waste-management practices.
- Avoid overcrowding and maintain good hygiene.
- Plan for future expansion.

10.0 Safety precautions when constructing livestock structures

Safety should be considered during construction and throughout the use of livestock facilities.

10.1 Safety during construction

- Wear appropriate protective clothing, including gloves, safety boots and eye protection.
- Use tools and equipment correctly.
- Keep nails, sharp wires and other dangerous materials away from animals.
- Store cement, paints and chemicals safely.
- Avoid working under unstable structures.
- Use ladders and other equipment safely.
- Keep children and livestock away from active construction areas.
- Dispose of construction waste responsibly.

10.2 Safety when using livestock structures

- Avoid overcrowding animals.
- Repair sharp edges and broken surfaces.
- Ensure floors are not excessively slippery.
- Provide suitable ventilation.
- Keep gates and doors secure.
- Maintain clean feeding and watering facilities.
- Ensure animals can move, rest and access feed and water comfortably.
- Use handling equipment correctly to avoid injury to animals and workers.

11.0 Farm layout and arrangement of livestock structures

Farm layout refers to the planned arrangement of buildings, livestock units, roads, water facilities, stores and other structures on a farm.

A good farm layout improves movement, hygiene, security and efficient use of available land.

11.1 Principles of a good livestock farm layout

1. Convenient arrangement

- Structures should be positioned to make daily activities easier.
- Feed stores should be accessible to the livestock units they serve.

2. Proper spacing

- Adequate space should be provided between structures.
- Spacing should allow ventilation, cleaning and movement.

3. Good drainage

- Buildings should be arranged to prevent wastewater from flowing into clean areas.
- Drainage should direct waste away from water sources.

4. Biosecurity

- Sick-animal isolation areas should be separated from healthy livestock.
- Unnecessary movement between animal units should be minimised.
- Entry points should be controlled where necessary.

5. Efficient movement

- Roads and pathways should connect important farm facilities.
- Loading areas should be accessible to transport vehicles.
- Animal movement routes should minimise stress and injuries.

6. Waste management

- Manure collection and composting areas should be suitably located.
- Waste should not contaminate feed stores, drinking water or residential areas.

7. Security

- The farm should have secure boundaries and controlled entrances.
- Livestock units should be positioned where they can be monitored.

8. Future expansion

- Space should be reserved for additional structures.
- Expansion should not interfere with existing farm operations.

11.2 Example of a small livestock farm layout

A small mixed-livestock farm may have the following arrangement:

Farm facility	**Main purpose**
Dairy unit	Housing dairy cattle
Calf pen	Housing young calves
Poultry house	Keeping poultry
Goat pen	Housing goats
Pigsty	Housing pigs
Rabbit hutches	Keeping rabbits
Feed store	Storing livestock feeds
Water tank	Storing water
Manure collection area	Collecting and composting manure
Loading area	Loading and offloading animals
Farm entrance	Controlling movement into and out of the farm

The exact arrangement should be determined by land size, drainage, wind direction, local regulations, animal welfare and the farmer's production objectives.

12.0 CBE integration in the sub-strand

The study of structures in livestock production develops practical skills and responsible attitudes that learners can apply in real-life farming situations.

12.1 Core competence: Creativity and imagination

Learners develop creativity and imagination through:

- Designing livestock production structures.
- Drawing sketches of poultry houses, rabbit hutches and pigsties.
- Selecting suitable construction materials.
- Finding innovative ways of using locally available resources.
- Making models of livestock production structures.
- Modifying designs to improve animal comfort and safety.
- Developing solutions to challenges experienced in livestock housing.

Expected evidence of competence

The learner should be able to design, sketch and construct a suitable livestock production structure or model using available materials.

12.2 Value: Integrity

Integrity is demonstrated when learners act honestly and responsibly during construction activities.

Learners should:

- Use construction materials prudently.
- Avoid wasting materials.
- Use resources for their intended purpose.
- Give accurate reports on materials used.
- Take responsibility for tools and equipment.
- Respect other learners' contributions.
- Avoid taking materials belonging to other people without permission.

Expected evidence of the value

The learner uses available materials responsibly and demonstrates honesty during the construction of livestock structures.

12.3 Pertinent and Contemporary Issue: Environmental awareness

Environmental awareness involves understanding the importance of protecting the environment when constructing and managing livestock structures.

Learners should:

- Re-use safe materials during construction.
- Avoid unnecessary cutting of trees.
- Dispose of construction waste properly.
- Prevent livestock waste from polluting water sources.
- Use locally available materials sustainably.
- Plant suitable trees around livestock units where appropriate.
- Construct proper manure collection facilities.
- Use water efficiently during cleaning.

Expected evidence of environmental awareness

The learner demonstrates responsible use of resources and constructs livestock structures while minimising environmental pollution.

12.4 Suggested learning experiences

Learners should be guided to:

1. Visit a nearby livestock farm and observe different structures.
2. Identify fences, zero-grazing units, poultry houses, rabbit hutches, pigsties and goat pens.
3. Discuss the functions of each structure.
4. Identify materials used in constructing different structures.
5. Observe the features of well-designed livestock houses.
6. Discuss factors considered when selecting construction sites.
7. Compare different livestock housing designs.
8. Draw sketch designs of selected livestock structures.
9. Estimate materials needed for construction.
10. Re-use suitable materials to construct a model.
11. Construct a simple, usable livestock structure under appropriate supervision.
12. Display completed structures or models.

13. Explain the importance of the constructed structures.
14. Give and receive feedback respectfully.

12.5 Suggested practical project

Project: Designing and constructing a model deep-litter poultry house

Objective: To enable learners to apply creativity and imagination in designing and constructing a model of a poultry house.

Materials

- Cardboard or suitable recycled timber.
- Wire mesh or safe mesh substitute.
- Glue.
- Nails or small fasteners.
- Ruler.
- Pencil.
- Scissors or appropriate cutting tools.
- Roofing material.
- Re-used clean containers for model feeders and drinkers.

Procedure

1. Identify the purpose of the model.
2. Draw a sketch of the proposed poultry house.
3. Label the main parts.
4. Identify the materials required.
5. Measure and cut the materials.
6. Assemble the floor and supporting frame.
7. Construct the walls and ventilation openings.
8. Fix the roof.
9. Add miniature feeders, drinkers and nest boxes.
10. Inspect the model for completeness and stability.
11. Display the model.
12. Explain the importance of each part to other learners.

Assessment criteria

Assessment area	What the teacher should observe
Design	Is the sketch clear and suitable for the intended purpose?
Creativity	Has the learner used available materials innovatively?
Material selection	Are the materials suitable and safe?
Construction	Is the model properly assembled?
Labelling	Are the main parts correctly identified?
Environmental awareness	Has the learner re-used suitable materials?
Integrity	Has the learner used materials responsibly?
Presentation	Can the learner explain the model clearly?

Reflection questions

- What materials did you use?
- Why did you select those materials?
- What challenges did you experience during construction?
- How did you overcome the challenges?
- How does the structure improve poultry production?
- How did you minimise material wastage?

13.0 Key inquiry question

How are farm structures used in livestock production processes?

Farm structures support livestock production in several ways:

- Animal houses provide shelter and resting places.
- Fences control animal movement and provide security.
- Feeding troughs provide access to feed.
- Water troughs provide drinking water.
- Milking parlours support hygienic milk production.
- Handling races and crushes facilitate examination and treatment.
- Feed stores protect feeds from damage and spoilage.
- Manure collection facilities support proper waste management.
- Loading ramps facilitate transportation of livestock.

Conclusion: Properly designed and constructed livestock structures improve animal welfare, productivity, farm organisation, hygiene and security.

Revision exercises

Section A: Multiple-choice questions

Choose the correct answer in each question.

1. A farmer constructs a physical barrier around a grazing field to prevent cattle from straying. Which livestock structure has the farmer constructed?

A. Feed store
B. Fence
C. Milking parlour
D. Calf pen

2. Which one of the following is the main purpose of a zero-grazing unit?

A. Keeping animals for free-range grazing
B. Housing dairy cattle that are fed within a confined unit
C. Storing harvested crop produce
D. Keeping poultry for egg production

3. A poultry farmer spreads wood shavings on the floor of a poultry house. The material is mainly used as:

A. Roofing material
B. Wall covering
C. Litter
D. Fencing material

4. Which one of the following structures is specifically designed for a rabbit to give birth and nurse its young?

A. Feeding trough
B. Nest box
C. Water trough
D. Droppings tray

5. A pig farmer wants to construct a pen for a sow during farrowing. Which type of pen should be constructed?

A. Boar pen
B. Grower pen
C. Farrowing pen
D. Fattening pen

6. Which one of the following is the most suitable feature of a good livestock production structure?

A. Poor drainage
B. Inadequate ventilation
C. Sharp edges
D. Adequate ventilation

7. A farmer selects a gently sloping site for a livestock unit. Which factor is the farmer mainly considering?

A. Topography
B. Security
C. Cost of labour
D. Availability of timber

8. Why should a livestock production structure be sited on well-drained land?

A. To increase the cost of construction
B. To prevent waterlogging
C. To reduce access to water
D. To prevent natural ventilation

9. Which one of the following factors is most important when selecting a site for a livestock structure?

A. Distance from all roads
B. Poor soil stability
C. Reliable water supply
D. Presence of stagnant water

10. A farmer constructs a poultry house near a river where wastewater can flow directly into the river. Which important siting consideration has been ignored?

A. Environmental protection
B. Availability of roofing materials
C. Shape of the roof
D. Colour of the walls

11. What is the main purpose of preparing a sketch design before constructing a livestock structure?

A. To increase material wastage
B. To show the proposed design and arrangement of parts
C. To avoid estimating costs
D. To prevent the selection of a suitable site

12. Which one of the following materials is commonly used to make the walls of a poultry house?

A. Wire mesh
B. Fresh animal manure
C. Loose soil
D. Wet litter

13. Which livestock structure is used to restrain cattle during vaccination and examination?

A. Loading ramp
B. Cattle crush
C. Feed store
D. Nest box

14. A farmer wants to load cattle into a lorry safely. Which structure would be most useful?

A. Rabbit hutch
B. Loading ramp
C. Poultry nest box
D. Calf pen

15. Which one of the following is an advantage of a raised rabbit hutch?

A. It exposes rabbits to wet ground
B. It makes cleaning and waste collection easier
C. It prevents ventilation
D. It increases contact with contaminated soil

16. Why should a livestock house have proper drainage?

A. To encourage water accumulation
B. To increase dampness
C. To remove wastewater and prevent waterlogging
D. To prevent cleaning

17. Which one of the following is an example of a live fence?

A. A concrete wall
B. A chain-link barrier
C. A row of closely planted kei apple shrubs
D. A barbed-wire barrier

18. A farmer uses old, clean and safe timber to construct a poultry-house partition. Which environmental practice is demonstrated?

A. Deforestation
B. Re-use of materials
C. Soil erosion
D. Water pollution

19. Which one of the following practices best demonstrates integrity during the construction of a livestock structure?

A. Wasting materials
B. Hiding damaged materials
C. Using construction materials responsibly
D. Taking other learners' tools without permission

20. Which one of the following is the main reason for regularly maintaining livestock structures?

A. To increase animal injuries
B. To shorten their useful life
C. To keep them safe and functional
D. To increase disease transmission

Section B: Structured questions

21.
a) Define the term livestock production structures. (2 marks)

b) Name six livestock production structures used in animal production. (6 marks)

c) State four reasons why livestock production structures are important to a farmer. (4 marks)

22.
a) Describe five types of fences used in livestock production. (10 marks)

b) Explain four importance of fences in livestock production. (4 marks)

23.
a) Describe the main parts of a zero-grazing unit. (8 marks)

b) Explain four advantages of zero-grazing structures in dairy production. (4 marks)

24.
a) Differentiate between a deep-litter poultry house and a free-range poultry housing system. (4 marks)

b) Describe six features of a good deep-litter poultry house. (6 marks)

c) State four advantages of using a deep-litter system. (4 marks)

25.
a) Describe six features of a good rabbit hutch. (6 marks)

b) Explain four factors to consider when siting a rabbit hutch. (4 marks)

26.
a) Explain eight factors to consider when selecting a site for constructing a livestock production structure. (8 marks)

b) Explain four reasons why drainage is important when siting livestock structures. (4 marks)

27.
a) Outline ten steps followed when constructing a livestock production structure. (10 marks)

b) State four precautions to observe when selecting materials for constructing livestock structures. (4 marks)

28.
a) Explain six importance of maintaining livestock production structures. (6 marks)

b) Describe four ways in which a farmer can demonstrate environmental awareness when constructing livestock structures. (4 marks)

Key terms and definitions

Term	**Meaning**
Livestock structure	A facility constructed to support the housing, feeding, handling or management of farm animals
Fence	A barrier used to enclose an area and control animal movement
Zero-grazing unit	A housing facility where livestock are confined and provided with feed and water
Poultry house	A building used to house domestic birds
Deep litter	A layer of absorbent bedding material spread on the floor of a poultry house

Rabbit hutch	A specially designed structure for housing rabbits
Pigsty	A structure used for housing pigs
Goat pen	An enclosure used for housing goats
Siting	Selecting a suitable location for constructing a structure
Topography	The physical features and shape of the land
Drainage	Removal of excess water from an area
Foundation	The supporting base of a building
Sketch design	A drawing showing the proposed appearance and arrangement of a structure
Livestock handling race	A narrow passage used to guide livestock during handling
Cattle crush	A restraining structure used when examining or treating cattle
Loading ramp	A sloping structure used to load and offload livestock
Farm layout	Planned arrangement of farm buildings and facilities
Maintenance	Regular cleaning, inspection and repair of structures
Biosecurity	Measures taken to prevent the introduction and spread of diseases
Re-use	Using a material again for another suitable purpose

STRAND 2.0: ANIMAL PRODUCTION

SUB-STRAND 2.5: REARING SELECTED ANIMALS

TOPIC: MANAGEMENT PRACTICES IN ANIMAL REARING

1.0 Introduction to animal rearing

Animal rearing refers to the keeping, feeding, breeding and management of domestic animals for food, income, employment and other useful products.

In Kenya, livestock farming is practised in different parts of the country depending on climatic conditions, availability of pasture, water, land and market opportunities.

1.1 Examples of domestic animals reared in Kenya

1. Cattle: Reared for milk, beef, hides, skins, manure and draught power.
2. Goats: Kept for meat, milk, skins and manure.
3. Sheep: Reared for mutton, wool, skins and manure.
4. Pigs: Kept mainly for pork production.
5. Poultry: Reared for eggs, meat and feathers.
6. Rabbits: Kept for meat, skins and manure.
7. Donkeys: Used for transportation and carrying loads.
8. Camels: Reared for milk, meat and transportation, especially in arid and semi-arid areas.

2.0 Animal management practices

Animal management practices are the activities carried out by farmers to ensure that domestic animals are healthy, comfortable, productive and economically useful.

They involve providing animals with appropriate housing, adequate feed, clean water, hygiene, disease prevention and proper handling.

2.1 Importance of animal management practices

1. Improves productivity: Healthy animals produce more milk, meat, eggs, wool and other products.
2. Prevents diseases: Proper hygiene and routine inspection help reduce disease infections and spread.
3. Promotes animal welfare: Proper handling prevents unnecessary pain, suffering, injuries and stress.
4. Improves growth: Adequate feeding and watering promote healthy growth and development.
5. Improves reproduction: Well-managed animals have better chances of successful breeding and producing healthy offspring.
6. Reduces production costs: Preventive management reduces veterinary expenses, deaths and production losses.
7. Improves product quality: Proper feeding, hygiene and housing improve the quality of animal products.
8. Increases farm income: Healthy and productive animals generate better returns.
9. Promotes safety: Proper handling and restraint reduce injuries to animals and farm workers.
10. Facilitates farm planning: Proper records help farmers monitor animal performance and make informed decisions.

3.0 Feeding domestic animals

Feeding is the practice of providing animals with suitable food containing nutrients required for maintenance, growth, reproduction and production.

Different animals have different feeding requirements depending on their species, age, body size, production level and physiological condition.

3.1 Importance of feeding domestic animals

1. Provides energy for movement and body activities.
2. Promotes growth and development.
3. Supports milk, meat and egg production.
4. Improves reproductive performance.
5. Maintains body temperature.
6. Strengthens the immune system.
7. Supports tissue repair and replacement.
8. Prevents nutritional deficiency diseases.

3.2 Types of animal feeds

Animal feeds can be classified into the following categories:

A. Roughages

Roughages are bulky feeds containing relatively high amounts of fibre.

Examples include:

- Napier grass.
- Rhodes grass.
- Hay.
- Maize stover.
- Lucerne.
- Desmodium.
- Natural pasture.

Importance of roughages

1. Provide fibre necessary for proper digestion in ruminants.
2. Stimulate rumination and saliva production.
3. Maintain normal functioning of the rumen.
4. Provide energy and some minerals.
5. Help prevent digestive disorders associated with inadequate fibre.

B. Concentrates

Concentrates are feeds containing relatively high levels of energy or protein and generally lower fibre content than roughages.

They include:

- Maize germ.
- Wheat bran.
- Rice bran.
- Cottonseed cake.
- Sunflower cake.
- Soya bean meal.
- Fish meal.

Examples of their uses:

- Maize germ provides energy.
- Soya bean meal supplies protein.
- Wheat bran provides energy, fibre and some minerals.
- Sunflower cake supplies protein.

C. Mineral supplements

These are feeds or additives provided to supply minerals required for proper body functioning.

Examples:

- Common salt.
- Calcium supplements.
- Phosphorus supplements.
- Mineral licks.
- Commercial mineral premixes.

Minerals support bone formation, muscle functioning, reproduction and other body processes.

D. Vitamin supplements

Vitamins are nutrients required in small quantities for normal growth, metabolism and health.

Examples include vitamins A, D, E and K, and B-complex vitamins.

E. Water

Water is an essential nutrient required by all domestic animals.

Importance of water:

1. Regulates body temperature.
2. Facilitates digestion and absorption of nutrients.
3. Transports nutrients and waste products.
4. Supports milk production.
5. Maintains normal body functions.
6. Prevents dehydration.

3.3 Good feeding practices

1. Provide feeds appropriate for the species and age of the animal.
2. Ensure that feeds are clean and free from mould.
3. Provide balanced rations containing the required nutrients.
4. Feed animals at regular times.
5. Avoid sudden changes in the type of feed.
6. Provide adequate clean drinking water.
7. Store feeds in dry, well-ventilated places.
8. Prevent contamination of feeds by chemicals and animal waste.
9. Avoid overfeeding and underfeeding.
10. Monitor animals' body condition and adjust feeding accordingly.

3.4 Examples of feeding practices in selected animals

Animal	Common feeds
Dairy cattle	Napier grass, hay, silage, dairy meal and mineral supplements
Goats	Browse plants, pasture, hay and supplementary concentrates
Sheep	Pasture, hay, crop residues and mineral supplements
Pigs	Balanced pig rations, maize-based feeds and protein supplements
Poultry	Chick mash, growers mash, layers mash and broiler feeds

Rabbits	Lucerne, suitable grasses, hay and balanced rabbit pellets

4.0 Watering domestic animals

Watering is the provision of clean and safe drinking water to domestic animals.

4.1 Importance of watering

1. Prevents dehydration.
2. Regulates body temperature.
3. Facilitates digestion.
4. Supports milk production.
5. Helps transport nutrients within the body.
6. Facilitates the removal of waste products.
7. Maintains normal body metabolism.
8. Supports reproduction and growth.

4.2 Good watering practices

- Provide clean drinking water regularly.
- Use suitable watering troughs and drinkers.
- Clean watering equipment frequently.
- Ensure that water sources are not contaminated by animal waste.
- Provide sufficient water for all animals.
- Repair leaking pipes and leaking drinkers.
- Monitor water consumption, especially during hot weather.
- Ensure that young animals can access drinking water safely.

Important: The amount of water required varies according to animal species, body size, temperature, feed type, age and production level. Lactating dairy cattle, for example, require considerable amounts of water to support milk production.

5.0 Sanitation in animal rearing

Sanitation refers to the maintenance of cleanliness in animal houses, equipment, feeding areas, watering facilities and the general livestock environment to prevent disease transmission.

5.1 Importance of sanitation

1. Prevents the spread of infectious diseases.
2. Reduces the multiplication of disease-causing organisms.

3. Controls parasites such as ticks, lice and mites.
4. Reduces bad smells in animal houses.
5. Improves the comfort of animals.
6. Prevents contamination of feeds and drinking water.
7. Reduces the breeding of flies and other disease vectors.
8. Improves the quality and safety of animal products.
9. Creates a healthy working environment for farm workers.
10. Reduces production losses associated with diseases.

5.2 Sanitation practices in animal rearing

A. Cleaning animal houses

This involves removing dirt, dung, leftover feeds and other waste materials from animal houses.

Procedure:

1. Remove animals where necessary to facilitate cleaning.
2. Remove leftover feeds from feeding areas.
3. Collect and remove dung.
4. Remove dirty bedding materials.
5. Sweep floors and clean surfaces.
6. Wash suitable floors and equipment using water and appropriate cleaning agents.
7. Allow surfaces to dry where possible.
8. Replace bedding with clean, dry materials.
9. Return animals to the house when it is safe.

B. Disinfection

Disinfection is the use of approved chemical or physical methods to destroy or reduce harmful microorganisms on cleaned surfaces and equipment.

Examples of disinfectants include:

- Approved chlorine-based disinfectants.
- Iodophors.
- Quaternary ammonium compounds.
- Other approved veterinary disinfectants.

Procedure:

1. Remove animals from the area if required by the product instructions.
2. Remove dung, dirt and organic materials.
3. Wash surfaces thoroughly.
4. Prepare the disinfectant according to the manufacturer's instructions.
5. Apply it to the required surfaces.
6. Allow the recommended contact time.
7. Rinse where instructed.
8. Allow the area to dry before animals are reintroduced.

Precaution: Disinfectants should be used according to their labels. Never mix different chemicals, and never apply a chemical directly to an animal unless it is specifically approved for that purpose.

C. Proper disposal of animal waste

Animal waste includes dung, urine, soiled bedding, leftover feeds and other materials produced during animal rearing.

Methods of waste management:

1. Composting dung to produce organic manure.
2. Proper disposal of contaminated bedding.
3. Using biogas systems where suitable.
4. Maintaining proper drainage systems.
5. Preventing animal waste from entering rivers and other water sources.
6. Separating waste from animal feeding and watering areas.

D. Control of flies and other pests

- Remove accumulated dung.
- Drain stagnant water.
- Keep animal houses clean.
- Store feeds properly.
- Use approved pest-control methods.
- Maintain proper waste disposal.

6.0 Identification of domestic animals

Animal identification is the process of assigning or attaching a unique identification mark, number or device to an animal so that it can be recognised and its records maintained.

Identification helps farmers distinguish individual animals in a herd or flock.

6.1 Importance of animal identification

1. Helps distinguish animals of the same species and breed.
2. Facilitates proper record keeping.
3. Helps monitor animal growth and performance.
4. Makes it easier to identify animals requiring treatment.
5. Facilitates breeding management.
6. Helps identify animals for sale and slaughter.
7. Assists in tracing animals during disease outbreaks.
8. Reduces confusion during feeding and handling.
9. Helps prevent theft and supports ownership verification.
10. Facilitates selection of superior breeding animals.

6.2 Methods of animal identification

A. Ear tagging

Ear tagging involves attaching a numbered or coded tag to an animal's ear using a special applicator.

Procedure:

1. Restrain the animal properly.
2. Select the appropriate ear tag.
3. Identify a suitable position on the ear, avoiding major blood vessels and cartilage ridges.
4. Clean the applicator and the site as appropriate.
5. Position the tag correctly in the applicator.
6. Apply the tag using the recommended technique.
7. Check that the tag is securely attached.
8. Record the identification number.

Advantages:

- Easy to apply.
- Relatively inexpensive.

- Numbers are easy to read.
- Useful for maintaining animal records.

Disadvantages:

- Tags can fall off.
- They may become damaged.
- Incorrect application may cause injury or infection.

B. Ear notching

Ear notching involves making small cuts or notches in specified positions along the edge of an animal's ear to represent identification numbers or codes.

It is commonly used in pig identification.

Advantages:

1. Provides permanent identification.
2. Does not require an attached tag.
3. Can identify individual animals or litters.

Disadvantages:

1. Causes pain and tissue injury.
2. Requires skill and correct identification coding.
3. Incorrect notching can lead to confusion.
4. May cause infection if poorly performed.

C. Branding

Branding involves marking an animal's skin using an approved identification method to create a permanent mark.

Types include:

- Hot branding: Uses a heated branding instrument.
- Freeze branding: Uses an extremely cold branding instrument to affect pigment-producing cells in the hair follicles.

Advantages:

- Can provide permanent identification.
- Useful for ownership identification in some livestock systems.

Disadvantages:

- Hot branding causes pain and tissue damage.
- Poor technique can cause serious injuries.
- Marks may become difficult to read.

D. Tattooing

Tattooing involves inserting permanent ink into the skin of an animal using special tattooing equipment.

It is commonly carried out on the inner surface of the ear in animals such as cattle, goats and pigs.

Advantages:

1. Provides permanent identification.
2. Does not easily fall off.
3. Useful for breeding and registration records.

Disadvantages:

1. Numbers may be difficult to read without proper examination.
2. Requires specialised equipment.
3. Poor application may cause infection.

E. Neck chains and collars

These involve attaching a numbered or coded collar around an animal's neck.

They are commonly used for cattle, goats and sheep in small-scale farms.

F. Electronic identification

This involves using electronic devices such as RFID ear tags or injectable transponders to identify animals.

The identification device stores or transmits a unique code that can be read using an electronic scanner.

Advantages:

- Improves accuracy in animal identification.
- Facilitates digital record keeping.
- Makes it easier to trace animals.
- Reduces manual identification errors.

6.3 Characteristics of a good animal identification system

1. It should be easy to apply.

2. It should be durable.
3. It should be easily recognised.
4. It should cause minimal pain and injury.
5. It should be affordable.
6. It should be difficult to alter or duplicate.
7. It should allow accurate record keeping.

7.0 Hoof trimming

Hoof trimming is the removal of excessive or overgrown hoof material from the feet of livestock to maintain proper hoof shape and enable normal movement.

It is commonly practised in cattle, sheep and goats.

7.1 Importance of hoof trimming

1. Prevents excessive hoof growth.
2. Maintains proper foot shape.
3. Improves movement and walking.
4. Reduces lameness.
5. Prevents injuries caused by overgrown hooves.
6. Helps detect hoof diseases and infections.
7. Improves animal comfort.
8. Supports normal feeding and grazing because animals can move comfortably.

7.2 Signs that an animal requires hoof trimming

- Overgrown or excessively long hooves.
- Uneven hoof surfaces.
- Hoof walls curling or folding.
- Difficulty walking.
- Uneven weight distribution.
- Abnormal posture.
- Excessive wear in some parts of the hoof.

7.3 Equipment used in hoof trimming

- Hoof shears.

- Hoof knife.
- Hoof trimmers.
- Restraining equipment.
- Disinfectant.
- Protective gloves.
- Suitable footwear.

7.4 Procedure for hoof trimming

1. Restrain the animal: Secure the animal safely to prevent unnecessary movement and injury.
2. Examine the hooves: Check for overgrowth, cracks, injuries, swelling and signs of infection.
3. Clean the hoof: Remove mud, dung and other dirt to expose the hoof clearly.
4. Identify excess growth: Determine the areas requiring trimming.
5. Trim carefully: Remove excess hoof material gradually using suitable equipment.
6. Maintain natural shape: Avoid cutting too deeply into sensitive living tissue.
7. Examine the trimmed hoof: Check for bleeding, injuries and uneven surfaces.
8. Treat injuries where necessary: Seek veterinary assistance for deep cuts, infections or severe hoof problems.
9. Release the animal: Allow it to stand and walk carefully.
10. Record the activity: Record the date and observations.

7.5 Precautions during hoof trimming

- Use clean and sharp equipment.
- Restrain the animal properly.
- Avoid cutting living tissue.
- Do not trim infected or badly injured hooves without appropriate professional guidance.
- Avoid unnecessary force.
- Seek assistance from a trained livestock handler or veterinarian where necessary.

8.0 Castration

Castration is the removal or permanent suppression of the reproductive ability of male animals.

It is commonly practised in cattle, sheep, goats and pigs.

8.1 Reasons for castration

1. Controls uncontrolled breeding: Prevents unwanted mating.
2. Improves herd management: Makes it easier to manage males that are not required for breeding.
3. Reduces aggressive behaviour in some animals: Castration may reduce fighting and certain male-related behaviours.
4. Facilitates fattening: In some production systems, castration can improve suitability for fattening.
5. Improves meat characteristics in some species: It may reduce undesirable odours and flavours associated with intact males, especially in pigs.
6. Prevents breeding by inferior males: Prevents undesirable genetic characteristics from being passed to offspring.
7. Facilitates group management: Makes it easier to keep certain males together, depending on the species and management system.

8.2 Methods of castration

A. Surgical castration

This involves the removal of the testes through a surgical procedure.

Characteristics:

- Requires proper surgical knowledge.
- Must be carried out under appropriate pain relief and hygienic conditions.
- Has risks of bleeding, infection and complications.
- Should be performed by a veterinarian or appropriately qualified professional.

B. Burdizzo method

This is a bloodless method of castration that uses a special instrument called a Burdizzo to crush the spermatic cords supplying blood to the testes.

Characteristics:

- Does not involve cutting the skin.
- Stops the blood supply to the testes.
- Requires correct positioning and professional skill.
- Incorrect application can result in incomplete castration or serious injury.

C. Elastrator or rubber-ring method

This involves using a special applicator to place a strong rubber ring around the neck of the scrotum in young animals.

The ring restricts blood supply to the testes and scrotal tissues.

Characteristics:

- Commonly used in young lambs and kids.
- Does not require surgical cutting.
- Can cause pain and complications.
- Must comply with animal-welfare requirements and veterinary guidance.

8.3 Precautions during castration

1. Castration should be performed by a competent and authorised person.
2. Use appropriate pain relief and anaesthesia as required.
3. Maintain high standards of hygiene.
4. Use clean and suitable equipment.
5. Choose an appropriate method based on the animal's age, species and condition.
6. Monitor the animal after the procedure.
7. Seek veterinary assistance if bleeding, swelling, infection or other complications occur.
8. Avoid unnecessary castration.

Important: Castration is a painful procedure. It should never be treated as a casual farm activity. Animal-welfare requirements and veterinary advice must be followed.

9.0 Teat clipping

Teat clipping refers to the careful removal of an unwanted extra teat or supernumerary teat in certain livestock, especially dairy animals.

It is done where an extra teat may interfere with milking, cause management difficulties or increase the risk of injury.

9.1 Importance of teat clipping

1. Removes unwanted extra teats where necessary.
2. Prevents interference with milking equipment.
3. Reduces the risk of injury to extra teats.
4. Improves udder management.
5. May improve the ease of routine milking.

9.2 Animals in which teat clipping may be practised

- Dairy cattle.

- Dairy goats.
- Dairy sheep.

9.3 Precautions during teat clipping

1. The udder should be examined by a competent person before the procedure.
2. The extra teat must be distinguished from a functional teat.
3. The procedure should be carried out by a veterinarian or qualified professional.
4. Suitable pain relief and hygienic conditions should be provided.
5. The wound should be monitored for infection and bleeding.

Note: Teat clipping is not necessary for every animal with extra teats. It should only be considered where there is a clear management or health reason.

10.0 Dehorning

Dehorning is the removal of developed horns from livestock.

It is commonly practised in cattle and goats in some livestock production systems.

10.1 Reasons for dehorning

1. Prevents injuries: Reduces injuries caused by animals fighting or pushing one another.
2. Improves safety: Reduces the risk of injury to farm workers.
3. Facilitates handling: Makes animals easier to restrain and manage.
4. Reduces damage to facilities: Prevents animals from damaging fences, feeding troughs and other structures with their horns.
5. Reduces bruising: Minimises injuries to other animals during transportation and handling.
6. Facilitates transportation: Allows animals to be packed and transported more safely.
7. Improves group management: Reduces horn-related aggression and injuries in confined groups.

10.2 Methods of dehorning

A. Disbudding

Disbudding involves destroying or removing the horn-producing tissue before the horns become fully developed and attached to the skull.

It is generally preferred to removing fully developed horns because it is less invasive when properly performed.

B. Hot-iron dehorning

This involves using a specially designed heated instrument to destroy the horn-producing tissue in young animals.

C. Surgical dehorning

This involves removing developed horns and associated horn-producing tissues using appropriate surgical instruments.

It is a more invasive procedure and may cause bleeding and infection if poorly performed.

D. Chemical disbudding

This involves applying an approved chemical paste to the horn buds of young animals to destroy the horn-producing tissue.

It requires strict precautions to prevent chemical burns to the animal, handler and other animals.

10.3 Precautions during dehorning

1. Use trained personnel.
2. Provide suitable pain relief.
3. Maintain hygienic conditions.
4. Use the appropriate method for the animal's age and condition.
5. Avoid excessive bleeding and tissue damage.
6. Protect other animals from chemical disbudding agents.
7. Monitor the animal for infection and complications.
8. Seek veterinary assistance where necessary.

Additional information: Some cattle breeds are naturally polled, meaning they are genetically hornless. Keeping polled animals can reduce the need for dehorning.

11.0 Teeth clipping

Teeth clipping is the careful shortening of certain teeth, particularly the sharp needle teeth of young piglets, to reduce injuries during suckling.

11.1 Importance of teeth clipping

1. Reduces injuries to the sow's teats during suckling.
2. Reduces facial injuries among piglets caused by biting and fighting.
3. May reduce infections associated with injuries.
4. Helps improve comfort during suckling where sharp teeth are causing damage.

11.2 Teeth commonly clipped in piglets

Young piglets are born with eight sharp needle teeth:

- Four upper canine teeth.

- Four lower canine teeth.

These teeth may be considered for treatment only when there is a genuine management or welfare reason.

11.3 Equipment used

- Suitable specialised tooth clippers.
- Restraining equipment.
- Appropriate cleaning and disinfection materials.

11.4 Precautions during teeth clipping

1. The procedure should only be done where necessary.
2. Use suitable equipment.
3. Avoid cutting into the gums.
4. Avoid crushing or splitting the teeth.
5. Maintain hygiene.
6. Use trained personnel.
7. Monitor piglets for oral injuries and infection.

Important: Routine teeth clipping is not recommended simply as a standard practice. It should be avoided unless there is a clear need, and veterinary guidance should be followed.

12.0 Tail docking

Tail docking is the removal of part or all of an animal's tail for specific management or welfare reasons.

It is commonly associated with sheep production and is also practised in some pig production systems.

12.1 Reasons for tail docking in sheep

1. Reduces accumulation of dung and urine around the tail and hindquarters in some sheep.
2. Helps maintain cleanliness around the rear end.
3. May reduce the risk of flystrike in susceptible sheep under appropriate management.
4. Makes inspection and cleaning of the hindquarters easier.

12.2 Reasons for tail docking in pigs

1. Historically practised to reduce tail biting in intensive pig production.
2. May reduce severe tail injuries where other control measures have failed.

However, tail biting is better addressed through improved management, adequate space, enrichment, suitable feeding and reduction of stress.

12.3 Methods of tail docking

A. Rubber-ring method

A special rubber ring is applied around the tail to restrict blood supply to the part that is to be removed.

B. Surgical method

Part of the tail is removed using appropriate surgical instruments under suitable pain relief and hygienic conditions.

C. Hot-iron method

A specialised instrument is used to cut and cauterise the tail at the same time.

12.4 Precautions during tail docking

1. Follow animal-welfare laws and relevant veterinary guidance.
2. Avoid unnecessary docking.
3. Use trained personnel.
4. Provide suitable pain relief.
5. Maintain hygienic conditions.
6. Avoid removing excessive portions of the tail.
7. Monitor for bleeding, infection and other complications.

Important: Tail docking is not automatically necessary in every sheep or pig production system. Good hygiene, housing and management should be prioritised.

13.0 Debeaking

Debeaking refers to the trimming of part of the beak of poultry using specialised equipment. It is sometimes called beak trimming.

It has traditionally been used in poultry production to reduce feather pecking, cannibalism and injuries.

13.1 Reasons for debeaking

1. Reduces severe feather pecking in some flocks.
2. Reduces injuries caused by aggressive pecking.
3. Helps control cannibalism under certain management conditions.

4. May reduce damage to eggs caused by pecking.
5. Helps manage some harmful pecking behaviours in intensive poultry systems.

13.2 Equipment used in debeaking

- Specialised beak-trimming equipment.
- Appropriate measuring guides.
- Restraining equipment.
- Suitable cleaning and maintenance materials.

13.3 Precautions during debeaking

1. Avoid unnecessary beak trimming.
2. Use trained and competent personnel.
3. Follow applicable animal-welfare standards.
4. Avoid excessive removal of beak tissue.
5. Maintain hygiene and proper equipment maintenance.
6. Monitor birds for difficulty feeding and drinking.
7. Provide suitable feeders and drinkers.
8. Address the underlying causes of pecking behaviour.

Alternative management practices

- Avoid overcrowding.
- Provide adequate feeders and drinkers.
- Maintain suitable lighting.
- Provide environmental enrichment.
- Supply balanced feeds.
- Reduce stress in poultry houses.

14.0 Routine management practices in selected domestic animals

Different domestic animals require different management practices depending on their species, production purpose and production system.

14.1 Management of dairy cattle

Dairy cattle are reared mainly for milk production.

Routine management practices

1. Feeding: Provide adequate roughages, concentrates and mineral supplements according to milk production and body condition.
2. Watering: Supply sufficient clean water throughout the day.
3. Milking: Milk cows at regular intervals using clean equipment and hygienic procedures.
4. Housing: Provide clean, dry and well-ventilated housing.
5. Cleaning: Remove dung and soiled bedding regularly.
6. Hoof care: Inspect hooves and arrange trimming when necessary.
7. Disease control: Monitor for mastitis, tick-borne diseases and other livestock diseases.
8. Breeding management: Keep records of mating, artificial insemination, pregnancy and calving.
9. Identification: Use suitable ear tags or other identification methods.
10. Record keeping: Record milk production, feeding, treatments, breeding and expenses.

14.2 Management of goats

Goats are hardy animals kept for meat, milk and other products.

Routine management practices

1. Provide adequate pasture and browse plants.
2. Supplement feeds during periods of feed shortage.
3. Provide clean drinking water.
4. Keep goats in dry and well-ventilated houses.
5. Clean houses regularly.
6. Trim hooves when necessary.
7. Monitor and control internal and external parasites.
8. Provide suitable mineral supplements.
9. Separate sick animals from healthy ones.
10. Keep breeding and kidding records.

14.3 Management of sheep

Sheep are reared mainly for meat, wool and skins.

Routine management practices

1. Provide adequate pasture and supplementary feeds.
2. Supply clean drinking water.

3. Maintain clean and dry housing.
4. Inspect hooves and trim when necessary.
5. Control internal and external parasites.
6. Monitor the condition of the fleece.
7. Carry out shearing in wool-producing breeds where appropriate.
8. Inspect animals for flystrike and other health problems.
9. Maintain breeding records.
10. Provide appropriate lambing care.

14.4 Management of pigs

Pigs are kept mainly for pork production.

Routine management practices

1. Provide balanced feeds suitable for the production stage.
2. Supply clean drinking water.
3. Maintain clean and dry pens.
4. Provide adequate ventilation.
5. Avoid overcrowding.
6. Clean feeders and drinkers regularly.
7. Monitor body condition and growth.
8. Control parasites and diseases.
9. Maintain breeding and farrowing records.
10. Provide suitable flooring and comfortable resting areas.

14.5 Management of poultry

Poultry are reared for meat and egg production.

Routine management practices

1. Provide feeds suitable for the age and production stage.
2. Supply clean water.
3. Maintain appropriate temperature and ventilation.
4. Clean feeders and drinkers.

5. Remove wet litter and replace it when necessary.
6. Monitor egg production and bird growth.
7. Follow appropriate vaccination programmes.
8. Control rodents and other pests.
9. Avoid overcrowding.
10. Keep records of feed consumption, mortality and production.

15.0 Record keeping in animal rearing

Record keeping is the systematic recording of important information about animals and livestock management activities.

It enables farmers to monitor production, health, reproduction and financial performance.

15.1 Importance of record keeping

1. Helps monitor animal growth and development.
2. Facilitates breeding decisions.
3. Helps monitor milk, meat and egg production.
4. Helps identify productive and unproductive animals.
5. Facilitates disease prevention and treatment monitoring.
6. Helps calculate production costs.
7. Helps determine farm profits and losses.
8. Facilitates planning and budgeting.
9. Helps monitor feed consumption.
10. Provides evidence of farm activities and animal ownership.

15.2 Types of records kept in animal rearing

A. Breeding records

These show information about mating and reproduction.

Information recorded:

- Animal identification number.
- Date of mating.
- Identification of the male parent.
- Date of expected birth.

- Actual birth date.
- Number of offspring.
- Breeding performance.

B. Health records

These contain information about animal health and veterinary care.

Information recorded:

- Animal identification.
- Date of illness.
- Signs observed.
- Diagnosis, where available.
- Treatment administered.
- Name of the attending veterinary professional.
- Follow-up observations.

C. Production records

These show the amount of products obtained from animals.

Examples:

- Daily milk production.
- Egg production.
- Body weight.
- Growth rate.
- Wool production.

D. Feeding records

These contain information about the feeds provided to animals.

Examples:

- Type of feed.
- Quantity supplied.
- Feeding dates.
- Feed costs.

- Changes in feeding programmes.

E. Financial records

These show money received and spent in livestock production.

Examples of expenses:

- Feed purchases.
- Veterinary expenses.
- Labour costs.
- Housing and equipment.
- Transport.

Examples of income:

- Milk sales.
- Sale of animals.
- Sale of eggs.
- Sale of meat.
- Sale of manure.

15.3 Sample animal management record

Date	Animal ID	Activity carried out	Observation	Person responsible
1/11/2026	G001	Feeding	Ate normally	Farmer
2/11/2026	G001	Hoof inspection	No abnormality	Farmer
3/11/2026	G001	Watering	Drank normally	Farmer
4/11/2026	G001	Health inspection	Healthy	Farmer

16.0 Animal handling and restraint

Animal handling refers to the activities involved in approaching, moving, controlling and restraining animals safely during routine management.

Restraint is the temporary restriction of an animal's movement to enable safe examination or management.

16.1 Importance of proper animal handling

1. Prevents injuries to animals.
2. Protects farm workers.
3. Reduces stress.

4. Makes routine management easier.
5. Facilitates veterinary examination.
6. Makes identification and weighing easier.
7. Supports safe transportation.
8. Improves animal welfare.

16.2 Methods of restraining domestic animals

Animal	Examples of restraint
Cattle	Crush, head gate and halter
Goats	Suitable handling pen and gentle manual restraint
Sheep	Sitting restraint or suitable handling race
Pigs	Pig boards and suitable handling pens
Poultry	Gentle manual restraint

16.3 Precautions during animal handling

1. Approach animals calmly.
2. Avoid shouting or sudden movements.
3. Understand the behaviour of the animal.
4. Use appropriate restraining equipment.
5. Avoid excessive force.
6. Avoid overcrowding during movement.
7. Ensure that floors are not slippery.
8. Seek assistance when handling large or aggressive animals.
9. Release animals safely after the procedure.
10. Observe animals for signs of stress or injury.

17.0 Animal welfare during routine management

Animal welfare refers to the physical and mental well-being of an animal in relation to the conditions in which it lives and dies.

Farmers have a responsibility to ensure that animals are treated humanely throughout their lives.

17.1 The five freedoms of animal welfare

1. Freedom from hunger and thirst: Animals should have access to adequate feed and clean drinking water.
2. Freedom from discomfort: Animals should be provided with suitable housing, shelter and resting areas.
3. Freedom from pain, injury and disease: Farmers should prevent injuries, control diseases and provide appropriate treatment.
4. Freedom to express normal behaviour: Animals should have sufficient space and suitable conditions to express natural behaviour.
5. Freedom from fear and distress: Animals should be handled calmly and protected from unnecessary suffering.

17.2 Signs of good animal welfare

- Normal feeding and drinking behaviour.
- Good body condition.
- Normal movement.
- Clean coat or feathers.
- Absence of untreated injuries.
- Normal social behaviour.
- Comfortable resting.
- Healthy growth and production.

17.3 Signs of poor animal welfare

- Loss of appetite.
- Excessive aggression or fear.
- Lameness.
- Unusual isolation.
- Injuries and wounds.
- Poor body condition.
- Abnormal behaviour.
- Persistent signs of stress.

18.0 Factors to consider when selecting animal management practices

The farmer should consider the following factors before carrying out any management practice:

1. Species of animal: Different animals require different management methods.

2. Age: Young animals may require different procedures and care from mature animals.
3. Purpose of rearing: Dairy, meat, breeding and wool animals have different management needs.
4. Animal health: Sick and weak animals may require special handling.
5. Available facilities: Appropriate housing, equipment and handling facilities should be available.
6. Cost: The farmer should consider the cost of carrying out the practice.
7. Availability of skilled labour: Some procedures require trained personnel.
8. Animal welfare: The practice should not expose animals to unnecessary pain and suffering.
9. Weather conditions: Some management activities are better carried out under suitable weather conditions.
10. Veterinary advice: Professional guidance should be sought for invasive or potentially harmful procedures.

19.0 Common challenges in animal rearing and possible solutions

Challenge	Possible solution
Disease outbreaks	Vaccination where appropriate, hygiene and veterinary care
Feed shortages	Fodder conservation, pasture improvement and feed budgeting
Water shortage	Water harvesting and reliable water storage
Parasite infestation	Appropriate parasite control and sanitation
Poor housing	Construct suitable, well-ventilated animal houses
High feed costs	Improve local feed production and formulate balanced rations
Animal injuries	Proper handling, suitable housing and equipment
Poor breeding performance	Proper selection and breeding records
Theft of animals	Identification, secure housing and record keeping
Poor market access	Market research, value addition and collective marketing

PRACTICAL LEARNING ACTIVITIES

Activity 1: Cleaning an animal house

Materials required:

- Broom.
- Spade.
- Wheelbarrow.
- Water.

- Appropriate cleaning materials.
- Protective clothing.

Procedure:

1. Observe the condition of the animal house.
2. Remove animals where necessary.
3. Collect and remove dung.
4. Remove leftover feeds and dirty bedding.
5. Clean the floor and feeding equipment.
6. Dispose of waste appropriately.
7. Replace bedding where necessary.
8. Record the activity carried out.

Reflection questions:

1. Why is sanitation important in animal rearing?
2. What diseases may be encouraged by poor sanitation?
3. How can animal waste be converted into useful farm manure?

Activity 2: Identification of domestic animals

Learners visit a livestock farm and observe the identification methods used.

They should:

1. Identify different animals.
2. Observe ear tags, tattoos, collars or other identification methods.
3. Record the identification numbers.
4. Explain the importance of animal identification.
5. Discuss the advantages and disadvantages of the methods observed.

Activity 3: Maintaining an animal management journal

Each learner selects a domestic animal such as a goat, sheep, pig or cow and maintains a journal.

Sample journal format

Date	Activity	Materials used	Observations	Lessons learnt
	Feeding			

	Watering			
	Cleaning			
	Health inspection			
	Record keeping			

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer.

1. Which one of the following best describes animal management practices?

A. Activities carried out to improve animal health and productivity.

B. Activities carried out to increase the number of farm workers.

C. Activities involving the construction of crop stores.

D. Activities involving the processing of farm crops.

2. Which one of the following is the main purpose of animal identification?

A. To increase animal body temperature.

B. To distinguish individual animals.

C. To reduce the amount of feed consumed.

D. To prevent animals from reproducing.

3. Which identification method involves attaching a numbered device to an animal's ear?

A. Branding.

B. Tattooing.

C. Ear tagging.

D. Ear notching.

4. Which one of the following is an importance of hoof trimming?

A. Increasing horn growth.

B. Improving movement and preventing lameness.

C. Increasing the number of teeth.

D. Preventing milk production.

5. The removal or permanent suppression of the reproductive ability of male animals is known as:

A. Dehorning.

B. Docking.

C. Castration.

D. Debeaking.

6. Which instrument is associated with bloodless castration?

A. Hoof knife.

B. Burdizzo.

C. Ear tag applicator.

D. Shearing machine.

7. Which one of the following is the main reason for dehorning cattle?

A. To increase milk colour.

B. To reduce horn-related injuries.

C. To increase feed wastage.

D. To prevent digestion.

8. Teat clipping may be carried out to:

A. Remove unwanted extra teats.

B. Increase the number of horns.

C. Improve hoof growth.

D. Reduce the size of the tail.

9. Teeth clipping in piglets has traditionally been used to reduce:

A. Hoof injuries.

B. Injuries caused by sharp needle teeth.

C. Horn growth.

D. Tail length.

10. Which one of the following is an important reason for tail docking in some sheep production systems?

A. Increasing wool colour.

B. Improving cleanliness around the hindquarters.

C. Increasing the number of offspring.

D. Improving horn development.

11. Debeaking is a management practice associated with:

A. Cattle.

B. Sheep.

C. Poultry.

D. Goats.

12. Which one of the following is an example of roughage?

A. Soya bean meal.

B. Fish meal.

C. Napier grass.

D. Mineral premix.

13. Which one of the following is the most important reason for maintaining sanitation in animal houses?

A. Increasing the size of the house.

B. Preventing disease transmission.

C. Reducing animal identification.

D. Increasing the number of workers.

14. The systematic recording of animal production and management activities is called:

A. Branding.

B. Record keeping.

C. Castration.

D. Disbudding.

15. Which one of the following records contains information about mating and offspring?

A. Financial records.

B. Feeding records.

C. Breeding records.

D. Production records.

16. Which one of the following is a characteristic of good animal welfare?

A. Continuous hunger.

B. Untreated injuries.

C. Adequate feed and clean water.

D. Overcrowding.

17. Which one of the following is a suitable method of identifying pigs?

A. Ear notching.

B. Hoof trimming.

C. Teat clipping.

D. Debeaking.

18. Which one of the following is a suitable practice when handling domestic animals?

A. Shouting at animals.

B. Using excessive force.

C. Approaching animals calmly.

D. Overcrowding animals.

19. Which one of the following is an important function of water in animal production?

A. Regulating body temperature.

B. Increasing horn length.

C. Preventing all diseases.

D. Replacing all feed nutrients.

20. Which value is demonstrated when learners cooperate and tolerate one another during animal management activities?

A. Peace.

B. Dishonesty.

C. Negligence.

D. Selfishness.

Section B: Structured questions

21.

a) Define animal management practices. (2 marks)

b) Explain five importance of carrying out proper animal management practices. (5 marks)

c) State three examples of domestic animals reared in Kenya. (3 marks)

22.

a) Explain four importance of feeding domestic animals. (4 marks)

b) Describe four good feeding practices in animal rearing. (4 marks)

c) Give two examples of roughages used in livestock feeding. (2 marks)

23.

a) Explain four importance of sanitation in animal rearing. (8 marks)

b) Describe three activities involved in maintaining sanitation in an animal house. (6 marks)

24.

a) Describe five methods of identifying domestic animals. (10 marks)

b) State four characteristics of a good animal identification system. (4 marks)

25.

a) Explain three importance of hoof trimming in livestock production. (6 marks)

b) State four precautions observed during hoof trimming. (4 marks)

c) Name four items of equipment used during hoof trimming. (4 marks)

26.

a) Explain four reasons for castrating male animals. (8 marks)

b) Describe two methods of castration. (4 marks)

c) State two precautions that should be observed during castration. (4 marks)

27.

a) Explain four reasons for dehorning livestock. (8 marks)

b) Describe two methods of dehorning. (4 marks)

c) State two precautions observed during dehorning. (4 marks)

28.

a) Explain three reasons why record keeping is important in animal rearing. (6 marks)

b) Identify four types of records kept in livestock production. (4 marks)

29.

a) State two reasons for debeaking poultry. (2 marks)

b) Explain three importance of proper animal handling. (6 marks)

c) State four signs of poor animal welfare. (4 marks)

30.

a) Explain five ways in which farmers can maintain animal welfare. (5 marks)

b) Describe five routine management practices carried out when rearing dairy cattle. (5 marks)

c) State three ways of demonstrating peace and love during animal management practical activities. (3 marks)

GLOSSARY OF KEY TERMS

Term	**Meaning**
Animal rearing	Keeping and managing domestic animals for useful purposes
Animal management	Activities carried out to maintain animal health and productivity
Sanitation	Maintenance of cleanliness to prevent disease
Disinfection	Destruction or reduction of harmful microorganisms on surfaces
Identification	Marking animals for individual recognition
Ear tagging	Attaching a numbered tag to an animal's ear
Ear notching	Making coded notches on an animal's ear
Branding	Marking an animal's skin for identification
Tattooing	Inserting permanent identification ink into the skin
Hoof trimming	Removing excessive hoof growth
Castration	Removing or suppressing the reproductive ability of male animals
Dehorning	Removing developed horns
Disbudding	Destroying horn-producing tissue before horns become fully developed
Teat clipping	Removing an unwanted extra teat
Teeth clipping	Shortening certain teeth, particularly piglet needle teeth
Tail docking	Removing part or all of an animal's tail
Debeaking	Trimming part of a bird's beak
Restraint	Restricting an animal's movement temporarily
Animal welfare	The physical and mental well-being of an animal
Record keeping	Systematic recording of farm activities and information

STRAND 2.0: ANIMAL PRODUCTION

SUB-STRAND 2.5: REARING SELECTED ANIMALS

Management Practices in Animal Rearing

1.0 INTRODUCTION TO REARING SELECTED ANIMALS

Animal rearing is the practice of keeping, feeding, breeding, protecting and managing domestic animals to obtain useful products and services.

Animal production is an important agricultural activity in Kenya. It contributes to household food security, employment creation, income generation, industrial development and national economic growth.

Farmers rear different types of animals depending on their climatic conditions, available resources, production objectives, market demand and cultural practices.

1.1 Examples of domestic animals reared in Kenya

1. Cattle

Cattle are large domestic ruminants kept for various agricultural and economic purposes.

Products and benefits obtained from cattle include:

- Milk for human consumption and processing.
- Beef for human consumption.
- Hides for leather production.
- Manure for improving soil fertility.
- Draught power for ploughing and transportation in some farming systems.
- Income through the sale of live animals and animal products.

Examples of cattle breeds include Friesian, Ayrshire, Jersey, Guernsey, Sahiwal and Boran.

2. Goats

Goats are hardy domestic ruminants that can survive under different environmental conditions.

Products and benefits include:

- Meat, commonly called chevon.
- Milk for human consumption.
- Skins for leather and other products.
- Manure for crop production.
- Income from the sale of live animals.

Examples of goat breeds include Galla, Small East African, Toggenburg, Saanen and Alpine.

3. Sheep

Sheep are domestic ruminants mainly reared for meat, wool and skins.

Products and benefits include:

- Mutton and lamb.
- Wool from wool-producing breeds.
- Skins and hides.
- Manure.

- Income from livestock sales.

Examples include Dorper, Merino, Red Maasai and Hampshire Down.

4. Pigs

Pigs are non-ruminant domestic animals mainly kept for meat production.

Products and benefits include:

- Pork.
- Processed meat products such as sausages and bacon.
- Manure for crop production.
- Income through the sale of live pigs and pork products.

Common pig breeds include Large White, Landrace, Duroc and Hampshire.

5. Poultry

Poultry refers to domesticated birds reared for eggs, meat and other products.

Examples include:

- Chicken.
- Ducks.
- Turkeys.
- Geese.
- Guinea fowls.
- Quails.

Products include eggs, meat, feathers and manure.

6. Rabbits

Rabbits are small mammals reared mainly for meat, skins and manure.

Examples of rabbit breeds include New Zealand White, Californian and Chinchilla.

7. Camels

Camels are adapted to dry environments and are particularly important in Kenya's arid and semi-arid regions.

They provide milk, meat, hides and transportation services.

8. Donkeys

Donkeys are used mainly for carrying loads and transportation, especially in rural areas.

They also provide manure and income through the sale of animals.

1.2 Importance of animal rearing in Kenya

1. Food production: Animals provide milk, meat, eggs and other nutritious foods.
2. Income generation: Farmers earn money from selling animals and their products.
3. Employment creation: Livestock farming creates employment for farmers, veterinary professionals, livestock traders, transporters and processors.
4. Manure production: Animal dung is used to produce organic manure, improving soil fertility.
5. Industrial raw materials: Animals provide hides, skins, wool, feathers and other materials used in industries.
6. Draught power: Oxen are used for ploughing and other farm operations.
7. Transport: Donkeys and camels provide transportation in some communities.
8. Food security: Livestock products provide important sources of food throughout the year.
9. Savings and investment: Livestock can act as an asset that farmers sell when they need money.
10. Export earnings: Livestock and livestock products contribute to trade and foreign exchange earnings.

2.0 ANIMAL MANAGEMENT PRACTICES

Animal management practices are the routine and specialised activities carried out by farmers to maintain animal health, comfort, growth, reproduction and productivity.

These practices ensure that animals are provided with appropriate environmental conditions and are protected against diseases, injuries, nutritional deficiencies and unnecessary suffering.

2.1 Categories of animal management practices

Animal management practices can be classified into the following categories.

A. Routine management practices

These are activities carried out regularly to maintain the health and productivity of animals.

Examples:

- Feeding.
- Watering.
- Cleaning animal houses.
- Cleaning feeding and watering equipment.
- Inspecting animals.
- Controlling parasites.

- Milking.
- Collecting eggs.
- Keeping records.

B. Preventive management practices

These are activities carried out to prevent diseases, injuries and other problems before they occur.

Examples:

- Vaccination.
- Quarantine of newly introduced animals.
- Biosecurity.
- Proper sanitation.
- Regular health inspections.
- Appropriate identification.
- Proper housing.

C. Specialised management practices

These are particular procedures carried out on animals for specific management purposes.

Examples:

- Castration.
- Dehorning.
- Disbudding.
- Hoof trimming.
- Teat clipping.
- Teeth clipping.
- Tail docking.
- Debeaking.

D. Reproductive management practices

These are activities concerned with controlling and improving animal breeding and reproduction.

Examples:

- Selection of breeding stock.

- Heat detection.
- Mating.
- Artificial insemination.
- Pregnancy diagnosis.
- Care of pregnant animals.
- Care of newborn animals.

2.2 Importance of proper animal management practices

1. Improves animal productivity: Well-managed animals produce more milk, meat, eggs, wool and other products.
2. Prevents diseases: Proper sanitation, vaccination and parasite control reduce disease occurrence.
3. Promotes healthy growth: Adequate feeding and watering support proper development.
4. Improves reproduction: Healthy animals are more likely to reproduce successfully.
5. Reduces animal mortality: Early disease detection and proper care reduce deaths.
6. Improves animal welfare: Proper handling prevents unnecessary pain, injuries and stress.
7. Reduces production costs: Preventive management minimises losses and unnecessary veterinary expenses.
8. Improves product quality: Good hygiene and feeding improve the quality of animal products.
9. Facilitates farm management: Records help farmers monitor performance and plan activities.
10. Increases profitability: Healthy, productive animals generate higher returns for farmers.

3.0 FEEDING OF DOMESTIC ANIMALS

Feeding is the practice of providing domestic animals with appropriate food containing nutrients required for maintenance, growth, reproduction and production.

Animals require different nutrients depending on their species, age, body weight, production level, physiological condition and environmental conditions.

3.1 Importance of feeding animals

1. Provides energy: Feeds supply energy needed for movement, growth, digestion and other body activities.

2. Promotes growth: Nutrients support the development of bones, muscles and body tissues.
3. Supports production: Feeding provides nutrients needed for milk, meat, eggs and wool production.
4. Supports reproduction: Adequate nutrition improves fertility, pregnancy and reproductive performance.
5. Maintains body condition: Proper feeding prevents excessive weight loss and poor body condition.
6. Strengthens immunity: Balanced nutrition supports the body's ability to resist diseases.
7. Repairs body tissues: Proteins and other nutrients help repair damaged tissues.
8. Supports digestion: Fibre is essential for normal digestive functioning, particularly in ruminants.
9. Prevents nutritional disorders: Balanced feeding reduces deficiency diseases.
10. Improves survival: Proper feeding is particularly important for young, pregnant and lactating animals.

3.2 Nutrients required by domestic animals

A nutrient is a substance in food that an animal uses for energy, growth, maintenance and production.

The major nutrients required by animals include carbohydrates, proteins, fats, vitamins, minerals and water.

A. Carbohydrates

Carbohydrates are energy-giving nutrients that supply energy for normal body activities.

Examples of carbohydrate-rich feeds include:

- Maize.
- Wheat.
- Barley.
- Sorghum.
- Cassava.
- Molasses.

Functions of carbohydrates

1. Supply energy for movement and other activities.
2. Provide energy for growth and production.
3. Help maintain body temperature.
4. Support normal body functioning.

B. Proteins

Proteins are nutrients required for the construction, repair and maintenance of body tissues.

Examples of protein-rich feeds include:

- Soya bean meal.
- Sunflower cake.
- Cottonseed cake.
- Fish meal.
- Lucerne.
- Leguminous fodder.

Functions of proteins

1. Build muscles and other body tissues.
2. Repair worn-out body cells.
3. Support growth and development.
4. Assist in the formation of enzymes and hormones.
5. Support milk and egg production.
6. Support pregnancy and foetal development.
7. Help maintain the immune system.

C. Fats and oils

Fats and oils are concentrated sources of energy in animal feeds.

Examples include vegetable oils and fats contained in oilseed meals.

Functions

1. Provide energy.
2. Assist in maintaining body temperature.
3. Help the body absorb fat-soluble vitamins.
4. Supply essential fatty acids.
5. Support normal body functioning.

D. Vitamins

Vitamins are organic nutrients required in small quantities for normal body functioning, growth and health.

Vitamin	Main function	Common sources
Vitamin A	Maintains healthy eyes, skin and body tissues	Green fodder, carrots and vitamin

		supplements
Vitamin D	Promotes calcium and phosphorus absorption and bone development	Sunlight-assisted synthesis and supplements
Vitamin E	Protects cells and supports reproduction and immunity	Green fodder and oilseeds
Vitamin K	Supports blood clotting	Green plants and intestinal microbial synthesis
Vitamin B complex	Supports energy metabolism and nervous system functioning	Grains, green feeds and microbial synthesis

E. Minerals

Minerals are inorganic nutrients required for bone development, body regulation, reproduction and production.

Examples include calcium, phosphorus, sodium, potassium, iron, iodine, zinc and selenium.

Mineral	**Function**
Calcium	Bone and teeth development, muscle contraction and milk production
Phosphorus	Bone formation and energy metabolism
Sodium	Fluid balance and nerve functioning
Potassium	Muscle and nerve functioning
Iron	Formation of haemoglobin
Iodine	Production of thyroid hormones
Zinc	Growth, immunity and tissue repair
Selenium	Antioxidant protection and normal body functioning

F. Water

Water is an essential nutrient required by all domestic animals.

Functions of water

1. Regulates body temperature.
2. Facilitates digestion.
3. Transports nutrients.
4. Removes metabolic waste products.

5. Supports milk production.
6. Maintains body fluid balance.
7. Supports chemical reactions in the body.
8. Prevents dehydration.

3.3 Classification of animal feeds

Animal feeds are classified according to their nutrient content, fibre content and functions.

A. Roughages

Roughages are bulky feeds containing relatively high amounts of fibre.

Examples:

- Napier grass.
- Rhodes grass.
- Natural pasture.
- Hay.
- Silage.
- Maize stover.
- Lucerne.
- Desmodium.
- Sweet potato vines.

Characteristics of roughages

1. Generally contain high fibre.
2. Are usually bulky.
3. May contain considerable moisture when fresh.
4. Are important in ruminant feeding.
5. Provide energy and other nutrients depending on the plant species and quality.

Importance of roughages

- Stimulate rumination in cattle, sheep and goats.
- Support normal rumen functioning.
- Provide fibre for proper digestion.

- Supply energy.
- Reduce the cost of feeding when produced on the farm.

B. Concentrates

Concentrates are feeds with relatively high energy or protein content and lower fibre content than roughages.

They are broadly classified into energy concentrates and protein concentrates.

Energy concentrates

Examples:

- Maize germ.
- Wheat bran.
- Barley.
- Sorghum.
- Molasses.
- Rice bran.

Functions:

1. Supply energy for growth and production.
2. Supplement energy obtained from roughages.
3. Support milk and meat production.
4. Help animals maintain body condition.

Protein concentrates

Examples:

- Soya bean meal.
- Sunflower cake.
- Cottonseed cake.
- Fish meal.
- Groundnut cake.

Functions:

1. Supply protein for body growth.
2. Support milk production.

3. Assist in tissue repair.
4. Support reproduction.

C. Mineral supplements

These are substances added to animal diets to provide minerals that may be insufficient in ordinary feeds.

Examples:

- Mineral licks.
- Common salt.
- Calcium supplements.
- Phosphorus supplements.
- Commercial mineral premixes.

D. Vitamin supplements

These are preparations containing vitamins added to animal feeds when necessary to meet nutritional requirements.

E. Feed additives

Feed additives are substances incorporated into animal feeds for particular nutritional, technological or health-related purposes.

Examples include approved enzymes, probiotics, antioxidants and preservatives.

Their use should follow appropriate feeding and regulatory guidance.

3.4 Feeding practices in different domestic animals

Animal	Common feeds
Dairy cattle	Napier grass, hay, silage, dairy meal and mineral supplements
Beef cattle	Pasture, hay, crop residues and supplementary concentrates
Goats	Browse plants, pasture, hay, leguminous fodder and concentrates
Sheep	Pasture, hay, crop residues and mineral supplements

Pigs	Balanced pig rations containing energy, protein, minerals and vitamins
Layers	Chick mash, growers mash and layers mash at appropriate stages
Broilers	Broiler starter, grower and finisher feeds
Rabbits	Hay, suitable grasses, leguminous fodder and balanced pellets

3.5 Good feeding practices

1. Provide balanced feeds appropriate for the animal species.
2. Feed animals according to their age and production stage.
3. Provide adequate roughage to ruminants.
4. Supply clean water regularly.
5. Avoid mouldy and contaminated feeds.
6. Introduce new feeds gradually.
7. Feed animals at regular intervals.
8. Avoid sudden changes in feeding programmes.
9. Store feeds in dry, clean and well-ventilated stores.
10. Monitor body condition and adjust rations accordingly.
11. Provide suitable mineral supplements where necessary.
12. Prevent competition at feeding points by providing adequate feeding space.

4.0 WATERING OF DOMESTIC ANIMALS

Watering refers to providing domestic animals with sufficient clean and safe water for drinking.

Water is essential for survival, digestion, nutrient transport, temperature regulation and production.

4.1 Importance of watering

1. Prevents dehydration.
2. Regulates body temperature.
3. Facilitates digestion and absorption of nutrients.

4. Supports milk production.
5. Helps remove waste products.
6. Maintains normal blood circulation.
7. Supports growth and reproduction.
8. Maintains normal metabolic activities.
9. Supports egg production in poultry.
10. Improves feed consumption.

4.2 Sources of water for livestock

- Rivers.
- Springs.
- Boreholes.
- Wells.
- Dams.
- Rainwater harvesting systems.
- Piped water supplies.
- Water storage tanks.

4.3 Good watering practices

1. Provide clean and safe drinking water.
2. Ensure water is available regularly.
3. Clean watering troughs and drinkers.
4. Prevent contamination by dung and urine.
5. Provide enough drinking points.
6. Repair leaking water pipes.
7. Position watering equipment at appropriate heights.
8. Monitor water consumption.
9. Protect water sources from contamination.
10. Provide additional water during hot weather and periods of increased production.

5.0 SANITATION IN ANIMAL REARING

Sanitation is the maintenance of cleanliness in animal houses, feeding equipment, watering facilities and the surrounding environment to minimise the spread of disease-causing organisms.

It is one of the most important preventive practices in livestock production.

5.1 Importance of sanitation

1. Prevents disease transmission: Reduces the spread of bacteria, viruses, fungi and parasites.
2. Controls parasites: Reduces breeding places for flies and other disease vectors.
3. Improves animal comfort: Clean and dry housing provides a suitable living environment.
4. Prevents feed contamination: Clean feeding equipment reduces contamination.
5. Protects water quality: Clean watering equipment prevents contamination.
6. Reduces bad odours: Proper waste removal reduces unpleasant smells.
7. Improves product quality: Clean production environments support safe milk, meat and egg production.
8. Reduces mortality: Prevents diseases that may lead to animal deaths.
9. Improves farm workers' health: Reduces exposure to harmful microorganisms.
10. Improves farm appearance: Maintains an orderly and attractive farm environment.

5.2 Sanitation practices

A. Cleaning animal houses

This involves removing dung, urine, leftover feeds, dirty bedding and other waste materials from animal houses.

Procedure

1. Put on appropriate protective clothing.
2. Remove animals where necessary.
3. Remove leftover feeds.
4. Collect dung and other solid waste.
5. Remove soiled bedding.
6. Sweep floors and clean surfaces.
7. Wash suitable surfaces and equipment.
8. Allow the area to dry where possible.
9. Replace bedding with clean, dry material.
10. Return animals when the environment is safe.

B. Cleaning feeding equipment

Feeding equipment includes troughs, feeders, buckets and feed containers.

Procedure:

1. Remove leftover feeds.
2. Scrape off stuck feed materials.
3. Wash using clean water and suitable detergent.
4. Rinse thoroughly.
5. Allow equipment to dry.
6. Store it in a clean area.

C. Cleaning watering equipment

1. Empty dirty water.
2. Remove algae and other deposits.
3. Wash troughs and drinkers.
4. Rinse thoroughly.
5. Refill with clean water.
6. Check for leaks and damage.

D. Disinfection

Disinfection is the process of destroying or reducing harmful microorganisms on surfaces and equipment using approved disinfectants.

Examples include approved chlorine-based products, iodophors and quaternary ammonium compounds.

Procedure

1. Remove animals if necessary.
2. Remove dung and visible dirt.
3. Wash surfaces thoroughly.
4. Prepare the disinfectant according to its label.
5. Apply the disinfectant to the required surfaces.
6. Allow the recommended contact time.
7. Rinse where the product instructions require it.
8. Allow the area to dry before animals return where appropriate.

Precautions

- Use approved disinfectants.
- Follow the manufacturer's instructions.
- Wear appropriate protective equipment.
- Never mix different chemicals.
- Keep chemicals away from animal feeds and drinking water.
- Do not use disinfectants directly on animals unless specifically approved.

E. Proper disposal of animal waste

Animal waste includes dung, urine, leftover feeds, soiled bedding and other materials from livestock houses.

Methods of disposal and utilisation include:

1. Composting.
2. Biogas production.
3. Use of properly treated manure in crop production.
4. Collection and safe disposal of contaminated materials.
5. Proper drainage of wastewater.
6. Preventing waste from entering rivers and other water sources.

5.3 Difference between cleaning, disinfection and sterilisation

Practice	**Meaning**
Cleaning	Removal of dirt, dung, feed residues and other visible materials
Disinfection	Destruction or reduction of many harmful microorganisms on surfaces
Sterilisation	Complete destruction or removal of all forms of microbial life, including resistant spores

6.0 IDENTIFICATION OF DOMESTIC ANIMALS

Animal identification is the process of assigning a unique mark, number, code or device to an animal to enable individual recognition.

It is important in livestock management because many animals in a herd or flock may look alike.

6.1 Importance of animal identification

1. Distinguishes individual animals.
2. Facilitates record keeping.
3. Helps monitor growth and production.

4. Facilitates selection of breeding animals.
5. Helps identify animals requiring treatment.
6. Supports disease surveillance and tracing.
7. Helps identify animals for sale.
8. Assists in ownership verification.
9. Reduces confusion during management.
10. Helps prevent and investigate livestock theft.

6.2 Methods of animal identification

A. Ear tagging

Ear tagging is the attachment of a numbered or coded plastic or metal tag to an animal's ear using a special applicator.

Equipment required

- Ear tags.
- Ear tag applicator.
- Appropriate cleaning materials.
- Animal restraint equipment.
- Record book.

Procedure

1. Restrain the animal safely.
2. Select the correct numbered tag.
3. Examine the ear and identify a suitable application site.
4. Avoid major blood vessels and cartilage ridges.
5. Clean equipment as appropriate.
6. Position the tag correctly in the applicator.
7. Apply the tag according to the manufacturer's instructions.
8. Check that the tag is secure.
9. Record the identification number.

Advantages

1. Easy to apply.

2. Relatively affordable.
3. Easy to read.
4. Suitable for large herds.
5. Supports record keeping.

Disadvantages

1. Tags may fall off.
2. They may become damaged.
3. Incorrect application may cause infection.
4. Numbers may become difficult to read.

B. Ear notching

Ear notching involves making small coded cuts or notches along the edge of an animal's ear to represent identification numbers.

It is commonly associated with pig identification.

Advantages

- Provides a relatively permanent identification mark.
- Does not require an attached tag.
- Can identify individual animals or litters.

Disadvantages

- Causes tissue injury and pain.
- Requires correct coding.
- Incorrect notching can cause identification errors.
- May cause infection if performed poorly.

C. Branding

Branding involves marking an animal's skin with a permanent identification mark.

There are two major types:

Hot branding

This uses a heated branding instrument to produce a permanent mark on the skin.

Freeze branding

This uses an extremely cold branding instrument to affect pigment-producing cells in the hair follicles.

Advantages

1. Can provide permanent identification.
2. May be useful for ownership identification.
3. The mark is difficult to lose.

Disadvantages

1. Can cause pain and tissue damage.
2. Requires skilled personnel.
3. Poor branding may result in unclear marks.
4. Freeze branding requires specialised equipment.

D. Tattooing

Tattooing involves inserting permanent ink into the skin using special tattooing instruments.

It is commonly performed on the inner surface of the ear.

Advantages

- Provides permanent identification.
- Does not easily fall off.
- Suitable for breeding records.
- Can be used in cattle, goats and pigs.

Disadvantages

- May be difficult to read without close examination.
- Requires special equipment.
- Poor application may cause infection.

E. Neck chains and collars

This involves attaching a numbered or coded collar around the neck of an animal.

It is commonly used in small-scale cattle, goat and sheep farming.

Advantages:

- Easy to apply.
- Can be removed and replaced.
- Numbers are relatively easy to read.

Disadvantages:

- May become loose or fall off.
- Can become entangled.
- May cause injury if poorly fitted.

F. Electronic identification

Electronic identification uses devices such as radio-frequency identification (RFID) tags or transponders to assign unique identification codes to animals.

Advantages

1. Improves identification accuracy.
2. Supports digital record keeping.
3. Facilitates livestock traceability.
4. Reduces manual recording errors.
5. Helps monitor animal performance.

Disadvantages

1. Requires specialised equipment.
2. May be costly.
3. Requires technical skills.
4. Some systems depend on electronic readers and power.

6.3 Characteristics of a good identification system

- Easy to apply.
- Durable.
- Affordable.
- Easy to recognise.
- Minimises pain and injury.
- Difficult to alter or duplicate.
- Suitable for the animal species.
- Supports accurate record keeping.

7.0 HOOF TRIMMING

Hoof trimming is the careful removal of excessive hoof growth to maintain the correct hoof shape and allow normal movement.

It is commonly practised in cattle, sheep and goats.

7.1 Importance of hoof trimming

1. Prevents excessive hoof growth.
2. Maintains correct hoof shape.
3. Improves walking and movement.
4. Reduces the risk of lameness.
5. Prevents injuries caused by overgrown hooves.
6. Helps detect hoof infections.
7. Improves animal comfort.
8. Supports normal grazing and feeding.
9. Helps maintain proper weight distribution.
10. Improves livestock productivity by reducing movement difficulties.

7.2 Signs that an animal requires hoof trimming

- Excessively long hoof walls.
- Uneven hoof surfaces.
- Hoof walls curling or folding.
- Difficulty walking.
- Abnormal posture.
- Uneven weight distribution.
- Cracks and abnormal hoof growth.

7.3 Equipment used in hoof trimming

1. Hoof shears.
2. Hoof knife.
3. Hoof trimmers.
4. Restraining equipment.
5. Protective gloves.
6. Appropriate disinfectants.

7. Suitable footwear.

7.4 Procedure for hoof trimming

1. Restrain the animal: Secure the animal safely to prevent unnecessary movement.
2. Examine the hooves: Look for overgrowth, cracks, injuries and infection.
3. Clean the hooves: Remove mud, dung and other dirt.
4. Identify excess growth: Determine which portions need trimming.
5. Trim carefully: Remove excess material gradually using appropriate tools.
6. Maintain natural shape: Avoid cutting too deeply into sensitive living tissue.
7. Examine the trimmed hoof: Check for injuries, bleeding and uneven surfaces.
8. Attend to complications: Seek veterinary assistance if infection or serious injury is present.
9. Release the animal: Allow the animal to stand and walk carefully.
10. Record the procedure: Enter the date and observations in the animal management records.

7.5 Precautions during hoof trimming

1. Use clean and sharp equipment.
2. Restrain the animal correctly.
3. Avoid excessive cutting.
4. Do not cut into living tissue.
5. Avoid unnecessary force.
6. Use protective equipment.
7. Seek professional help for severe hoof problems.
8. Disinfect equipment appropriately.

8.0 CASTRATION

Castration is the removal or permanent suppression of the reproductive ability of male animals.

It is commonly practised in cattle, sheep, goats and pigs where there is a justified management or production purpose.

8.1 Importance of castration

1. Controls breeding: Prevents unwanted mating and uncontrolled reproduction.
2. Improves herd management: Makes it easier to manage males that are not selected for breeding.
3. Reduces some aggressive behaviours: May reduce certain forms of male aggression and fighting.

4. Supports fattening programmes: In some systems, castrated males are managed for meat production.
5. Prevents undesirable breeding: Prevents inferior males from passing unwanted traits to offspring.
6. Improves meat characteristics in some species: May reduce undesirable odours and flavours associated with intact males.
7. Facilitates group management: May allow easier management of some groups of animals.

8.2 Methods of castration

A. Surgical castration

This involves the removal of the testes through a surgical procedure.

Characteristics:

- Requires appropriate surgical skills.
- Involves cutting and removal of the testes.
- Requires hygienic conditions.
- Requires suitable pain relief.
- Carries risks of bleeding and infection.

B. Burdizzo method

This is a bloodless method of castration in which a special instrument called a Burdizzo crushes the spermatic cords.

Characteristics:

- Does not involve cutting the skin.
- Interrupts the blood supply to the testes.
- Requires accurate positioning.
- Incorrect application can cause incomplete castration.

C. Rubber-ring method

This method uses a special applicator to place a strong rubber ring around the neck of the scrotum in young animals.

Characteristics:

- Commonly associated with young lambs and kids.
- Restricts blood supply to the tissues below the ring.
- Can cause pain and complications.
- Requires careful veterinary and welfare guidance.

8.3 Precautions during castration

1. The procedure should be performed by a trained and authorised person.
2. Appropriate pain relief should be provided.
3. Maintain hygiene.
4. Use suitable equipment.
5. Select an appropriate method for the animal.
6. Monitor the animal after the procedure.
7. Seek veterinary attention for bleeding or infection.
8. Avoid unnecessary castration.

Animal welfare note: Castration is a painful procedure. It should never be carried out casually or without appropriate welfare safeguards.

9.0 TEAT CLIPPING

Teat clipping refers to the removal of an unwanted extra teat, also known as a supernumerary teat, in certain livestock.

It may be considered in dairy animals where an extra teat interferes with milking or causes management problems.

9.1 Importance of teat clipping

1. Removes unwanted extra teats where necessary.
2. May prevent injury to extra teats.
3. May reduce interference with milking equipment.
4. Improves ease of udder management.
5. May reduce difficulties during routine milking.

9.2 Animals in which teat clipping may be considered

- Dairy cattle.
- Dairy goats.
- Dairy sheep.

9.3 Precautions during teat clipping

1. Examine the udder before the procedure.
2. Correctly distinguish an extra teat from a functional teat.
3. Seek veterinary assessment.

4. Provide suitable pain relief.
5. Maintain hygienic conditions.
6. Monitor the wound for bleeding and infection.

Important: Not all extra teats require removal. The procedure should only be undertaken where there is a clear management or health reason.

10.0 DEHORNING AND DISBUDDING

Dehorning is the removal of developed horns from livestock.

Disbudding is the destruction or removal of horn-producing tissue before the horns become fully developed and attached to the skull.

Both practices may be used in cattle and goats where appropriate.

10.1 Importance of dehorning

1. Reduces injuries caused by animals fighting.
2. Improves safety during handling.
3. Reduces injuries to farm workers.
4. Prevents horn-related damage to farm structures.
5. Reduces bruising during transportation.
6. Facilitates management in confined housing.
7. Reduces horn-related injuries during feeding.

10.2 Methods of dehorning and disbudding

A. Disbudding

This involves destroying horn-producing tissue while the horn buds are still developing.

It is generally preferred over removing fully developed horns because it is less invasive when properly performed.

B. Hot-iron disbudding

A specialised heated instrument is used to destroy the horn-producing tissue.

C. Chemical disbudding

An approved chemical preparation is applied to horn buds to destroy the horn-producing tissue.

It requires strict precautions to prevent chemical burns.

D. Surgical dehorning

This involves removing developed horns and associated horn-producing tissue using appropriate surgical instruments.

10.3 Precautions during dehorning

1. Use trained personnel.
2. Provide suitable pain relief.
3. Maintain hygienic conditions.
4. Avoid excessive tissue damage.
5. Protect animals from chemical burns.
6. Monitor for bleeding and infection.
7. Seek veterinary help where necessary.
8. Avoid unnecessary dehorning.

Alternative to dehorning: Farmers can select naturally polled cattle breeds or breeding lines where suitable.

11.0 TEETH CLIPPING

Teeth clipping refers to the careful shortening of certain teeth, particularly the sharp needle teeth of young piglets.

It has traditionally been used to reduce injuries during suckling and fighting.

11.1 Teeth found in young piglets

Piglets are born with eight sharp needle teeth:

- Four upper canine teeth.
- Four lower canine teeth.

These teeth may cause injuries to the sow's teats and other piglets under certain conditions.

11.2 Importance of teeth clipping

1. May reduce injuries to the sow's teats.
2. May reduce facial injuries among piglets.
3. May reduce wounds caused by sharp teeth.
4. May improve comfort during suckling where tooth-related injuries occur.

11.3 Precautions during teeth clipping

1. Only undertake it when there is a clear need.

2. Use suitable equipment.
3. Avoid cutting into the gums.
4. Avoid splitting or crushing the teeth.
5. Maintain hygiene.
6. Use trained personnel.
7. Monitor piglets for injuries and infection.

Note: Routine teeth clipping is not recommended as an automatic practice. Good management should be prioritised, and veterinary guidance should be followed.

12.0 TAIL DOCKING

Tail docking is the removal of part or all of an animal's tail for specific management or welfare reasons.

It is commonly associated with sheep production and has also been practised in some pig production systems.

12.1 Reasons for tail docking in sheep

1. Helps maintain cleanliness around the hindquarters in some systems.
2. Reduces accumulation of dung and urine around the tail.
3. May help reduce the risk of flystrike under appropriate conditions.
4. Facilitates inspection of the hindquarters.
5. Makes certain hygiene management practices easier.

12.2 Reasons for tail docking in pigs

Tail docking has traditionally been practised to reduce injuries associated with tail biting.

However, tail biting is strongly influenced by environmental and management factors. Better housing, sufficient space, environmental enrichment and appropriate nutrition should be prioritised.

12.3 Methods of tail docking

A. Rubber-ring method

A special rubber ring is placed around the tail to restrict blood supply to the part being removed.

B. Surgical method

Part of the tail is removed using appropriate surgical equipment under suitable pain relief and hygienic conditions.

C. Hot-iron method

A specialised instrument is used to cut and cauterise the tail.

12.4 Precautions during tail docking

1. Avoid unnecessary docking.
2. Follow animal-welfare requirements.
3. Use trained personnel.
4. Provide suitable pain relief.
5. Maintain hygienic conditions.
6. Avoid removing excessive portions of the tail.
7. Monitor the animal for bleeding and infection.
8. Seek veterinary attention if complications occur.

13.0 DEBEAKING IN POULTRY

Debeaking, commonly referred to as beak trimming, is the trimming of part of a bird's beak using specialised equipment.

It has traditionally been practised in some poultry production systems to reduce harmful pecking behaviour.

13.1 Reasons for debeaking

1. May reduce severe feather pecking.
2. May reduce injuries caused by aggressive pecking.
3. May help control cannibalism under certain conditions.
4. May reduce damage to eggs caused by pecking.
5. May reduce injuries in some intensive poultry systems.

13.2 Equipment used

- Specialised beak-trimming equipment.
- Appropriate measuring guides.
- Restraining equipment.
- Cleaning and maintenance materials.

13.3 Precautions during debeaking

1. Avoid unnecessary beak trimming.
2. Use trained personnel.

3. Follow animal-welfare requirements.
4. Avoid excessive removal of beak tissue.
5. Maintain proper hygiene.
6. Monitor birds for feeding and drinking difficulties.
7. Provide suitable feeders and drinkers.
8. Address causes of pecking behaviour.

13.4 Alternatives to debeaking

- Avoid overcrowding.
- Provide sufficient feeders and drinkers.
- Maintain appropriate lighting.
- Provide environmental enrichment.
- Supply balanced feeds.
- Reduce stress.
- Maintain good poultry-house ventilation.

14.0 RECORD KEEPING IN ANIMAL REARING

Record keeping is the systematic collection and recording of information about animals, production, feeding, health, reproduction and farm expenditure.

It is an important management tool because it helps farmers make informed decisions.

14.1 Importance of record keeping

1. Monitoring growth: Helps determine whether animals are growing properly.
2. Monitoring production: Helps establish milk, meat and egg production levels.
3. Breeding management: Helps monitor mating, pregnancy and births.
4. Disease management: Helps track illness, vaccination and treatment.
5. Financial management: Helps calculate production costs and income.
6. Selection: Helps identify animals with superior production performance.
7. Planning: Helps farmers plan feeding, breeding and marketing activities.
8. Feed management: Helps monitor feed consumption and wastage.
9. Livestock identification: Links animal performance to individual identification numbers.
10. Farm evaluation: Helps determine whether livestock enterprises are profitable.

14.2 Types of records kept in animal rearing

A. Breeding records

These contain information about mating and reproduction.

Information includes:

- Animal identification number.
- Date of mating.
- Male parent identification.
- Date of expected birth.
- Actual birth date.
- Number of offspring.
- Reproductive performance.

B. Health records

These contain information about animal health and veterinary care.

Information includes:

- Animal identification.
- Date of illness.
- Signs observed.
- Diagnosis.
- Treatment administered.
- Name of veterinary professional.
- Follow-up observations.

C. Production records

These show the quantity of products obtained from animals.

Examples:

- Daily milk production.
- Egg production.
- Body weight.
- Growth rate.

- Wool production.

D. Feeding records

These show the type and quantity of feeds given to animals.

Information includes:

- Type of feed.
- Quantity supplied.
- Date of feeding.
- Feed costs.
- Changes in feeding programme.

E. Financial records

These contain information about money received and spent in livestock production.

Examples of expenditure:

- Feed purchases.
- Veterinary services.
- Labour.
- Equipment.
- Housing.
- Transportation.

Examples of income:

- Milk sales.
- Egg sales.
- Sale of animals.
- Meat sales.
- Sale of manure.

F. Mortality records

These show the number of animals that die on a farm and the possible causes of death.

G. Inventory records

These show the number of animals kept on the farm at a particular time.

14.3 Sample livestock record

Date	Animal ID	Activity	Observation	Action taken
1/11/2026	C001	Feeding	Ate normally	Routine feeding continued
2/11/2026	C001	Health inspection	No abnormal signs	No action required
3/11/2026	C001	Hoof inspection	Overgrowth observed	Referred for hoof care
4/11/2026	C001	Watering	Drank normally	Clean water supplied

15.0 ANIMAL HANDLING AND RESTRAINT

Animal handling refers to approaching, moving, controlling and managing animals during routine farm operations.

Animal restraint refers to temporarily restricting an animal's movement to enable safe examination or management.

15.1 Importance of proper animal handling

1. Prevents injuries to animals.
2. Protects farm workers from accidents.
3. Reduces stress.
4. Makes routine management easier.
5. Facilitates veterinary examinations.
6. Makes identification easier.
7. Supports safe transportation.
8. Improves animal welfare.
9. Reduces damage to equipment and facilities.
10. Makes group management more efficient.

15.2 Methods of restraining selected animals

Animal	Suitable restraint methods
Cattle	Cattle crush, head gate and halter
Goats	Handling pen and gentle manual restraint
Sheep	Suitable handling race and careful manual restraint
Pigs	Pig boards and handling pens
Poultry	Gentle manual restraint

Rabbits	Careful support of the body and hindquarters

15.3 Precautions during animal handling

1. Approach animals calmly.
2. Avoid sudden movements.
3. Understand animal behaviour.
4. Use appropriate restraint equipment.
5. Avoid excessive force.
6. Avoid overcrowding.
7. Use non-slip floors.
8. Seek assistance when handling aggressive animals.
9. Avoid causing unnecessary pain.
10. Release animals safely.

16.0 ANIMAL HOUSING AND COMFORT

Animal housing refers to the provision of suitable structures and facilities for protecting domestic animals from harsh environmental conditions, predators, theft and other dangers.

Proper housing supports animal health, comfort and productivity.

16.1 Importance of animal housing

1. Protects animals from rain, wind and excessive sunlight.
2. Provides shelter from extreme temperatures.
3. Protects animals from predators.
4. Reduces theft.
5. Facilitates feeding and watering.
6. Makes sanitation easier.
7. Provides suitable resting areas.
8. Facilitates observation and disease detection.
9. Improves management efficiency.
10. Protects young and vulnerable animals.

16.2 Characteristics of a good animal house

1. Adequate space: Animals should have sufficient room to stand, lie down and move.

2. Good ventilation: Allows fresh air to enter and reduces the accumulation of harmful gases.
3. Proper drainage: Prevents water accumulation and dampness.
4. Suitable flooring: Should be safe, comfortable and easy to clean.
5. Adequate lighting: Enables observation and supports normal activities.
6. Weather protection: Protects animals from excessive heat, cold and rain.
7. Clean water supply: Ensures animals can access drinking water.
8. Feeding facilities: Provides suitable feeding points.
9. Security: Protects animals against theft and predators.
10. Easy cleaning: The structure should allow effective sanitation.

17.0 HEALTH MANAGEMENT IN ANIMAL REARING

Health management refers to the activities carried out to maintain animal health and prevent, detect and control diseases.

17.1 Importance of health management

1. Prevents disease outbreaks.
2. Reduces animal deaths.
3. Improves production.
4. Reduces veterinary costs.
5. Protects other animals from infection.
6. Improves reproductive performance.
7. Supports food safety.
8. Maintains animal welfare.

17.2 Common signs of a healthy animal

- Active and alert behaviour.
- Good appetite.
- Normal drinking.
- Smooth coat or healthy feathers.
- Normal movement.
- Good body condition.
- Normal breathing.

- Normal droppings.
- Clear eyes.
- No abnormal discharge.

17.3 Signs of an unhealthy animal

- Loss of appetite.
- Excessive weakness.
- Isolation from other animals.
- Diarrhoea.
- Coughing.
- Abnormal breathing.
- Lameness.
- Swollen body parts.
- Unusual discharges.
- Sudden drop in production.

17.4 Disease prevention practices

1. Maintain cleanliness.
2. Provide balanced feeds.
3. Supply clean water.
4. Follow appropriate vaccination programmes.
5. Control parasites.
6. Isolate sick animals.
7. Quarantine newly introduced animals.
8. Avoid overcrowding.
9. Maintain proper ventilation.
10. Seek veterinary assistance when animals become ill.

18.0 MANAGEMENT OF SELECTED DOMESTIC ANIMALS

18.1 Management of dairy cattle

Dairy cattle are reared mainly for milk production.

Routine management practices

1. Provide adequate roughages such as Napier grass, hay and silage.
2. Supplement the ration according to milk production and body condition.
3. Provide sufficient clean drinking water.
4. Milk at regular intervals.
5. Clean and disinfect milking equipment appropriately.
6. Maintain clean, dry and well-ventilated housing.
7. Inspect hooves regularly.
8. Control ticks and other parasites.
9. Monitor for mastitis and other diseases.
10. Keep records of milk production, breeding, treatment and expenses.

18.2 Management of goats

1. Provide adequate pasture and browse.
2. Supply supplementary feeds when necessary.
3. Provide clean water.
4. Maintain dry and well-ventilated housing.
5. Clean goat houses regularly.
6. Inspect and trim hooves when required.
7. Control internal and external parasites.
8. Provide appropriate mineral supplements.
9. Separate sick animals from healthy animals.
10. Maintain breeding and kidding records.

18.3 Management of sheep

1. Provide adequate pasture.
2. Supply supplementary feeds when necessary.
3. Provide clean drinking water.
4. Maintain dry housing.
5. Inspect and trim hooves when necessary.

6. Control internal and external parasites.
7. Inspect fleece and skin for health problems.
8. Shear wool-producing breeds when appropriate.
9. Monitor lambing.
10. Maintain breeding and production records.

18.4 Management of pigs

1. Provide balanced pig rations.
2. Supply clean drinking water.
3. Maintain clean and dry pens.
4. Provide proper ventilation.
5. Avoid overcrowding.
6. Clean feeders and drinkers.
7. Monitor growth and body condition.
8. Control parasites and diseases.
9. Provide suitable resting areas.
10. Maintain breeding and farrowing records.

18.5 Management of poultry

1. Provide suitable feeds according to age and production stage.
2. Supply clean water.
3. Maintain appropriate temperature.
4. Ensure proper ventilation.
5. Remove wet litter.
6. Clean feeders and drinkers.
7. Follow suitable vaccination programmes.
8. Control rodents and other pests.
9. Avoid overcrowding.
10. Keep records of mortality, feed consumption and production.

19.0 ANIMAL WELFARE

Animal welfare refers to the physical and mental well-being of an animal in relation to the conditions in which it lives and dies.

It requires farmers to provide animals with suitable living conditions and protect them from unnecessary pain, suffering, fear, injuries and diseases.

19.1 The five freedoms of animal welfare

1. Freedom from hunger and thirst

Animals should have access to adequate feed and clean drinking water.

2. Freedom from discomfort

Animals should have suitable housing, shelter and comfortable resting areas.

3. Freedom from pain, injury and disease

Farmers should prevent injuries, control diseases and provide appropriate treatment.

4. Freedom to express normal behaviour

Animals should have sufficient space and suitable conditions to express natural behaviour.

5. Freedom from fear and distress

Animals should be handled calmly and protected from unnecessary suffering.

19.2 Signs of good animal welfare

- Normal feeding and drinking.
- Good body condition.
- Normal movement.
- Healthy coat or feathers.
- Absence of untreated injuries.
- Comfortable resting.
- Normal social behaviour.
- Healthy growth and production.

19.3 Signs of poor animal welfare

- Persistent hunger or thirst.
- Poor body condition.
- Lameness.
- Untreated wounds.

- Abnormal behaviour.
- Excessive fear.
- Aggression caused by poor management.
- Overcrowding.
- Lack of shelter.
- Persistent discomfort.

19.4 Ways of promoting animal welfare

1. Provide sufficient feed and water.
2. Construct suitable housing.
3. Handle animals gently.
4. Avoid unnecessary painful procedures.
5. Provide veterinary care.
6. Maintain good sanitation.
7. Avoid overcrowding.
8. Provide adequate resting space.
9. Protect animals from extreme weather.
10. Follow appropriate animal-welfare guidelines.

21.0 PRACTICAL LEARNING ACTIVITIES

Practical Activity 1: Cleaning an animal house

Learning objective: To develop skills in maintaining sanitation in animal rearing.

Materials required

- Broom.
- Spade.
- Wheelbarrow.
- Water.

- Appropriate cleaning agents.
- Protective clothing.

Procedure

1. Observe the condition of the animal house.
2. Identify areas requiring cleaning.
3. Remove leftover feeds.
4. Collect dung and other waste.
5. Remove dirty bedding.
6. Sweep the floor.
7. Clean feeding and watering equipment.
8. Wash suitable surfaces.
9. Allow the area to dry.
10. Replace bedding where necessary.
11. Dispose of waste appropriately.
12. Record the activity.

Reflection questions

1. Why is sanitation important in animal production?
2. What problems may result from poor sanitation?
3. How can animal waste be converted into useful manure?

Practical Activity 2: Identification of domestic animals

Learning objective: To identify and describe methods used to identify domestic animals.

Procedure

1. Visit a livestock farm.
2. Observe different animals.
3. Identify the identification methods used.
4. Record identification numbers.
5. Explain the importance of identification.

6. Compare the advantages and disadvantages of different methods.

Practical Activity 3: Animal management journal

Each learner selects a domestic animal such as a goat, sheep, pig or cow and maintains a journal of management activities.

Date	Activity	Materials used	Observations	Lessons learnt
	Feeding			
	Watering			
	Cleaning			
	Health inspection			
	Record keeping			

22.0 CHALLENGES IN ANIMAL REARING AND POSSIBLE SOLUTIONS

Challenge	Explanation	Possible solution
Feed shortage	Insufficient feed during dry seasons	Fodder conservation and feed budgeting
Water shortage	Inadequate clean water	Water harvesting and storage
Disease outbreaks	Infections reduce productivity	Vaccination where appropriate, sanitation and veterinary care
Parasite infestation	Ticks, lice and internal parasites affect health	Appropriate parasite control
Poor housing	Inadequate shelter causes discomfort	Construct suitable animal houses
High feed costs	Commercial feeds may be expensive	Improve on-farm feed production
Animal theft	Loss of livestock reduces income	Identification and secure housing
Poor breeding	Unproductive animals reduce output	Proper selection and breeding management
Labour shortage	Inadequate workers affect daily activities	Improve farm organisation
Poor market access	Farmers may fail to sell products profitably	Market research and collective marketing

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer.

1. Which one of the following best describes animal management practices?

A. Activities carried out to improve animal health and productivity.

B. Activities carried out to increase the number of farm workers.

C. Activities involving the construction of crop stores.

D. Activities involving the processing of farm crops.

2. Which one of the following is the main purpose of animal identification?

A. To increase animal body temperature.

B. To distinguish individual animals.

C. To reduce the amount of feed consumed.

D. To prevent animals from reproducing.

3. Which identification method involves attaching a numbered device to an animal's ear?

A. Branding.

B. Tattooing.

C. Ear tagging.

D. Ear notching.

4. Which one of the following is an importance of hoof trimming?

A. Increasing horn growth.

B. Improving movement and preventing lameness.

C. Increasing the number of teeth.

D. Preventing milk production.

5. The removal or permanent suppression of the reproductive ability of male animals is known as:

A. Dehorning.

B. Docking.

C. Castration.

D. Debeaking.

6. Which instrument is associated with bloodless castration?

A. Hoof knife.

B. Burdizzo.

C. Ear tag applicator.

D. Shearing machine.

7. Which one of the following is the main reason for dehorning cattle?

A. To increase milk colour.

B. To reduce horn-related injuries.

C. To increase feed wastage.

D. To prevent digestion.

8. Teat clipping may be carried out to:

A. Remove unwanted extra teats.

B. Increase the number of horns.

C. Improve hoof growth.

D. Reduce the size of the tail.

9. Teeth clipping in piglets has traditionally been used to reduce:

A. Hoof injuries.

B. Injuries caused by sharp needle teeth.

C. Horn growth.

D. Tail length.

10. Which one of the following is an important reason for tail docking in some sheep production systems?

A. Increasing wool colour.

B. Improving cleanliness around the hindquarters.

C. Increasing the number of offspring.

D. Improving horn development.

11. Debeaking is a management practice associated with:

A. Cattle.

B. Sheep.

C. Poultry.

D. Goats.

12. Which one of the following is an example of roughage?

A. Soya bean meal.

B. Fish meal.

C. Napier grass.

D. Mineral premix.

13. Which one of the following is the most important reason for maintaining sanitation in animal houses?

A. Increasing the size of the house.

B. Preventing disease transmission.

C. Reducing animal identification.

D. Increasing the number of workers.

14. The systematic recording of animal production and management activities is called:

A. Branding.

B. Record keeping.

C. Castration.

D. Disbudding.

15. Which one of the following records contains information about mating and offspring?

A. Financial records.

B. Feeding records.

C. Breeding records.

D. Production records.

16. Which one of the following is a characteristic of good animal welfare?

A. Continuous hunger.

B. Untreated injuries.

C. Adequate feed and clean water.

D. Overcrowding.

17. Which one of the following is a suitable method of identifying pigs?

A. Ear notching.

B. Hoof trimming.

C. Teat clipping.

D. Debeaking.

18. Which one of the following is a suitable practice when handling domestic animals?

A. Shouting at animals.

B. Using excessive force.

C. Approaching animals calmly.

D. Overcrowding animals.

19. Which one of the following is an important function of water in animal production?

A. Regulating body temperature.

B. Increasing horn length.

C. Preventing all diseases.

D. Replacing all feed nutrients.

20. Which value is demonstrated when learners cooperate and tolerate one another during animal management activities?

A. Peace.

B. Dishonesty.

C. Negligence.

D. Selfishness.

Section B: Structured questions

21.

a) Define animal management practices. (2 marks)

b) Explain five importance of carrying out proper animal management practices. (5 marks)

c) State three examples of domestic animals reared in Kenya. (3 marks)

22.

a) Explain four importance of feeding domestic animals. (4 marks)

b) Describe four good feeding practices in animal rearing. (4 marks)

c) Give two examples of roughages used in livestock feeding. (2 marks)

23.

a) Explain four importance of sanitation in animal rearing. (8 marks)

b) Describe three activities involved in maintaining sanitation in an animal house. (6 marks)

24.

a) Describe five methods of identifying domestic animals. (10 marks)

b) State four characteristics of a good animal identification system. (4 marks)

25.

a) Explain three importance of hoof trimming in livestock production. (6 marks)

b) State four precautions observed during hoof trimming. (4 marks)

c) Name four items of equipment used during hoof trimming. (4 marks)

26.

a) Explain four reasons for castrating male animals. (8 marks)

b) Describe two methods of castration. (4 marks)

c) State two precautions that should be observed during castration. (4 marks)

27.

a) Explain four reasons for dehorning livestock. (8 marks)

b) Describe two methods of dehorning. (4 marks)

c) State two precautions observed during dehorning. (4 marks)

28.

a) Explain three reasons why record keeping is important in animal rearing. (6 marks)

b) Identify four types of records kept in livestock production. (4 marks)

29.

a) State two reasons for debeaking poultry. (2 marks)

b) Explain three importance of proper animal handling. (6 marks)

c) State four signs of poor animal welfare. (4 marks)

30.

a) Explain five ways in which farmers can maintain animal welfare. (5 marks)

b) Describe five routine management practices carried out when rearing dairy cattle. (5 marks)

c) State three ways of demonstrating peace and love during animal management practical activities. (3 marks)

GLOSSARY OF KEY TERMS

Term	**Meaning**
Animal rearing	Keeping and managing domestic animals for useful purposes
Animal management	Activities carried out to maintain animal health and productivity
Roughage	Bulky feed containing relatively high fibre
Concentrate	Feed with relatively high energy or protein and lower fibre
Nutrient	Substance required by an animal for growth, maintenance and production
Sanitation	Maintenance of cleanliness to prevent disease
Cleaning	Removal of visible dirt and waste

Disinfection	Destruction or reduction of harmful microorganisms on surfaces
Sterilisation	Complete destruction or removal of microbial life
Identification	Marking animals for individual recognition
Ear tagging	Attaching a numbered tag to an animal's ear
Ear notching	Making coded notches on an animal's ear
Branding	Marking an animal's skin for identification
Tattooing	Inserting permanent identification ink into the skin
Hoof trimming	Removal of excessive hoof growth
Castration	Removal or suppression of male reproductive ability
Dehorning	Removal of developed horns
Disbudding	Destruction of developing horn-producing tissue
Teat clipping	Removal of an unwanted extra teat
Teeth clipping	Shortening certain teeth, particularly piglet needle teeth
Tail docking	Removal of part or all of an animal's tail
Debeaking	Trimming part of a bird's beak
Restraint	Temporary restriction of an animal's movement
Animal welfare	Physical and mental well-being of animals
Record keeping	Systematic recording of livestock information
Biosecurity	Measures used to prevent introduction and spread of diseases

KEY TAKEAWAYS

Successful animal rearing requires proper feeding, watering, sanitation, identification, health management, suitable housing, handling and record keeping.

Specialised procedures such as castration, dehorning, teat clipping, teeth clipping, tail docking and debeaking must only be undertaken where justified, with appropriate professional guidance and animal-welfare safeguards.

A competent livestock farmer should be able to:

- Identify the management needs of different domestic animals.
- Carry out routine feeding, watering and sanitation.
- Recognise signs of healthy and unhealthy animals.

- Maintain accurate animal management records.
- Handle animals safely and humanely.
- Demonstrate responsibility, peace, love and concern for animal welfare.

STRAND 2.0: ANIMAL PRODUCTION

SUB-STRAND 2.6: LIVESTOCK PRODUCTION PRODUCTS

OBTAINING SELECTED LIVESTOCK PRODUCTS

1. Wool Shearing

2. Milking of Dairy Animals

PART I: OBTAINING WOOL FROM SHEEP

1.0 INTRODUCTION TO WOOL PRODUCTION

Wool is a natural animal fibre obtained mainly from the fleece of sheep. It grows from the skin of the sheep and forms a protective covering over the animal's body.

Wool is an important livestock product used in textile and clothing industries. It is processed into yarn, fabrics, blankets, carpets, sweaters and other products.

Wool production involves keeping suitable sheep breeds, maintaining their health and nutrition, harvesting the fleece through shearing, sorting, grading, cleaning and storing the wool appropriately.

Wool shearing is the process of cutting and removing the fleece from the body of a sheep using appropriate shearing equipment.

Shearing is an important livestock management operation because it enables farmers to harvest wool for sale and processing while improving the comfort and cleanliness of sheep.

1.1 Importance of wool production

1. Source of income: Farmers earn money by selling raw wool to wool processors, textile industries and traders.
2. Employment creation: Wool production creates employment for sheep farmers, shearers, wool sorters, transporters and textile workers.
3. Raw material for industries: Wool is used in textile and garment industries to manufacture different products.
4. Export earnings: Wool and wool products can contribute to foreign exchange earnings through international trade.
5. Supports rural livelihoods: Sheep rearing provides income and employment opportunities in rural communities.
6. Value addition: Raw wool can be processed into yarn, blankets, carpets, clothing and other valuable products.
7. Utilisation of marginal lands: Some sheep breeds can graze on pasture in areas where crop production may be limited.
8. Diversification of farm income: Wool production provides an additional source of income alongside meat, skins and other livestock products.

1.2 Characteristics of good wool

Good-quality wool has the following characteristics:

1. Fine fibres: The fibres are relatively small in diameter, making the wool soft and suitable for fine textiles.
2. Good length: Fibres have sufficient length for spinning into yarn.
3. Strength: The fibres resist breaking during processing.
4. Elasticity: Wool fibres can stretch and return towards their original shape.
5. Crimp: Good wool fibres have natural waves or bends that contribute to elasticity and bulk.
6. Cleanliness: The fleece contains minimal dirt, vegetable matter, dung and other contaminants.

7. Uniformity: Fibres have relatively consistent characteristics throughout the fleece.
8. Good colour: White or naturally suitable colour is desirable for many textile applications.
9. Softness: Fine wool is generally soft and comfortable when used in clothing.
10. Fibre density: A suitable fleece has adequate fibre coverage and density.

1.3 Sheep breeds kept for wool production

Different sheep breeds produce wool of varying quality, quantity and fibre characteristics.

Sheep breed	Characteristics	Main use
Merino	Produces fine, soft and high-quality wool	Fine clothing and textile products
Rambouillet	Produces fine wool and has a relatively large body	Wool and meat
Corriedale	Produces medium wool and is dual-purpose	Wool and meat
Lincoln	Produces long, lustrous wool fibres	Long-wool textile products
Romney	Produces relatively strong medium-to-long wool	Wool and meat

Note: Merino is particularly well known for fine-wool production. The suitability of a breed depends on climate, feeding, management and the farmer's production objectives.

2.0 WOOL SHEARING

Wool shearing is the removal of the fleece from a sheep's body using suitable shearing equipment.

Shearing is usually carried out when the fleece has grown sufficiently for harvesting and when environmental conditions are suitable for the welfare of the sheep.

It should be performed carefully to avoid cutting the animal's skin, causing unnecessary stress or contaminating the fleece.

2.1 Importance of shearing sheep

1. Harvesting wool: Shearing enables farmers to obtain wool for sale and processing.
2. Improves animal comfort: Removing excessive fleece helps sheep remain comfortable, particularly in warm conditions.
3. Promotes cleanliness: Shearing removes fleece that may contain accumulated dirt, dung and other contaminants.
4. Facilitates health inspection: The farmer can examine the skin for wounds, parasites, infections and other abnormalities.
5. Reduces fleece contamination: Timely shearing may reduce the accumulation of dirt and vegetable matter in the fleece.
6. Facilitates management: Shorter fleece makes it easier to inspect and handle sheep.

7. Improves hygiene around the animal: Removing heavily soiled fleece can help maintain cleanliness.
8. Supports commercial production: Regular harvesting enables farmers to market wool at appropriate intervals.

2.2 Considerations when planning wool shearing

Before shearing, a farmer should consider the following factors:

A. Condition of the sheep

- The sheep should be healthy enough to undergo shearing.
- Sick, weak or injured animals require special attention and may need veterinary assessment before shearing.
- Pregnant ewes should be handled carefully to avoid stress and injury.
- Animals should be checked for wounds and skin infections.

B. Weather conditions

- Shearing should be carried out when weather conditions are suitable.
- Avoid exposing freshly shorn sheep to extreme cold, heavy rain or strong winds.
- Provide shelter for sheep after shearing.
- Plan shearing to reduce the risk of heat or cold stress.

C. Length and condition of the fleece

- The fleece should have grown sufficiently to justify harvesting.
- Wool should not be excessively contaminated with mud, dung or vegetable matter.
- The fleece should be reasonably dry before shearing.

D. Availability of equipment

- Ensure that suitable shearing equipment is available.
- Equipment should be clean, sharp and in good working condition.
- Provide appropriate protective equipment for workers.

E. Availability of skilled labour

- Shearing should be performed by trained or experienced personnel.
- Skilled shearers minimise skin cuts, injuries and fleece damage.
- Adequate labour should be available to complete the operation without rushing.

F. Safety and animal welfare

- Sheep should be restrained gently.
- Avoid excessive force and rough handling.
- Prevent cuts and injuries.
- Provide first aid and veterinary assistance when necessary.

G. Market requirements

- Consider wool quality standards required by buyers.
- Avoid contamination that may reduce the market value.
- Ensure that wool is sorted, packed and stored appropriately.

2.3 Equipment used in wool shearing

Equipment	Function
Electric shearing machine	Cuts and removes wool fleece efficiently
Hand shears	Used for manual shearing
Shearing comb	Guides and separates wool during cutting
Cutter blades	Cut wool fibres during machine shearing
Restraining equipment	Helps hold sheep safely during shearing
Protective clothing	Protects the shearer from dirt and injury
Wool sorting table	Provides a clean surface for sorting fleece
Wool sacks or bales	Used for packaging harvested wool
First-aid kit	Provides basic care for minor injuries
Cleaning equipment	Removes dirt and wool residues from the shearing area

2.4 Preparation before shearing

Proper preparation helps improve the quality of wool and reduces injuries.

1. Select the sheep: Identify sheep that are ready for shearing.
2. Inspect the animals: Check their health and identify any injuries or abnormalities.
3. Prepare the shearing area: Ensure the area is clean, dry, spacious and well-lit.
4. Prepare the equipment: Check shears, combs, cutters and other tools.
5. Clean the equipment: Remove dirt and wool residues and ensure equipment is hygienic.

6. Prepare the workers: Ensure shearers understand safe handling and shearing techniques.
7. Prepare the sheep: Keep sheep in a clean holding area and prevent unnecessary contamination of the fleece.
8. Ensure adequate labour: Arrange sufficient workers to handle sheep, shear, sort and package the wool.
9. Prepare storage facilities: Ensure clean and dry storage space is available.
10. Prepare records: Have a record book ready to record the animals shorn and the quantity of wool obtained.

2.5 Procedure for wool shearing

Step 1: Restrain the sheep

- Hold the sheep securely but gently.
- Position it appropriately to allow access to the fleece.
- Avoid excessive force.
- Ensure the animal is comfortable and does not struggle unnecessarily.

Step 2: Position the sheep

- Place the sheep in a suitable shearing position.
- Support its body carefully.
- Ensure the shearer can access different parts of the body safely.

Step 3: Begin shearing

- Start at an appropriate part of the body using the selected shearing method.
- Use controlled, smooth movements.
- Keep the cutting equipment in the correct position.
- Avoid pressing the blades too deeply against the skin.

Step 4: Remove fleece systematically

- Shear the belly and other appropriate areas.
- Continue to the sides, back, neck and other fleece-covered parts.
- Follow an organised sequence to minimise repeated cutting.
- Aim to remove the fleece in large, clean sections where possible.

Step 5: Protect the animal

- Avoid cutting the skin.

- If a minor cut occurs, stop and provide appropriate first aid.
- Serious injuries should receive veterinary attention.
- Do not continue shearing an animal that is experiencing significant distress.

Step 6: Remove the fleece

- Carefully separate the fleece from the sheep.
- Avoid pulling or tearing the fibres unnecessarily.
- Place the fleece on a clean sorting surface.

Step 7: Inspect the sheep

- Examine the skin for cuts, wounds, parasites and abnormalities.
- Provide appropriate treatment for minor injuries.
- Seek veterinary assistance for serious conditions.

Step 8: Release the sheep

- Release the sheep gently.
- Move it to a clean and sheltered area.
- Protect freshly shorn sheep from unfavourable weather.

Step 9: Sort and grade the wool

- Separate clean fleece from heavily contaminated wool.
- Remove undesirable foreign materials.
- Sort according to fibre quality, length and other characteristics.

Step 10: Package and store the wool

- Place wool in clean, dry sacks or suitable packaging.
- Label the packages appropriately.
- Store in a dry, clean and well-ventilated place.

2.6 Methods of shearing

A. Manual shearing

This involves removing wool using hand-operated shears.

Advantages

1. Requires relatively simple equipment.

2. Does not depend on electricity.
3. Can be used in small-scale sheep farms.
4. Has relatively low equipment costs.

Disadvantages

1. Takes more time.
2. Requires considerable physical effort.
3. May result in uneven shearing if the worker is inexperienced.
4. Can cause injuries if poorly performed.

B. Mechanical shearing

This involves the use of an electrically powered shearing machine.

Advantages

1. Faster than manual shearing.
2. Suitable for large flocks.
3. Reduces physical effort.
4. Can produce more uniform shearing when performed correctly.
5. Improves efficiency where many sheep are kept.

Disadvantages

1. Equipment may be expensive.
2. Requires electricity or a suitable power source.
3. Requires maintenance.
4. Poor handling may cause serious injuries.
5. Requires trained operators.

2.7 Sorting and grading of wool

Wool sorting is the separation of harvested fleece into different categories according to quality and characteristics.

Wool grading is the assessment and classification of wool according to recognised quality standards.

Factors considered when grading wool

1. Fibre diameter: Fine fibres are generally more suitable for high-quality clothing.
2. Fibre length: Fibre length affects spinning and processing.

3. Fibre strength: Strong fibres withstand processing better.
4. Fibre uniformity: Uniform fibres produce more consistent yarn.
5. Colour: Colour affects the suitability of wool for different textile products.
6. Cleanliness: Contaminated wool may have a lower market value.
7. Crimp: The natural waviness of wool fibres affects elasticity and bulk.
8. Vegetable matter: Seeds, grass and other plant materials lower wool quality.

Parts of a fleece that may be separated during sorting

- Main fleece: Wool covering the major parts of the sheep's body.
- Belly wool: Wool from the underside, often more contaminated.
- Locks: Small groups or sections of wool fibres.
- Skirtings: Edges of the fleece that may contain more dirt, dung or other contamination.

2.8 Storage of wool

Proper wool storage prevents contamination, moisture damage and deterioration before sale or processing.

Requirements for proper wool storage

1. Store wool in a clean building.
2. Ensure the store is dry.
3. Provide good ventilation.
4. Protect wool from rain and moisture.
5. Keep wool away from chemicals and fuels.
6. Protect wool from rodents and other pests.
7. Use clean sacks or suitable packaging.
8. Separate different grades of wool.
9. Label packages clearly.
10. Keep records of quantities stored and sold.

Problems associated with poor wool storage

- Mould development.
- Bad odours.
- Contamination.

- Discolouration.
- Reduced fibre quality.
- Reduced market value.
- Losses through pests and moisture damage.

2.9 Safety precautions during shearing

1. Use sharp, well-maintained shearing equipment.
2. Ensure shearers are trained.
3. Restrain sheep gently.
4. Avoid cutting too close to the skin.
5. Keep the shearing area clean and dry.
6. Wear suitable protective clothing and footwear.
7. Keep electrical equipment away from wet areas.
8. Disconnect electric equipment before maintenance.
9. Avoid overcrowding sheep in the holding area.
10. Provide first aid for minor injuries.
11. Seek veterinary attention for serious injuries.
12. Protect freshly shorn sheep from cold, rain and excessive sunlight.

2.10 Records kept during wool production

Record	**Information recorded**
Sheep identification record	Identification number and breed
Shearing record	Date each sheep was shorn
Wool production record	Quantity of wool obtained
Wool quality record	Grade and characteristics of wool
Labour record	Names or number of shearers and work done
Equipment record	Equipment used and maintenance carried out
Sales record	Quantity sold, buyer and selling price
Health record	Injuries or health conditions observed during shearing

Importance of wool production records

- Helps monitor wool production per sheep.
- Assists in identifying high-producing animals.
- Helps determine the profitability of wool production.
- Facilitates planning for future shearing.
- Supports accurate marketing and stock control.

PART II: OBTAINING MILK FROM DAIRY ANIMALS

3.0 INTRODUCTION TO MILK PRODUCTION

Milk is a nutritious liquid food produced by the mammary glands of female mammals to feed their young ones.

In livestock production, milk is obtained mainly from dairy cattle, dairy goats, sheep and camels.

Milk is an important agricultural product because it provides nutrients required for human growth, development and health. It is also processed into products such as yoghurt, cheese, butter, cream and fermented milk.

Milking is the process of extracting milk from the udder of a lactating animal using appropriate techniques and equipment.

Milking may be carried out manually using hands or mechanically using milking machines.

The production of clean milk requires proper animal health, good udder hygiene, clean equipment, hygienic milking practices, correct milk handling and suitable storage.

3.1 Importance of milk production

1. Food for human consumption: Milk is consumed as a nutritious food by people of different ages.
2. Source of income: Farmers earn money by selling fresh milk and processed dairy products.
3. Employment creation: Dairy production provides jobs for farmers, milk transporters, processors and traders.
4. Industrial raw material: Milk is used in dairy processing industries.
5. Food security: Milk provides a regular source of food for households.
6. Value addition: Milk can be processed into yoghurt, cheese, butter, ghee and other products.
7. Supports rural development: Dairy farming contributes to economic activities in rural communities.
8. Export opportunities: Dairy products can be marketed beyond local markets where quality and regulatory requirements are met.

3.2 Nutritional composition of milk

Milk contains several nutrients that make it an important food.

Component	Function in human nutrition

Water	Supports hydration and body processes
Proteins	Build and repair body tissues
Fat	Provides energy and helps absorption of fat-soluble vitamins
Lactose	Supplies energy
Calcium	Supports strong bones and teeth
Phosphorus	Supports bones and energy metabolism
Vitamins	Support growth, immunity and body functioning
Minerals	Support normal body processes

Examples of milk proteins

- Casein.
- Whey proteins.

Examples of vitamins found in milk

- Vitamin A.
- Vitamin B-group vitamins.
- Vitamin B12.
- Riboflavin.
- Vitamin D, depending on the milk and whether it is fortified.

Note: The exact composition of milk varies with animal species, breed, feed, stage of lactation and other factors.

3.3 Dairy animals and their milk products

Dairy animal	Product obtained	Important characteristics
Dairy cattle	Cow milk	Widely produced and processed into many dairy products
Dairy goats	Goat milk	Has characteristic flavour and is used fresh or processed
Dairy camels	Camel milk	Important in arid and semi-arid regions
Dairy sheep	Sheep milk	Often used in cheese and yoghurt production

3.4 Characteristics of a good dairy animal

A good dairy animal should possess characteristics that support high and sustained milk production.

1. Well-developed udder: The udder should be well attached and have functional teats.
2. Good milk-producing ability: The animal should have a history or potential for high milk production.
3. Healthy body condition: It should be neither excessively thin nor excessively fat.
4. Good health: It should be free from clinical signs of disease.
5. Good reproductive performance: It should reproduce successfully and maintain suitable calving or kidding intervals.
6. Strong feet and legs: Good legs enable the animal to move comfortably and access feed and water.
7. Good temperament: A calm animal is easier and safer to handle during milking.
8. Good feeding ability: It should have a healthy appetite and be able to consume adequate feed.
9. Well-developed mammary system: The udder should be healthy and suitable for milk production.
10. Adaptability: The animal should be able to perform well under the local climatic and management conditions.

4.0 MILK PRODUCTION IN DAIRY ANIMALS

4.1 The mammary gland

The mammary gland is the milk-producing organ of female mammals.

In dairy cattle and goats, the mammary gland forms the udder.

The udder contains milk-producing tissue, milk ducts and teats through which milk is released.

Main parts of the udder

1. Mammary alveoli

- These are small sac-like structures found within the milk-producing tissue.
- They contain milk-secreting cells.
- Milk is produced and stored temporarily within the alveoli.

2. Milk ducts

- These are small tubes that carry milk from the alveoli towards the larger milk channels.
- They help transport milk within the udder.

3. Milk cistern

- This is a space where milk collects before passing towards the teat.
- It helps temporarily hold milk before milking.

4. Teat cistern

- This is the internal space within the teat where milk collects.
- It allows milk to flow towards the teat opening.

5. Teat canal

- This is a narrow passage at the end of the teat.
- Milk passes through this canal during milking.
- It also helps protect the udder against the entry of microorganisms.

6. Teat opening

- This is the external opening through which milk leaves the teat.

4.2 Milk synthesis

Milk synthesis is the process by which mammary gland cells produce milk using nutrients transported through the blood.

The process involves:

1. Digested nutrients are absorbed into the bloodstream.
2. Blood transports nutrients to the mammary gland.
3. Milk-producing cells use these nutrients to manufacture milk components.
4. Milk is secreted into the alveoli.
5. Milk collects in the ducts and other storage spaces within the udder.
6. Milk is released during the milking process.

4.3 Milk let-down reflex

Milk let-down is the process through which milk is released from the alveoli into the milk ducts and towards the teat.

It is controlled mainly by the hormone oxytocin.

How milk let-down occurs

1. The farmer prepares the animal for milking.
2. The animal receives sensory stimulation through udder washing, teat preparation, calf presence or the normal milking routine.
3. Nerve signals are transmitted to the brain.
4. The pituitary gland releases oxytocin into the bloodstream.
5. Oxytocin reaches the mammary gland.

6. Special cells surrounding the alveoli contract.
7. Milk is pushed towards the ducts and teat cisterns.
8. Milk becomes available for removal through milking.

Factors that may interfere with milk let-down

- Fear and stress.
- Pain.
- Rough handling.
- Sudden changes in milking routine.
- Loud noise.
- Poor handling of the animal.
- Inadequate stimulation before milking.

Ways of promoting proper milk let-down

1. Handle the animal calmly.
2. Maintain a regular milking routine.
3. Prepare the udder gently.
4. Avoid shouting and unnecessary noise.
5. Ensure the animal is comfortable.
6. Avoid causing pain or fear.

5.0 CONSIDERATIONS WHEN OBTAINING MILK FROM DAIRY ANIMALS

Before, during and after milking, a farmer should consider several factors to ensure that milk is obtained safely, hygienically and efficiently.

5.1 Health condition of the dairy animal

- The animal should be healthy and free from clinical signs of infectious disease.
- The udder should be examined for swelling, pain, wounds and abnormalities.
- Animals suspected of having mastitis should be assessed.
- Milk from animals under treatment should be handled according to veterinary advice and withdrawal periods.
- Milk from animals with conditions that make it unsafe for consumption should not enter the human food supply.

5.2 Cleanliness of the animal

- The animal's body should be reasonably clean.
- The udder and teats should be free from dung, mud and other dirt.
- Hair around the udder may be managed where necessary to reduce contamination.
- The tail should be kept from contaminating the udder and milk.

5.3 Cleanliness of the milking environment

- The milking area should be clean and dry.
- It should be free from excessive dust.
- The floor should be easy to clean.
- There should be adequate lighting.
- The area should be well ventilated.
- Flies and other pests should be controlled.
- Animals should be protected from unnecessary disturbance.

5.4 Personal hygiene of the milker

The person milking the animal should:

1. Wash hands with clean water and soap before milking.
2. Keep fingernails short and clean.
3. Wear clean clothing or protective clothing.
4. Cover cuts and wounds with suitable waterproof dressings.
5. Avoid milking when suffering from a condition that could contaminate milk.
6. Avoid coughing or sneezing over milk and equipment.
7. Avoid handling milk with dirty hands.
8. Maintain personal cleanliness throughout the milking process.

5.5 Cleanliness of milking equipment

Equipment used during milking should be clean and suitable for food contact.

Examples include:

- Stainless-steel milk buckets.
- Milking cans.
- Teat-cleaning materials.

- Udder towels.
- Milking machines.
- Milk filters or strainers.
- Milk storage containers.

Important considerations

- Avoid rusty or dirty containers.
- Do not use containers previously used for chemicals or fuel.
- Wash and sanitise equipment appropriately.
- Allow equipment to drain and dry hygienically.
- Protect clean equipment from dust and insects.

5.6 Milking technique

- Use the correct milking method.
- Avoid pulling or injuring teats.
- Milk gently and consistently.
- Avoid leaving milk in the udder unnecessarily.
- Avoid excessive force.
- Follow a regular milking routine.
- Ensure that milk is collected in clean containers.

5.7 Milking time and frequency

- Milk animals at regular times.
- Maintain a consistent milking schedule.
- The frequency depends on the species, production level and management system.
- Dairy cattle are commonly milked twice daily, although some systems use other schedules.
- Goats and camels are milked according to their production systems and management requirements.

5.8 Record keeping

The farmer should record:

- Animal identification number.
- Date and time of milking.

- Quantity of milk obtained.
- Milk quality observations.
- Health condition of the animal.
- Treatment and withdrawal information where applicable.
- Milk sold or stored.
- Any unusual occurrence during milking.

5.9 Milk storage and transportation

- Milk should be protected from contamination.
- It should be cooled promptly after milking.
- Use clean, food-grade containers.
- Maintain the cold chain during transportation.
- Avoid prolonged exposure to high temperatures.
- Follow applicable milk safety and regulatory requirements.

6.0 MILKING EQUIPMENT AND THEIR FUNCTIONS

6.1 Manual milking equipment

Equipment	Function
Stainless-steel milking bucket	Collects milk during manual milking
Milk can	Holds and transports milk
Udder towel	Cleans and dries the udder and teats
Clean water container	Supplies water for washing
Food-safe detergent	Cleans milking equipment
Approved sanitiser	Reduces microorganisms on equipment
Milk filter or strainer	Removes visible physical particles from milk
Milking stool	Provides a comfortable working position
Teat dip cup	Holds teat-dipping solution
Protective clothing	Maintains personal hygiene

6.2 Mechanical milking equipment

Mechanical milking involves using a milking machine to extract milk from the udder.

Main parts and functions

1. Vacuum pump

- Produces the vacuum required for machine milking.
- Provides the suction needed to remove milk.

2. Teat cups

- Fit around the teats.
- Apply controlled vacuum and pulsation to extract milk.

3. Liners

- Flexible parts inside teat cups.
- Contact the teats during milking.
- Open and close during pulsation.

4. Milk claw

- Collects milk from the teat cups.
- Directs milk into the milk line.

5. Milk pipeline

- Carries milk from the milking unit to the collection system.

6. Pulsator

- Controls the alternating vacuum and pressure that produce the milking action.

7. Milk receiver or collection container

- Receives milk from the milking system.

8. Cleaning system

- Facilitates washing and sanitising of the milking equipment.

Advantages of mechanical milking

1. Saves time.
2. Reduces manual labour.
3. Suitable for large dairy herds.
4. Can improve milking efficiency.
5. Provides a more consistent milking process when correctly operated.

6. Can improve milk handling and collection in well-managed systems.

Disadvantages of mechanical milking

1. High initial installation cost.
2. Requires electricity or another power source.
3. Requires regular maintenance.
4. Requires trained operators.
5. Poor cleaning can spread microorganisms.
6. Incorrect machine settings can injure teats and damage udder health.

7.0 PRE-MILKING PRACTICES

Pre-milking practices are activities carried out before extracting milk from a dairy animal.

Their main purpose is to prepare the animal, milker, equipment and milking environment to obtain clean milk.

7.1 Importance of pre-milking practices

1. Reduce contamination of milk.
2. Promote milk let-down.
3. Reduce the spread of mastitis-causing organisms.
4. Prepare the animal for milking.
5. Improve milking efficiency.
6. Protect milk quality.
7. Ensure personal safety.
8. Create a clean milking environment.

7.2 Steps followed before milking

Step 1: Prepare the milking area

- Clean the milking floor.
- Remove dung, urine and leftover feeds.
- Ensure proper drainage.
- Reduce dust.
- Control flies.
- Ensure adequate lighting and ventilation.

Step 2: Prepare the milking equipment

- Collect clean milking containers.
- Wash equipment with suitable detergent.
- Rinse appropriately.
- Sanitise where required.
- Allow equipment to drain hygienically.
- Ensure that containers are ready for use.

Step 3: Prepare the milker

- Wash hands with soap and clean water.
- Wear clean clothing.
- Cover any cuts or wounds.
- Ensure fingernails are short and clean.
- Avoid activities that may contaminate milk.

Step 4: Bring the animal to the milking area

- Move the animal calmly.
- Avoid shouting or beating.
- Secure it using suitable restraint.
- Ensure it is comfortable.

Step 5: Inspect the animal

- Observe the animal's general health.
- Check the udder for swelling, heat, pain or wounds.
- Observe the teats for abnormalities.
- Check for signs of mastitis.
- Follow veterinary advice if abnormalities are detected.

Step 6: Clean the udder and teats

- Remove visible dirt from the udder and teats.
- Use clean water where washing is necessary.
- Avoid unnecessarily wetting the whole udder.

- Use individual clean towels for drying.
- Ensure teats are thoroughly dried before milking.

Step 7: Examine the first streams of milk

- Strip a few streams of milk from each teat into a suitable strip cup.
- Observe the milk for clots, flakes, blood or watery appearance.
- Do not strip foremilk onto the floor.
- Abnormal milk should not be mixed with the normal milk supply.
- Seek veterinary advice where mastitis or other abnormalities are suspected.

Step 8: Prepare for milking

- Position the milking bucket correctly.
- Ensure the animal is calm.
- Begin milking promptly after preparation to take advantage of the milk let-down response.

8.0 MILKING TECHNIQUES

Milking techniques are the methods used to extract milk from the udder of a dairy animal.

The two main methods are:

1. Hand milking.
2. Machine milking.

8.1 Hand milking

Hand milking is the extraction of milk from an animal's udder using the hands.

It is commonly practised in small-scale dairy farms, especially where farmers keep a small number of dairy cattle or goats.

Equipment required

- Clean milking bucket.
- Clean water.
- Clean towels.
- Suitable stool.
- Teat-dipping solution where required.
- Protective clothing.

Procedure for hand milking

Step 1: Wash hands

- Wash hands thoroughly with soap and clean water.
- Dry hands using a clean towel.
- Ensure fingernails are short and clean.

Step 2: Position the animal

- Bring the animal to a clean milking area.
- Restrain it gently.
- Position yourself safely beside the animal.
- Place the milking bucket below the udder.

Step 3: Prepare the udder

- Examine the udder and teats.
- Clean dirty teats and dry them thoroughly.
- Strip the first few streams of milk into a strip cup.
- Observe the milk for abnormalities.

Step 4: Hold the teat correctly

- Hold the teat near its base using the thumb and index finger.
- Close these fingers gently to trap milk in the teat.
- Avoid pulling the teat downwards.

Step 5: Compress the teat

- Close the middle finger.
- Follow with the ring finger and little finger.
- Apply gentle, controlled pressure.
- Milk flows out through the teat opening.

Step 6: Release the pressure

- Release the fingers to allow the teat to refill.
- Repeat the process rhythmically.
- Maintain a steady milking rhythm.

Step 7: Milk all functional teats

- Continue milking using a consistent technique.
- Avoid causing pain or injury.
- Use a suitable hand position for the animal and teat size.

Step 8: Complete milking

- Ensure the udder has been milked appropriately.
- Avoid excessive manipulation of the teats.
- Do not leave the animal unnecessarily stressed.

Step 9: Post-milking care

- Apply an approved teat dip where recommended.
- Release the animal calmly.
- Clean and store the equipment appropriately.
- Record the milk yield.

Correct hand-milking techniques

A. Full-hand method

- The teat is enclosed using all fingers and the thumb.
- Pressure is applied progressively from the top towards the end of the teat.
- It is suitable for teats that can be comfortably enclosed by the hand.

B. Stripping method

- The teat is held between the thumb and fingers.
- Pressure is applied along the teat towards its end.
- It is used to remove milk remaining in the teat, but should not involve harsh pulling.

C. Knuckling

- This involves bending or pressing the teat using the knuckles.
- It is an incorrect milking practice because it can cause teat injury and discomfort.
- It should be avoided.

Advantages of hand milking

1. Requires relatively simple equipment.
2. Has low initial capital costs.

3. Suitable for small-scale dairy farms.
4. Does not require electricity.
5. Allows the farmer to observe the udder closely.
6. Can be used in areas without access to milking machines.

Disadvantages of hand milking

1. Time-consuming.
2. Requires considerable labour.
3. May result in contamination if hygiene is poor.
4. May cause teat injuries if done incorrectly.
5. Difficult to use efficiently with large dairy herds.
6. Milk yield may vary with the skill of the milker.

8.2 Machine milking

Machine milking is the extraction of milk using a mechanically operated milking system.

It is commonly used in medium- and large-scale dairy farms.

Procedure for machine milking

1. Prepare the milking area.
2. Wash and sanitise the milking equipment according to instructions.
3. Prepare the animal by cleaning and drying the teats.
4. Examine the first milk streams.
5. Check that the milking machine is functioning correctly.
6. Attach the teat cups correctly.
7. Allow the machine to extract milk under appropriate vacuum and pulsation settings.
8. Monitor the animal during milking.
9. Remove the teat cups correctly when milking is complete.
10. Apply an approved teat dip where recommended.
11. Clean the equipment after milking.
12. Record the milk yield.

Precautions during machine milking

- Use the correct vacuum level.
- Ensure the pulsator is working properly.
- Check that liners are clean and in good condition.
- Avoid attaching teat cups to wet or dirty teats.
- Avoid over-milking.
- Remove teat cups correctly.
- Clean the system after every milking session according to the manufacturer's instructions.
- Maintain the equipment regularly.

8.3 Comparison between hand milking and machine milking

Hand milking	**Machine milking**
Uses hands to extract milk	Uses a mechanical system
Requires simple equipment	Requires specialised equipment
Suitable for small herds	Suitable for medium and large herds
Takes more time	Generally faster
Requires more manual labour	Reduces manual labour
Does not require electricity	Usually requires a power source
Skill of the milker affects efficiency	Machine operation and maintenance affect efficiency
Lower initial investment	Higher initial investment

9.0 DURING-MILKING HYGIENE PRACTICES

During-milking hygiene practices are measures taken while extracting milk to prevent contamination and protect milk quality.

9.1 Importance of hygiene during milking

1. Prevents microorganisms from entering milk.
2. Protects consumers against milk-borne infections.
3. Maintains milk quality.
4. Reduces contamination by dirt and foreign materials.
5. Prevents the spread of mastitis-causing organisms.
6. Maintains the cleanliness of the milking environment.
7. Reduces milk spoilage.

8. Supports consumer confidence.

9.2 Hygiene practices during milking

1. Milk only healthy animals whose milk is suitable for human consumption.
2. Use clean, food-grade containers.
3. Avoid touching the inside of milk containers.
4. Keep hands clean throughout milking.
5. Avoid coughing or sneezing over milk.
6. Prevent dung, hair, mud and dust from entering milk.
7. Avoid mixing abnormal milk with normal milk.
8. Do not milk animals with visibly contaminated udders before proper cleaning.
9. Milk animals under treatment according to veterinary advice and applicable withdrawal periods.
10. Keep the milking area free from unnecessary people and animals.
11. Avoid smoking, eating or drinking over milk.
12. Use proper milking techniques to avoid teat injuries.
13. Filter milk using suitable clean milk filters where appropriate.
14. Cover milk containers immediately after collection.

10.0 POST-MILKING HYGIENE PRACTICES

Post-milking practices are activities carried out immediately after milk extraction to maintain milk quality, protect the animal and clean the equipment.

10.1 Importance of post-milking practices

1. Prevents milk contamination.
2. Reduces multiplication of microorganisms.
3. Protects the udder against infection.
4. Maintains milk quality.
5. Reduces milk spoilage.
6. Promotes safe milk storage.
7. Maintains cleanliness of the milking environment.
8. Supports proper farm record keeping.

10.2 Post-milking procedures

A. Teat dipping

- Dip the teats in an approved teat disinfectant where recommended.
- Ensure the product is suitable for dairy animals.
- Follow the manufacturer's instructions.
- This helps reduce the risk of microorganisms entering the teat canal.

B. Milk filtering

- Pass milk through a suitable clean milk filter where appropriate.
- Remove visible physical particles such as hair and dirt.
- Filtering does not remove all microorganisms and does not make contaminated milk safe.

C. Milk cooling

- Cool milk promptly after milking.
- Use an appropriate cooling system.
- Maintain the required storage temperature according to applicable standards.
- Avoid leaving milk at warm temperatures for long periods.

D. Milk storage

- Store milk in clean, covered, food-grade containers.
- Use stainless-steel containers or other approved food-grade materials.
- Protect milk from dust, insects and chemicals.
- Maintain the cold chain.

E. Cleaning milking equipment

- Empty remaining milk from equipment.
- Rinse using suitable water.
- Wash with appropriate detergent.
- Rinse according to the cleaning procedure.
- Sanitise where required.
- Allow equipment to drain and dry hygienically.
- Store in a clean area.

F. Cleaning the milking area

- Remove dung and other waste.
- Wash the floor and surfaces where appropriate.
- Clean feeding and watering equipment.
- Dispose of waste safely.
- Maintain good drainage.

G. Recording milk production

- Record the quantity of milk obtained.
- Record the date and time.
- Identify the animal.
- Record abnormal observations.
- Record milk sold, consumed or stored.

11.0 MASTITIS IN DAIRY ANIMALS

Mastitis is inflammation of the mammary gland, usually caused by infection with microorganisms.

It is a major disease affecting dairy animals and can lead to reduced milk production, poor milk quality and financial losses.

11.1 Causes of mastitis

1. Bacteria entering the udder through the teat canal.
2. Poor milking hygiene.
3. Dirty animal housing.
4. Failure to maintain clean milking equipment.
5. Injuries to the teats.
6. Poor milking technique.
7. Inadequate post-milking teat care.
8. Contact with contaminated bedding and surfaces.

11.2 Signs of mastitis

- Swollen udder.
- Hot udder.
- Pain when the udder is touched.
- Redness of the affected udder quarter.

- Abnormal milk containing clots or flakes.
- Watery milk.
- Reduced milk production.
- Loss of appetite in severe cases.
- Fever in some severe cases.

11.3 Types of mastitis

A. Clinical mastitis

This is mastitis that produces visible signs such as udder swelling, pain and abnormal milk.

B. Subclinical mastitis

This is mastitis without obvious visible signs, although milk quality and production may be affected. It may be detected through tests such as the California Mastitis Test (CMT) or laboratory examination.

11.4 Prevention and control of mastitis

1. Maintain proper milking hygiene.
2. Clean and dry teats before milking.
3. Use clean milking equipment.
4. Apply approved post-milking teat disinfectant where recommended.
5. Maintain clean and dry animal housing.
6. Avoid injuries to teats.
7. Check foremilk for abnormalities.
8. Identify and manage infected animals.
9. Seek veterinary diagnosis and treatment.
10. Observe withdrawal periods for veterinary medicines.
11. Maintain accurate health records.

Important: Milk from an animal suspected of having mastitis should be handled according to veterinary guidance and food-safety requirements. It should not be mixed with milk intended for consumers.

12.0 FACTORS AFFECTING MILK QUALITY

Milk quality refers to the physical, chemical, microbiological and sensory characteristics that determine whether milk is suitable for processing and consumption.

12.1 Factors affecting milk quality

1. Animal health

- Sick animals may produce abnormal milk.
- Mastitis can alter milk composition and quality.
- Proper health management helps maintain good milk quality.

2. Feeding

- Balanced feeding supports normal milk production.
- Poor nutrition may reduce milk yield and affect milk composition.
- Contaminated feeds may introduce undesirable substances into the production system.

3. Water quality

- Dirty water may contaminate the animal and milking environment.
- Clean drinking water supports animal health and milk production.

4. Milking hygiene

- Dirty hands, udders and equipment can introduce microorganisms into milk.
- Proper cleaning reduces contamination.

5. Milk storage temperature

- Warm conditions encourage the multiplication of microorganisms.
- Prompt cooling helps slow microbial growth.

6. Milk handling

- Uncovered containers may allow dust and insects to enter milk.
- Rough handling and poor transportation practices may increase contamination.

7. Animal species and breed

- Different species and breeds produce milk with different compositions.
- Fat, protein and other components vary between animals.

8. Stage of lactation

- Milk composition and production can change during the lactation period.

9. Milking equipment

- Poorly cleaned equipment may contaminate milk.
- Damaged equipment may interfere with hygienic milk collection.

10. Environmental cleanliness

- Dirty floors, bedding and surroundings increase the risk of milk contamination.

12.2 Characteristics of clean, good-quality milk

- Normal appearance.
- Characteristic fresh milk smell.
- No visible dirt or foreign matter.
- No abnormal clots or flakes.
- No unusual colour.
- Properly cooled and stored.
- Obtained from healthy animals.
- Free from unacceptable contamination and residues.

PART III: HANDLING, STORAGE AND MARKETING OF LIVESTOCK PRODUCTS

13.0 MILK HANDLING AND STORAGE

Milk is highly perishable because it contains nutrients and moisture that support the growth of microorganisms.

Proper handling and storage are therefore necessary to maintain milk quality and safety.

13.1 Importance of proper milk handling

1. Prevents contamination by microorganisms.
2. Reduces milk spoilage.
3. Maintains the nutritional quality of milk.
4. Prevents the development of unpleasant smells and flavours.
5. Protects consumers from milk-borne diseases.
6. Maintains the market value of milk.
7. Reduces losses during transportation.
8. Extends the period during which milk can be safely stored under appropriate conditions.

13.2 Steps in proper milk handling

1. Collect milk in clean food-grade containers.
2. Avoid mixing milk from animals with abnormal milk.
3. Filter milk using an appropriate clean filter where required.
4. Cover the milk container immediately.

5. Transfer milk to a suitable cooling facility promptly.
6. Maintain the recommended storage temperature.
7. Avoid unnecessary exposure to sunlight and high temperatures.
8. Transport milk using clean, suitable containers.
9. Maintain the cold chain until processing or delivery.
10. Keep records of milk quantities collected, stored and sold.

13.3 Milk storage methods

A. Refrigeration

Refrigeration involves cooling milk to a low temperature to slow down the multiplication of microorganisms.

Advantages

1. Slows microbial growth.
2. Helps maintain milk quality.
3. Reduces rapid spoilage.
4. Allows temporary storage before collection or processing.
5. Supports hygienic milk transportation.

Precautions

- Use clean and properly maintained cooling equipment.
- Cool milk promptly after milking.
- Monitor storage temperature.
- Avoid mixing warm milk with already cooled milk without an appropriate cooling system.
- Keep the tank covered.

B. Bulk milk cooling tanks

These are specialised tanks used to cool and store milk on dairy farms or at milk collection centres.

Functions

- Cool freshly collected milk.
- Maintain suitable storage temperatures.
- Protect milk from external contamination.
- Facilitate collection and transportation.

C. Milk cans

Milk cans are containers used to collect and transport milk.

Characteristics of suitable milk cans

1. Made from food-grade materials.
2. Easy to clean.
3. Have secure lids.
4. Do not rust easily.
5. Do not react with milk.
6. Are strong enough for transportation.

D. Pasteurisation

Pasteurisation is the controlled heating of milk to a specified temperature for a specified time, followed by appropriate cooling, to destroy disease-causing microorganisms and reduce spoilage microorganisms.

It does not sterilise milk.

Common examples of pasteurisation processes include:

- Low-temperature long-time (LTLT): 63°C for 30 minutes.
- High-temperature short-time (HTST): 72°C for at least 15 seconds.

These are standard examples; actual processing must use calibrated equipment and applicable food-safety requirements.

Importance of pasteurisation

1. Destroys many disease-causing microorganisms.
2. Improves milk safety.
3. Reduces the number of spoilage microorganisms.
4. Extends the useful storage life of milk when properly packaged and refrigerated.
5. Supports safe dairy processing.

Important: Pasteurisation does not make milk safe if it is contaminated after heating. Proper packaging and storage are still necessary.

13.4 Factors to consider when storing milk

- Storage temperature.
- Cleanliness of containers.
- Storage duration.

- Type of storage equipment.
- Protection from sunlight.
- Protection from dust and insects.
- Milk quality at the time of collection.
- Availability of refrigeration.
- Transportation arrangements.
- Applicable food-safety standards.

13.5 Consequences of poor milk storage

1. Rapid multiplication of microorganisms.
2. Sourness due to microbial activity.
3. Unpleasant smell.
4. Changes in taste.
5. Milk clotting or curdling.
6. Reduced nutritional and processing quality.
7. Economic losses.
8. Increased risk of food-borne illness.

14.0 MILK PRODUCTION RECORDS

Record keeping is the systematic recording of information relating to milk production, animal health, milking activities, sales and storage.

It enables farmers to monitor performance and make informed decisions.

14.1 Importance of milk production records

1. Help monitor daily milk production.
2. Identify high-producing and low-producing animals.
3. Help detect sudden drops in milk yield.
4. Support breeding and selection decisions.
5. Help monitor animal health.
6. Facilitate financial planning.
7. Help calculate the profitability of dairy farming.
8. Support milk marketing.

9. Help monitor milk sold and consumed.
10. Assist in planning feed requirements.

14.2 Types of dairy records

A. Daily milk production record

Shows the quantity of milk obtained from an animal each day.

B. Milk sales record

Shows the quantity of milk sold, selling price, buyer and date of sale.

C. Feeding record

Shows the type and quantity of feeds given to dairy animals.

D. Health record

Shows illnesses, veterinary examinations, treatment and vaccination details.

E. Breeding record

Shows mating dates, insemination, pregnancy and calving information.

F. Milk storage record

Shows the quantity of milk stored, cooling details and quantities dispatched.

G. Financial record

Shows expenditure and income from the dairy enterprise.

14.3 Sample daily milk production record

Date	Animal ID	Morning yield (litres)	Evening yield (litres)	Total yield (litres)
1/11/2026	C001	8	7	15
1/11/2026	C002	6	5	11
1/11/2026	C003	10	9	19

Calculation of total daily milk production

Total daily yield=Morning yield+ Evening yield

For animal C001:

8+7=15 litres

14.4 Sample weekly milk production record

Day	Milk obtained (litres)
Monday	35
Tuesday	37
Wednesday	36
Thursday	40
Friday	38
Saturday	42
Sunday	39
Total	267

Calculation of average daily milk production

Average daily yield=Total weekly milk/7

=267/7=38.14

The figures above are illustrative examples for classroom calculations.

15.0 VALUE ADDITION IN MILK PRODUCTION

Value addition refers to processing raw milk into other products to increase its usefulness, marketability and economic value.

Milk can be processed into several products.

15.1 Products obtained from milk

1. Fresh milk

Milk that has been collected and handled appropriately for consumption or processing.

2. Yoghurt

A fermented milk product produced using suitable microorganisms that convert part of the lactose into lactic acid.

3. Cheese

A dairy product made by coagulating milk proteins and separating the curd from whey.

4. Butter

A product made by churning cream to concentrate milk fat.

5. Ghee

A clarified milk-fat product prepared by removing most of the water and non-fat milk solids from butter or cream.

6. Cream

The fat-rich portion separated from milk.

7. Fermented milk

Milk that has undergone controlled fermentation using suitable microorganisms.

8. Milk powder

A product made by removing most of the water from milk through industrial drying processes.

15.2 Importance of value addition

1. Increases the market value of milk.
2. Creates additional sources of income.
3. Reduces losses where processing improves product shelf life.
4. Creates employment.
5. Diversifies dairy products available to consumers.
6. Supports the development of dairy-processing industries.
7. Provides opportunities for small-scale dairy enterprises.
8. May open access to wider markets.

PART IV: PRACTICAL AGRICULTURE AND CBE LEARNING EXPERIENCES

16.0 PRACTICAL ACTIVITY 1: MILKING A DAIRY COW

Practical skill development

Learning outcome: The learner should be able to milk a dairy animal hygienically using the correct procedure.

Materials and equipment

- Healthy dairy cow.
- Clean stainless-steel milking bucket.
- Clean water.
- Soap.

- Clean towels.
- Strip cup.
- Suitable teat-dipping solution.
- Protective clothing.
- Milking record book.

Procedure

1. Prepare a clean milking area.
2. Assemble the required equipment.
3. Wash hands with soap and clean water.
4. Put on clean protective clothing.
5. Bring the cow calmly into the milking area.
6. Restrain the cow gently.
7. Examine the udder and teats for abnormalities.
8. Clean the udder and teats where necessary.
9. Dry the teats using clean individual towels.
10. Strip the first few streams of milk into a strip cup.
11. Examine the milk for clots, flakes, blood or watery appearance.
12. Position a clean milking bucket.
13. Use the correct full-hand milking technique.
14. Milk the animal gently and consistently.
15. Collect the milk in the clean container.
16. Apply an approved post-milking teat dip where recommended.
17. Release the animal calmly.
18. Filter the milk where appropriate.
19. Cool the milk promptly.
20. Record the milk yield.

Observation table

Activity	Observation

General condition of the cow	
Condition of the udder	
Cleanliness of the teats	
Appearance of first milk streams	
Milking technique used	
Quantity of milk obtained	
Post-milking care carried out	
Milk storage method	

Reflection questions

1. Why should a farmer wash hands before milking?
2. Why should the udder be cleaned and dried?
3. What is the importance of examining the first streams of milk?
4. Why should milk be cooled promptly?
5. Why should milk from an animal with suspected mastitis be separated?
6. What could happen if milking equipment is not cleaned properly?

16.1 PRACTICAL ACTIVITY 2: MILKING A GOAT

Procedure

1. Select a healthy lactating dairy goat.
2. Prepare a clean and suitable milking area.
3. Prepare clean equipment.
4. Wash hands thoroughly.
5. Restrain the goat gently.
6. Examine the udder and teats.
7. Clean and dry the teats where necessary.
8. Examine the first milk streams.
9. Position a clean milking container.
10. Hold the teat correctly.
11. Apply gentle pressure using the fingers.

12. Release the fingers to allow the teat to refill.
13. Repeat the process rhythmically.
14. Milk the functional teats appropriately.
15. Apply suitable post-milking teat care.
16. Filter and cool the milk appropriately.
17. Clean the equipment.
18. Record the quantity of milk obtained.

Important: Goat teats are usually smaller than cattle teats. The learner should use a comfortable hand position and avoid excessive pressure.

16.2 PRACTICAL ACTIVITY 3: WOOL SHEARING OBSERVATION

Learning outcome: The learner should be able to explain how wool is obtained from sheep.

Materials

- Sheep.
- Shearing machine or hand shears.
- Protective clothing.
- Wool sorting table.
- Wool sack.
- Record book.

Procedure

1. Visit a sheep farm or observe a demonstration.
2. Identify sheep suitable for shearing.
3. Observe how the animal is restrained.
4. Identify the shearing equipment.
5. Observe the shearing technique.
6. Identify precautions taken to avoid injuries.
7. Observe how the fleece is removed.
8. Examine the harvested fleece.
9. Observe wool sorting and grading.
10. Observe packaging and storage.

11. Record the quantity and quality of wool obtained.

Reflection questions

1. Why is sheep shearing carried out?
2. What equipment is required?
3. Why should the sheep be restrained gently?
4. Why should wool be stored in a dry place?
5. What factors determine wool quality?

16.3 PRACTICAL ACTIVITY 4: MILKING HYGIENE PRESENTATION

The learner should prepare a presentation on hygiene practices observed during the three stages of milking.

Stage	Hygiene practices
Pre-milking	Washing hands, cleaning the udder, preparing clean equipment and examining the animal
During milking	Using clean containers, avoiding contamination and observing correct milking techniques
Post-milking	Teat dipping where appropriate, filtering, cooling, storing milk and cleaning equipment

17.0 INTEGRATION OF CORE COMPETENCE, VALUES AND PCI

17.1 Core competence: Self-efficacy

Self-efficacy refers to the learner's belief and confidence in their ability to perform a particular task successfully.

How it is developed in this sub-strand

The learner:

1. Participates in practical milking activities.
2. Learns how to prepare a dairy animal for milking.
3. Handles milking equipment correctly.
4. Practises proper hand-milking techniques.
5. Observes hygiene requirements.
6. Records milk yields.
7. Makes presentations on clean milk production.
8. Reflects on practical performance.
9. Seeks guidance when difficulties arise.
10. Gradually performs milking activities with increased confidence.

Expected outcome: The learner gains confidence in obtaining clean milk from a dairy animal.

17.2 Value: Responsibility

Responsibility is the ability to perform duties carefully and accept accountability for one's actions.

How the learner demonstrates responsibility

1. Handles dairy animals gently.
2. Observes personal hygiene.
3. Uses equipment correctly.
4. Avoids wasting milk.
5. Maintains cleanliness.
6. Protects animals from unnecessary pain.
7. Follows instructions during practical activities.
8. Records milk production accurately.
9. Cleans equipment after use.
10. Ensures milk is stored appropriately.

17.3 PCI: Consumer protection

Consumer protection involves ensuring that products supplied to consumers meet appropriate quality and safety requirements.

How the learner demonstrates consumer protection

1. Observes hygiene during milking.
2. Prevents contamination of milk.
3. Ensures that milk is obtained from healthy animals.
4. Separates abnormal milk.
5. Uses clean containers.
6. Cools milk promptly.
7. Observes veterinary medicine withdrawal periods.
8. Maintains appropriate milk storage conditions.
9. Prevents adulteration of milk.
10. Maintains accurate production records.

18.0 COMMON CHALLENGES IN OBTAINING LIVESTOCK PRODUCTS

18.1 Challenges in wool production

Challenge	Explanation	Possible solution
Shortage of skilled shearers	Poor shearing techniques may damage the fleece and injure sheep	Train shearers
Poor wool quality	Poor nutrition, breed and management affect fibre quality	Select suitable breeds and improve feeding
Fleece contamination	Dirt, dung and vegetable matter lower wool quality	Maintain clean sheep and shearing areas
Poor storage	Moisture causes mould and deterioration	Store wool in clean, dry places
Equipment breakdown	Delays shearing	Maintain equipment regularly
Animal injuries	Poor handling and shearing cause wounds	Use trained shearers and humane restraint
Unreliable markets	Farmers may receive low prices or fail to sell wool	Improve marketing and cooperative arrangements
Weather challenges	Rain and cold may affect freshly shorn sheep	Plan shearing during suitable weather

18.2 Challenges in milk production

Challenge	Explanation	Possible solution
Mastitis	Causes abnormal milk and reduced production	Maintain milking hygiene and seek veterinary care
Poor hygiene	Contaminates milk	Clean the animal, equipment and milking area
High feed costs	Increase the cost of production	Improve on-farm fodder production
Water shortage	Reduces animal performance and milk production	Harvest and store water
Poor milk storage	Encourages microbial growth	Cool milk promptly
Inadequate equipment	Makes hygienic milking difficult	Invest in suitable equipment
Poor milking skills	Causes injuries and contamination	Train milkers
Unreliable markets	Farmers may fail to sell milk at profitable prices	Strengthen marketing arrangements
Power interruptions	Affect refrigeration and machine milking	Provide backup power and suitable

		contingency plans
Animal diseases	Reduce milk yield and quality	Maintain preventive health programmes

REVISION QUESTIONS

Section A: Multiple-choice questions

Choose the correct answer.

1. The process of removing fleece from a sheep's body is known as:

A. Docking

B. Shearing

C. Castration

D. Branding

2. Which one of the following sheep breeds is particularly known for producing fine wool?

A. Merino

B. Dorper

C. Red Maasai

D. Hampshire Down

3. Which one of the following is an important characteristic of good-quality wool?

A. High contamination

B. Poor fibre strength

C. Fibre uniformity

D. Excessive moisture

4. Which equipment is commonly used for mechanical wool shearing?

A. Milking machine

B. Electric shearing machine

C. Hoof trimmer

D. Ear tag applicator

5. Which one of the following is an important consideration when planning sheep shearing?

A. Colour of the milking bucket

B. Weather conditions

C. Quantity of milk produced

D. Size of the poultry house

6. Which one of the following is the correct place for storing harvested wool?

A. Wet floor

B. Open drainage channel

C. Clean and dry store

D. Chemical storage room

7. Milk is produced in the:

A. Lungs

B. Mammary glands

C. Kidneys

D. Liver

8. Which hormone is mainly responsible for milk let-down?

A. Insulin

B. Oxytocin

C. Adrenaline

D. Thyroxine

9. The process of extracting milk from a dairy animal is called:

A. Shearing

B. Milking

C. Docking

D. Weaning

10. Which one of the following is an important pre-milking practice?

A. Washing hands

B. Leaving the udder dirty

C. Using rusty containers

D. Mixing abnormal milk with normal milk

11. The first streams of milk are examined mainly to:

A. Increase the fat content.

B. Detect abnormalities in milk.

C. Increase the size of the udder.

D. Reduce the number of teats.

12. Which one of the following is a correct hand-milking technique?

A. Knuckling

B. Pulling the teats forcefully

C. Full-hand milking

D. Twisting the teats

13. Which one of the following is a function of a milking machine's vacuum pump?

A. Cooling the milk.

B. Producing the vacuum required for milking.

C. Storing wool.

D. Filtering milk.

14. Which one of the following is a major cause of mastitis?

A. Poor milking hygiene.

B. Proper udder cleaning.

C. Clean bedding.

D. Correct milking technique.

15. Which one of the following practices helps maintain milk quality after milking?

A. Leaving milk uncovered.

B. Storing milk in dirty containers.

C. Cooling milk promptly.

D. Exposing milk to direct sunlight.

16. Which one of the following is the main purpose of pasteurisation?

A. Increasing milk contamination.

B. Destroying many disease-causing microorganisms.

C. Increasing dirt in milk.

D. Removing all milk nutrients.

17. Which one of the following is a dairy product obtained by churning cream?

A. Wool

B. Butter

C. Hide

D. Honey

18. Which one of the following records shows the quantity of milk obtained from an animal?

A. Wool grading record.

B. Milk production record.

C. Equipment inventory only.

D. Labour attendance record.

19. Which value is demonstrated when a learner carefully handles a dairy animal during milking?

A. Negligence

B. Responsibility

C. Dishonesty

D. Carelessness

20. Which one of the following practices best protects consumers from contaminated milk?

A. Using dirty containers.

B. Mixing milk from sick animals with normal milk.

C. Observing proper milking hygiene.

D. Leaving milk at high temperatures for long periods.

Section B: Structured questions

21.

a) Define wool shearing. (2 marks)

b) Explain four importance of wool shearing in sheep production. (8 marks)

c) Name four sheep breeds used for wool production. (4 marks)

22.

a) Explain five considerations when planning wool shearing. (10 marks)

b) State four pieces of equipment used during wool shearing. (4 marks)

23.

a) Describe the procedure followed when shearing sheep. (10 marks)

b) Explain four safety precautions observed during shearing. (8 marks)

24.

a) Explain five characteristics of good-quality wool. (10 marks)

b) Describe four requirements for proper wool storage. (8 marks)

25.

a) Define milking. (2 marks)

b) Explain four importance of milk production in Kenya. (8 marks)

c) Name four dairy animals kept in Kenya. (4 marks)

26.

a) Describe the structure of the udder in a dairy cow. (8 marks)

b) Explain the process of milk let-down in dairy animals. (6 marks)

27.

a) Explain six considerations when obtaining milk from dairy animals. (12 marks)

b) State four pieces of equipment used during manual milking. (4 marks)

28.

a) Describe the procedure followed when milking a dairy cow by hand. (10 marks)

b) Explain four advantages of machine milking over hand milking. (8 marks)

29.

a) Explain four pre-milking hygiene practices. (8 marks)

b) Explain four hygiene practices observed during milking. (8 marks)

c) State two post-milking hygiene practices. (2 marks)

30.

a) Explain four causes of mastitis in dairy animals. (8 marks)

b) State four signs of mastitis. (4 marks)

c) Explain four ways of preventing mastitis. (8 marks)

31.

a) Explain four factors affecting milk quality. (8 marks)

b) Describe four ways of maintaining milk quality after milking. (8 marks)

32.

a) Explain four importance of keeping milk production records. (8 marks)

b) State five types of records kept in dairy farming. (5 marks)

c) A dairy cow produces 9 litres of milk in the morning and 7 litres in the evening. Calculate its total daily milk yield. (2 marks)

33.

a) Explain five products obtained through milk processing. (10 marks)

b) State four advantages of value addition in milk production. (4 marks)

GLOSSARY OF KEY TERMS

Term	**Meaning**
Livestock products	Useful products obtained from domestic animals
Wool	Natural animal fibre obtained mainly from sheep
Fleece	The wool covering the body of a sheep
Shearing	Cutting and removing wool from a sheep

Shearer	A person who removes wool from sheep
Wool grading	Classification of wool according to quality
Wool sorting	Separation of fleece into different categories
Fibre	A fine thread-like structure forming wool
Fibre diameter	The thickness of an individual wool fibre
Crimp	Natural waviness of wool fibres
Milking	Extraction of milk from a dairy animal
Dairy animal	An animal kept mainly for milk production
Udder	The mammary organ in dairy animals
Mammary gland	An organ responsible for producing milk
Alveoli	Small milk-producing structures in the mammary gland
Teat	The external structure through which milk is released
Milk let-down	Release of milk from the mammary gland towards the teats
Oxytocin	Hormone that causes contraction of cells around mammary alveoli
Mastitis	Inflammation of the mammary gland
Foremilk	The first streams of milk extracted from a teat
Hand milking	Extraction of milk using hands
Machine milking	Extraction of milk using a milking machine
Pasteurisation	Controlled heating of milk to destroy many harmful microorganisms
Milk filtration	Removal of visible physical particles from milk
Refrigeration	Cooling milk to slow microbial growth
Teat dipping	Applying an approved disinfectant to teats after milking
Milk yield	Quantity of milk obtained from an animal
Value addition	Processing raw products to increase their value
Cold chain	Maintaining appropriate low temperatures during storage and transportation
Withdrawal period	Time required after veterinary medicine administration before animal products can enter the food supply

STRAND 3.0: AGRICULTURAL TECHNOLOGIES AND ENTREPRENEURSHIP

SUB-STRAND 3.1: POWERED TOOLS AND EQUIPMENT

1.0 Introduction to powered tools and equipment

Agricultural production involves various activities such as land preparation, planting, weeding, harvesting, livestock feeding, milking, construction and maintenance of farm structures. These activities require tools and equipment to make work easier, faster, safer and more efficient.

Traditionally, most agricultural operations were carried out using human labour and simple hand tools. However, technological advancement has led to the development of powered tools and equipment that use different sources of energy to perform agricultural tasks.

Powered tools and equipment are devices or machines that use an external or stored source of energy to perform work. They reduce the amount of human effort required and improve the speed, quality and efficiency of agricultural operations.

Examples include:

- Grass cutters used to trim grass and maintain lawns.
- Soil augers used to make holes in the soil.
- Chaff cutters used to chop fodder for livestock.
- Milking machines used to extract milk from dairy animals.
- Power drills used to make holes and drive screws.
- Hand-held circular saws used to cut timber and other suitable materials.

Importance of powered tools and equipment in agriculture

1. Saving time: Powered tools perform tasks faster than manual tools. For example, a grass cutter can clear a large area of grass within a short time.
2. Reducing human labour: They reduce physical effort, making it possible for fewer workers to complete demanding tasks.
3. Increasing productivity: Farmers can carry out more agricultural operations within a given period.
4. Improving quality of work: Properly operated equipment produces more uniform and accurate results. For example, a milking machine can provide consistent milking when correctly adjusted and maintained.
5. Reducing production costs in the long term: Although powered equipment may be expensive to purchase, it can reduce recurrent labour costs and improve farm output.
6. Supporting large-scale production: Powered equipment enables farmers to manage larger farms and livestock units.
7. Improving working conditions: Equipment reduces strenuous activities such as manually chopping large quantities of fodder.
8. Promoting agricultural innovation: Powered equipment encourages the adoption of modern farming technologies.
9. Improving timeliness of farm operations: Activities such as fodder preparation and grass cutting can be completed when needed.
10. Creating employment opportunities: People are needed to operate, repair, maintain and sell agricultural machinery.

2.0 Sources of power used in agricultural tools and equipment

A source of power is the form of energy used to operate a tool or piece of equipment. Different powered tools use different sources of energy depending on their design, size, purpose and operating environment.

The main sources of power used in agricultural tools and equipment include:

1. Solar energy.
2. Electrical energy.
3. Animal power.
4. Fuel power.

2.1 Solar energy

Solar energy is power obtained from sunlight. It is converted into usable energy through solar technologies such as solar panels.

Solar panels contain photovoltaic cells that convert sunlight directly into electrical energy. The electricity can operate equipment directly or be stored in batteries for later use.

Applications of solar energy in agriculture

1. Solar water pumps: These use electricity generated by solar panels to pump water from wells, rivers, boreholes or storage tanks for irrigation and livestock.
2. Solar lighting: Solar lamps provide lighting in poultry houses, animal shelters, stores and farm compounds.
3. Solar-powered electric fences: Solar panels charge batteries that supply electricity to electric fencing systems used to control livestock movement.
4. Solar milk cooling systems: Solar energy can operate cooling equipment in areas without reliable electricity, where the system is appropriately designed.
5. Solar dryers: Solar energy is used to dry agricultural products such as maize, fruits, vegetables and herbs.
6. Solar incubators: Some incubators use solar electricity to provide controlled temperatures for hatching eggs.
7. Solar water heating: Solar heaters provide warm water for cleaning dairy equipment and other farm operations.

Advantages of solar energy in agriculture

- It is renewable because sunlight is naturally replenished.
- It reduces dependence on grid electricity and fuel.
- It has low operating costs after installation.
- It can be used in remote areas without electricity connections.
- It produces no direct smoke or exhaust gases during operation.
- It can reduce environmental pollution.

- It is useful for pumping water and powering small farm systems.

Limitations of solar energy

- Initial installation costs may be high.
- Energy production depends on the availability and intensity of sunlight.
- Solar panels may produce less electricity during cloudy or rainy weather.
- Batteries may be required to store electricity for use at night.
- Panels require cleaning and protection against physical damage.
- Some agricultural machines require more power than a small solar system can supply.

Example: A farmer in a dry area of Kenya can install solar panels to operate a water pump and irrigate vegetable crops without relying entirely on diesel fuel or grid electricity.

2.2 Electrical energy

Electrical energy is power obtained from the movement of electric charges through a conductor. In agriculture, it may be supplied through the national electricity grid, generators, batteries or solar-powered systems.

Electrical energy operates equipment through electric motors and other electrical components.

Uses of electrical energy in agriculture

1. Operating milking machines: Electric motors create the vacuum required for machine milking.
2. Chaff cutting: Electric chaff cutters chop fodder into smaller pieces for livestock feeding.
3. Water pumping: Electric pumps move water from sources to farms, tanks and irrigation systems.
4. Grass cutting: Electric grass cutters trim grass around homes, gardens and farm compounds.
5. Ventilation: Electric fans circulate air in poultry houses, pig houses and other livestock buildings.
6. Incubation: Electric incubators maintain suitable temperatures and humidity for hatching eggs.
7. Cooling and refrigeration: Electric refrigerators and milk coolers preserve milk and other perishable agricultural products.
8. Workshop operations: Electric drills, grinders and saws assist in repairing and constructing farm structures.
9. Feed processing: Electric mixers and grinders assist in preparing livestock feeds.

Advantages of electrical power

- It is convenient to operate.
- It provides a consistent source of power where supply is reliable.
- It can operate many types of agricultural equipment.

- Electric motors can be efficient.
- It produces no exhaust fumes at the point of use.
- It reduces manual labour.
- It can be used indoors when the equipment and installation are suitable.

Limitations of electrical power

- Equipment may stop working during power outages.
- Electricity may not be available in remote areas.
- Installation and connection costs may be high.
- Faulty wiring can cause electric shocks and fires.
- Electrical equipment should be protected from water and excessive moisture.
- Some machines require special electrical connections and voltage ratings.

Example: A dairy farmer can use an electrically powered milking machine to milk several cows more efficiently than relying entirely on manual milking.

2.3 Animal power

Animal power is energy obtained from the muscular strength of domesticated animals. It is used to pull, carry or operate agricultural implements.

Common animals used for draught power include:

- Oxen.
- Donkeys.
- Horses.
- Mules.
- Camels, in suitable areas and for appropriate tasks.

Uses of animal power in agriculture

1. Ploughing: Oxen can pull animal-drawn ploughs to turn the soil during land preparation.
2. Harrowing: Draught animals can pull suitable harrows to break soil clods and prepare a seedbed.
3. Transportation: Donkeys, horses and oxen can pull carts carrying farm produce, manure, water and farm inputs.
4. Weeding: Animals can pull inter-row cultivators in crops planted in suitable rows.
5. Ridging: Animal-drawn implements can make ridges for crops such as potatoes and other suitable crops.

6. Planting: Specially designed animal-drawn planters can place seeds in prepared rows.
7. Carrying loads: Donkeys and camels can transport agricultural materials where vehicles cannot easily access the area.

Advantages of animal power

- It is relatively affordable where suitable animals are available.
- It can be used in areas without electricity or fuel supplies.
- Animals can work on farms where tractors may be too expensive or unsuitable.
- Animal manure can be used to improve soil fertility.
- Animals can provide transport in difficult terrain.
- It reduces dependence on petroleum fuels.

Limitations of animal power

- Animals require feeding, watering and veterinary care.
- They may work more slowly than tractors and powered machinery.
- Their working capacity is limited by their strength and physical condition.
- They may become tired and require rest.
- Poor handling can cause injuries and suffering.
- They may not be suitable for very large farms or heavy operations.

Animal welfare considerations

- Provide adequate feed and clean water.
- Avoid overloading animals.
- Use properly fitted harnesses and yokes.
- Allow animals sufficient rest.
- Treat injuries and seek veterinary attention when necessary.
- Do not force sick, weak or exhausted animals to work.

2.4 Fuel power

Fuel power is energy obtained from burning fuels to produce heat and mechanical energy. Agricultural machines commonly use internal combustion engines that convert the energy in fuel into mechanical movement.

Common fuels include:

- Petrol.

- Diesel.
- Kerosene, for certain specialised equipment.
- Liquefied petroleum gas (LPG), for suitable farm applications.
- Biogas, in appropriately designed engines and equipment.

Uses of fuel power in agriculture

1. Grass cutting: Petrol-powered brush cutters clear grass and weeds.
2. Water pumping: Petrol and diesel pumps move water for irrigation and livestock.
3. Land preparation: Diesel-powered tractors operate ploughs, harrows and other implements.
4. Fodder preparation: Some chaff cutters use petrol or diesel engines to chop fodder.
5. Transportation: Fuel-powered tractors, motorcycles and farm vehicles transport farm inputs and produce.
6. Harvesting: Some harvesters and other harvesting equipment are powered by diesel engines.
7. Spraying: Some motorised sprayers use petrol engines to generate pressure for spraying operations.
8. Power generation: Petrol or diesel generators supply electricity when grid power is unavailable.

Advantages of fuel power

- It can provide high power for demanding agricultural tasks.
- Fuel-powered equipment can operate in remote locations.
- Machines can work independently of the electricity grid.
- Some machines are portable and easy to move around the farm.
- It is suitable for heavy-duty operations.
- Refuelling can allow equipment to continue operating without waiting for batteries to recharge.

Limitations of fuel power

- Fuel costs can be high.
- Burning fuel releases exhaust gases and contributes to air pollution.
- Machines produce noise and vibration.
- Engines require regular servicing.
- Fuel is flammable and must be handled carefully.
- Oil and fuel leakages can contaminate soil and water.
- Fuel-powered equipment may be expensive to maintain.

Example: A farmer may use a petrol-powered grass cutter to clear weeds around a farm boundary or a diesel-powered tractor to prepare land for planting.

2.5 Comparison of the sources of power

Source of power	Examples of equipment	Main advantage	Main limitation
Solar	Solar pump, solar dryer	Renewable energy	Depends on sunlight
Electrical	Milking machine, electric drill	Convenient and efficient	Depends on electricity supply
Animal	Ox-drawn plough, donkey cart	Useful where fuel and electricity are unavailable	Limited by animal strength
Fuel	Tractor, petrol grass cutter	Suitable for demanding tasks	Fuel costs and pollution

Factors to consider when selecting a source of power

1. Availability of the power source.
2. Cost of purchasing and operating the equipment.
3. Size of the farm.
4. Nature and amount of work to be performed.
5. Availability of spare parts.
6. Availability of skilled operators.
7. Reliability of the power supply.
8. Environmental effects.
9. Safety requirements.
10. Ease of maintenance and repair.

3.0 Powered tools and equipment used in agriculture

Powered agricultural tools and equipment are designed to perform specific tasks in crop production, livestock production, farm construction and general farm maintenance.

They may be classified according to the agricultural operations they perform.

The main categories covered in this sub-strand are:

1. Gardening and crop production tools.
2. Livestock production equipment.

3. Assembling and dissembling tools.
4. Other farm maintenance equipment.

3.1 Gardening and crop production tools

Gardening tools are equipment used to prepare gardens, maintain crops, control weeds, establish planting holes and carry out other crop production activities.

3.1.1 Soil auger

A soil auger is a tool used to bore holes into the ground. It may be manually operated or powered by an electric motor or a fuel-powered engine.

Main parts of a powered soil auger

1. Engine or electric motor: Provides the power required to rotate the auger.
2. Handle: Enables the operator to hold and control the equipment.
3. Throttle control: Regulates engine speed in fuel-powered models.
4. Drive shaft: Transfers rotational movement from the motor to the drilling bit.
5. Auger bit: A spiral-shaped metal component that cuts into the soil and removes loosened soil from the hole.
6. Drill tip: Helps the auger penetrate the ground.
7. Safety switch or control: Helps the operator stop or control the machine, depending on the model.

Uses of a soil auger in agriculture

1. Planting tree seedlings: It makes holes for planting fruit trees, timber trees and other seedlings.
2. Fence construction: It makes holes for erecting fence posts.
3. Soil sampling: It collects soil samples from different depths for soil analysis.
4. Establishing poles: It makes holes for supporting poles used in farm structures.
5. Planting large seedlings: It creates holes of suitable depth and diameter for transplanting.
6. Establishing support structures: It makes holes for posts used in trellising crops such as passion fruits.

Advantages of using a powered soil auger

- Makes holes faster than manual digging.
- Reduces physical effort.
- Produces holes of relatively uniform dimensions.
- Makes it easier to establish many planting holes.
- Can be operated in areas where digging with a spade is difficult, depending on soil conditions.

Limitations

- May be difficult to operate in very rocky or root-filled soil.
- Requires fuel or electricity.
- Can cause serious injuries if poorly handled.
- Requires regular inspection and maintenance.
- The rotating bit may become jammed in hard soil.

Maintenance practices

1. Clean soil and other materials from the auger after use.
2. Inspect the drilling bit for wear and damage.
3. Sharpen or replace worn cutting edges according to the manufacturer's instructions.
4. Lubricate the required moving parts.
5. Check bolts, nuts and handles for tightness.
6. For petrol models, inspect the engine, air filter, fuel system and spark plug.
7. For electric models, inspect the power cable, battery and electrical connections.
8. Store the equipment in a dry and secure place.

Safety precautions

- Wear safety boots, gloves, eye protection and hearing protection where required.
- Ensure that underground water pipes, electricity cables and other services are not in the drilling area.
- Hold the machine firmly with both hands where the design requires this.
- Keep other people away from the drilling area.
- Do not touch the rotating auger bit.
- Stop the machine before clearing trapped soil or inspecting the bit.
- Do not operate the equipment when tired or under the influence of substances that impair judgement.

3.1.2 Grass cutter

A grass cutter is a powered tool used to cut grass, weeds and other unwanted vegetation. It may be powered by petrol, electricity or rechargeable batteries.

Common types include:

- Petrol-powered brush cutters.
- Electric grass trimmers.

- Battery-powered grass cutters.
- Powered lawn mowers.

Main parts of a brush cutter

1. Engine or motor: Supplies power to rotate the cutting mechanism.
2. Drive shaft: Transfers power to the cutting head.
3. Handle: Allows the operator to control the machine.
4. Throttle trigger: Controls the speed of the engine in models fitted with this feature.
5. Cutting head: Holds the cutting blade or nylon line.
6. Cutting blade: Cuts thick grass and suitable vegetation.
7. Nylon cutting line: Cuts lighter grass and weeds.
8. Guard: Protects the operator from flying grass, stones and debris.
9. Harness: Supports the equipment and distributes its weight in models designed for harness use.
10. Stop switch: Enables the operator to switch off the engine or motor.

Uses of a grass cutter in agriculture

1. Clearing overgrown grass around farm buildings.
2. Controlling weeds along farm paths and boundaries.
3. Maintaining lawns and gardens.
4. Clearing vegetation around livestock structures.
5. Cutting grass around irrigation channels.
6. Maintaining areas around water tanks and farm equipment.
7. Cutting suitable vegetation in orchards and plantations.

Advantages of a grass cutter

- Saves time during grass cutting.
- Reduces manual labour.
- Makes it easier to clear large areas.
- Can reach areas where larger mowing machines cannot operate.
- Helps maintain farm hygiene and appearance.
- Improves access to farm structures and pathways.

Maintenance practices

1. Remove grass, soil and debris after use.
2. Inspect the cutting blade or nylon line.
3. Sharpen or replace blades when necessary.
4. Check that the blade is properly fitted and secured.
5. Inspect the protective guard.
6. Clean or replace the air filter in petrol models.
7. Check fuel and oil levels as recommended by the manufacturer.
8. Inspect the spark plug in petrol-powered models.
9. Check electrical cables and battery connections in electric models.
10. Lubricate moving parts as directed.
11. Store the grass cutter in a dry and secure location.

Safety precautions

- Wear protective clothing, safety boots, gloves, goggles or a face shield.
- Use hearing protection when necessary.
- Keep people and animals away from the cutting area.
- Inspect the area and remove stones, wire, glass and other objects that may be thrown by the cutting head.
- Never remove the protective guard during operation.
- Do not refuel a hot engine.
- Switch off the machine before replacing the blade or nylon line.
- Never use a damaged blade.
- Avoid cutting grass in wet or slippery conditions when this makes operation unsafe.

3.2 Livestock production equipment

Livestock production equipment is used to perform activities such as preparing animal feeds, milking, cleaning animal houses, watering livestock and handling animal products.

3.2.1 Chaff cutter

A chaff cutter is a machine used to cut fodder and other suitable livestock feed materials into smaller pieces. It may be powered by electricity, a fuel engine or, in some designs, another mechanical power source.

Examples of materials chopped using a chaff cutter include:

- Napier grass.
- Green maize fodder.
- Hay.
- Lucerne.
- Suitable crop residues.
- Other suitable fodder crops.

Main parts of a chaff cutter

1. Power unit: An electric motor or fuel-powered engine that provides energy.
2. Feeding chute: The opening through which fodder is introduced into the machine.
3. Cutting blades: Sharp components that cut the fodder into smaller pieces.
4. Flywheel: Stores rotational energy and helps maintain smooth operation in applicable designs.
5. Cutting chamber: The enclosed section where fodder is cut.
6. Discharge outlet: The opening through which chopped fodder leaves the machine.
7. Transmission system: Transfers power from the motor or engine to the cutting mechanism.
8. Frame: Supports the machine and keeps its components in position.
9. Protective covers and guards: Prevent accidental contact with moving components.
10. Switch or control lever: Starts, stops or controls the machine.

Uses of a chaff cutter in livestock production

1. Chopping Napier grass into manageable pieces.
2. Preparing green maize fodder for cattle.
3. Reducing the length of hay and suitable crop residues.
4. Preparing fodder for dairy cattle, goats and other livestock.
5. Facilitating the mixing of different feed materials.
6. Reducing wastage caused by animals rejecting long or poorly presented fodder.
7. Making it easier to transport and distribute chopped fodder around the livestock unit.

Importance of chopping fodder

1. Improves feed handling: Shorter pieces are easier to handle and distribute.
2. Reduces feed wastage: Properly chopped fodder may reduce rejection and trampling.

3. Facilitates mixing: Chopped materials are easier to mix with other feed ingredients.
4. Improves feeding management: Farmers can prepare more uniform portions.
5. Saves labour: A powered chaff cutter can prepare large quantities of fodder quickly.

Important: Chopping fodder does not automatically improve its nutritional value. The quality of the feed still depends on the plant species, maturity, harvesting stage, storage and feeding management.

Maintenance practices

- Clean the cutting chamber after use.
- Remove trapped fodder and dirt after switching off and isolating the machine.
- Sharpen or replace blunt blades.
- Tighten loose nuts and bolts.
- Lubricate bearings and other specified moving parts.
- Inspect belts and pulleys for wear and correct tension.
- Check the engine or electric motor.
- Replace damaged guards.
- Inspect the power cable or fuel system.
- Store the machine under shelter.

Safety precautions

1. Never insert hands into the feeding chute while the machine is running.
2. Keep all protective guards in position.
3. Use a suitable feeding stick or approved feeding mechanism where provided.
4. Avoid wearing loose clothing that can be caught by moving parts.
5. Do not allow children or untrained persons to operate the machine.
6. Switch off and isolate the power source before cleaning or adjusting blades.
7. Wear safety boots, overalls and hearing protection where appropriate.
8. Ensure the machine is firmly positioned before operation.
9. Keep the working area free from unnecessary materials.
10. Never operate a machine with exposed belts, damaged blades or faulty electrical connections.

3.2.2 Milking machine

A milking machine is powered equipment used to extract milk from dairy animals, especially cows and goats. It uses a controlled vacuum and pulsation system to remove milk from the teats.

Milking machines are commonly powered by electricity. Some portable units may use other suitable power arrangements.

Main parts of a milking machine

1. Vacuum pump: Creates the vacuum required for milk extraction.
2. Vacuum regulator: Maintains the vacuum at the recommended operating level.
3. Vacuum gauge: Displays the vacuum level.
4. Pulsator: Alternates the vacuum and air admission to produce the pulsating action.
5. Teat cups: Fit over the teats and contain the liners.
6. Teat cup liners: Flexible rubber or silicone components that make contact with the teats.
7. Milk claw or cluster: Collects milk from the teat cups.
8. Milk tubes: Carry milk from the teat cups to the collection container or pipeline.
9. Milk receiver or bucket: Collects the extracted milk.
10. Milk filter: Removes visible physical particles from milk.
11. Cleaning system: Allows cleaning and sanitising of milk-contact surfaces.

Uses of a milking machine

- Extracting milk from dairy cows.
- Milking goats using suitable goat-milking equipment.
- Milking several dairy animals efficiently.
- Reducing the time spent on milking.
- Supporting hygienic milk handling when properly cleaned and maintained.
- Improving consistency in milking routines.

Advantages of machine milking over hand milking

1. Saves time: It can milk several animals within a shorter period.
2. Reduces labour requirements: Fewer workers may be needed for milking.
3. Reduces physical strain: It minimises the repetitive hand movements associated with manual milking.
4. Improves milking efficiency: It supports organised and consistent milking routines.
5. Facilitates milk handling: Milk can be collected through a closed system, reducing some opportunities for contamination.

6. Supports large-scale dairy farming: It is suitable for farms with many dairy animals.
7. Improves record management: Some modern systems can record individual animal milk yields.

Limitations of machine milking

- Initial purchase and installation costs may be high.
- It requires electricity or another suitable power supply.
- It needs regular cleaning and maintenance.
- Incorrect vacuum levels or poor use may injure teats.
- Poorly cleaned equipment can spread microorganisms and contribute to mastitis.
- Operators require training.

Maintenance practices

1. Clean teat cups and milk tubes immediately after milking according to the manufacturer's instructions.
2. Use approved cleaning and sanitising procedures.
3. Inspect liners for cracks, wear and damage.
4. Replace worn liners at the recommended intervals.
5. Check the vacuum pump and vacuum regulator.
6. Inspect the pulsator for correct operation.
7. Check hoses for cracks and leakage.
8. Ensure milk filters are replaced as required.
9. Inspect electrical connections and cables.
10. Arrange regular servicing by a qualified technician.

Safety and hygiene precautions

- Wash hands before handling the equipment.
- Ensure the udder and teats are clean and dry.
- Inspect foremilk using a strip cup.
- Do not attach teat cups to dirty or wet teats.
- Use the correct vacuum and pulsation settings.
- Remove the milking cluster correctly after milking.
- Do not pull teat cups off while vacuum is still applied.

- Keep the milk-contact surfaces clean and sanitised.
- Separate milk from animals suspected of having mastitis or undergoing veterinary treatment, observing withdrawal periods.

3.3 Assembling and dissembling tools

Assembling involves joining different components of a machine, tool or structure to form a complete working unit. Dissembling involves separating components for repair, cleaning, replacement or storage.

Powered tools used in farm workshops help farmers carry out repairs, construct structures and maintain agricultural equipment.

Examples include:

1. Power drills.
2. Hand-held circular saws.
3. Electric grinders.
4. Powered screwdrivers.
5. Electric sanders.

3.3.1 Power drill

A power drill is an electrically powered or battery-operated tool used to make holes in materials such as wood, metal and suitable plastics. Some models also drive screws when fitted with appropriate bits.

Main parts of a power drill

1. Electric motor: Converts electrical energy into rotational movement.
2. Trigger switch: Starts and controls the drill.
3. Battery or power cable: Supplies electrical energy.
4. Chuck: Holds the drill bit or screwdriver bit.
5. Drill bit: Cuts into the material to make a hole.
6. Gear selector: Changes the rotational speed or torque range in applicable models.
7. Direction selector: Changes the direction of rotation.
8. Handle: Provides a firm grip.
9. Torque adjustment ring: Controls the turning force in drill-driver models.
10. Auxiliary handle: Provides additional control in certain models.

Uses of a power drill in agriculture

1. Making holes in timber used to construct animal houses.

2. Drilling holes in metal components using suitable drill bits.
3. Installing screws when assembling farm structures.
4. Repairing farm gates and fencing structures.
5. Constructing poultry houses and livestock shelters.
6. Assembling shelves and storage units in farm stores.
7. Repairing wooden feeding troughs.
8. Installing suitable fittings on farm buildings.

Types of drill bits

Drill bit	Main use
Twist drill bit	Drilling metal and other suitable materials
Brad-point bit	Drilling accurate holes in wood
Masonry bit	Drilling brick, concrete and masonry using a suitable drill
Spade bit	Making relatively wide holes in wood
Screwdriver bit	Driving and removing screws

Advantages of a power drill

- Makes holes faster than manual drilling.
- Reduces physical effort.
- Produces more uniform holes when correctly operated.
- Can be used with different bits for different materials.
- Can be used for both drilling and screw driving in suitable models.

Maintenance practices

1. Remove dust and debris after use.
2. Clean the chuck and drill body.
3. Inspect drill bits for bluntness or damage.
4. Replace damaged bits.
5. Check the power cable for cuts or exposed wires.
6. Inspect battery condition and charging equipment.
7. Keep ventilation openings free from dust.

8. Store drill bits in a dry case.
9. Follow the manufacturer's lubrication and servicing instructions.
10. Store the drill in a dry and secure place.

Safety precautions

- Wear safety goggles to protect the eyes from flying particles.
- Secure the workpiece using a vice or clamp.
- Select the correct drill bit for the material.
- Ensure the bit is firmly fitted in the chuck.
- Keep fingers away from the rotating bit.
- Do not force the drill beyond its capacity.
- Disconnect the power supply or remove the battery before changing bits.
- Avoid drilling near concealed electrical cables or water pipes.
- Use suitable hearing protection where necessary.

3.3.2 Hand-held circular saw

A hand-held circular saw is a powered cutting tool fitted with a rotating circular blade. It is mainly used to cut timber and other materials using a blade designed for the particular material.

Main parts of a hand-held circular saw

1. Electric motor: Provides power to rotate the blade.
2. Circular blade: Cuts the material.
3. Blade guard: Covers the blade to reduce accidental contact.
4. Base plate or shoe: Supports the saw on the material being cut.
5. Handle: Provides a firm grip and control.
6. Trigger switch: Starts and stops the saw.
7. Depth adjustment: Controls how deeply the blade cuts.
8. Bevel adjustment: Allows angled cuts in suitable models.
9. Power cable or battery: Supplies electrical energy.
10. Spindle lock: Holds the spindle in position when changing the blade in applicable models.

Uses of a circular saw in agriculture

1. Cutting timber for constructing poultry houses.

2. Cutting boards for livestock feeding troughs.
3. Preparing timber for farm gates.
4. Cutting materials used in constructing stores and sheds.
5. Preparing boards for farm furniture.
6. Cutting suitable building materials when fitted with the correct blade.

Maintenance practices

- Remove sawdust after use.
- Inspect the blade for cracks, missing teeth and damage.
- Replace damaged blades.
- Keep the blade sharp.
- Inspect the blade guard to ensure that it moves and returns correctly.
- Check the power cable or battery.
- Clean the ventilation openings.
- Inspect the base plate and adjustment mechanisms.
- Store the saw safely with the blade protected.

Safety precautions

1. Wear eye and hearing protection.
2. Use a suitable blade for the material being cut.
3. Secure the material before cutting.
4. Keep both hands in the recommended operating positions.
5. Never remove or tie back the blade guard.
6. Keep the power cable away from the blade.
7. Allow the blade to stop completely before placing the saw down.
8. Disconnect the power supply before changing the blade.
9. Do not cut materials that are unstable or poorly supported.
10. Operate the saw only after receiving proper training.

4.0 Maintenance practices for powered tools and equipment

Maintenance refers to the activities carried out to keep tools and equipment in good working condition, prevent breakdowns, improve performance and extend their useful life.

Powered agricultural equipment contains moving parts, electrical components, cutting edges, engines and other mechanisms that require regular attention.

Importance of maintaining powered tools and equipment

1. Extends equipment lifespan: Regular maintenance reduces premature wear and damage.
2. Prevents breakdowns: Inspection helps identify faults before they cause serious failures.
3. Improves efficiency: Well-maintained equipment performs tasks more effectively.
4. Promotes safety: Faulty equipment can cause injuries, electric shocks, fires and other accidents.
5. Reduces repair costs: Small faults can be corrected before they develop into expensive problems.
6. Saves time: Properly maintained equipment is less likely to fail during important farm operations.
7. Maintains quality of work: Sharp blades, properly adjusted components and functional motors improve performance.
8. Reduces wastage: Properly functioning equipment reduces unnecessary losses of materials and energy.
9. Improves reliability: Farmers can depend on their equipment when carrying out scheduled operations.
10. Maintains resale value: Equipment in good condition may retain a higher resale value.

4.1 Types of maintenance

4.1.1 Routine maintenance

Routine maintenance refers to simple maintenance activities carried out regularly, often before or after each use.

Examples include:

- Cleaning the equipment after use.
- Checking fuel or battery levels.
- Inspecting cables and connections.
- Checking bolts and nuts.
- Removing dust, soil and crop residues.
- Checking protective guards.
- Inspecting blades for damage.
- Checking for oil or fuel leakages.

4.1.2 Preventive maintenance

Preventive maintenance refers to planned maintenance activities carried out at specified intervals to prevent equipment failure.

Examples include:

- Changing engine oil at recommended intervals.
- Replacing air filters.
- Sharpening or replacing cutting blades.
- Replacing worn belts.
- Lubricating bearings.
- Inspecting electrical connections.
- Servicing the vacuum pump of a milking machine.
- Replacing worn milking machine liners.

4.1.3 Corrective maintenance

Corrective maintenance refers to repairs carried out after a fault or breakdown has occurred.

Examples include:

- Replacing a damaged electric cable.
- Repairing a faulty motor.
- Replacing a broken cutting blade.
- Repairing a leaking fuel pipe.
- Replacing worn bearings.
- Repairing a faulty switch.

4.1.4 Predictive maintenance

Predictive maintenance involves monitoring the condition and performance of equipment to identify signs of possible failure before it occurs.

Examples include:

- Monitoring unusual vibration in a motor.
- Listening for unusual engine sounds.
- Monitoring the temperature of a motor.
- Checking for unusual changes in power consumption.
- Monitoring vacuum performance in milking machines.

4.2 Specific maintenance practices

4.2.1 Cleaning

Cleaning is the removal of dirt, dust, grease, soil, crop residues and other unwanted materials from equipment.

Importance of cleaning

1. Prevents the accumulation of materials that may interfere with machine operation.
2. Reduces corrosion caused by moisture and harmful substances.
3. Helps identify cracks, leaks and damaged components.
4. Maintains hygiene in livestock equipment.
5. Prevents the spread of disease-causing microorganisms through poorly cleaned livestock equipment.

Procedure for cleaning powered equipment

1. Switch off the machine.
2. Disconnect it from the power supply or remove the battery where appropriate.
3. Allow hot components to cool.
4. Remove loose dirt and plant residues.
5. Use suitable brushes or cleaning materials.
6. Clean surfaces using the manufacturer's recommended method.
7. Dry the equipment where moisture may cause corrosion or electrical damage.
8. Inspect the equipment for damage.
9. Store it in a safe and dry place.

Note: Do not pour water onto electric motors, batteries, switches or electrical connections unless the equipment is specifically designed for such cleaning.

4.2.2 Sharpening blades

Sharpening is the process of restoring the cutting edge of a blade to improve its ability to cut materials.

Examples of blades that require sharpening include:

- Grass cutter blades.
- Chaff cutter blades.
- Circular saw blades, where sharpening is permitted by the manufacturer.
- Other agricultural cutting blades.

Importance of sharpening blades

1. Improves cutting efficiency.
2. Reduces the amount of force required during operation.
3. Reduces unnecessary strain on the motor or engine.
4. Produces cleaner and more uniform cuts.
5. Reduces the time required to complete cutting tasks.
6. Prevents excessive fuel or electricity consumption caused by inefficient cutting.

Procedure for sharpening a suitable blade

1. Switch off and isolate the machine from its power source.
2. Remove the blade according to the manufacturer's instructions.
3. Inspect the blade for cracks, excessive wear or other damage.
4. Do not sharpen a blade that is unsafe or structurally damaged; replace it.
5. Use the correct sharpening tool.
6. Maintain the recommended cutting angle.
7. Sharpen evenly to avoid imbalance.
8. Clean the blade after sharpening.
9. Refit and secure the blade correctly.
10. Test the equipment safely before returning it to normal use.

4.2.3 Lubrication

Lubrication is the application of oil, grease or another suitable lubricant to moving parts to reduce friction and wear.

Importance of lubrication

1. Reduces friction between moving parts.
2. Minimises wear and tear.
3. Prevents overheating.
4. Reduces noise during operation.
5. Protects metal surfaces against corrosion.
6. Improves the efficiency of moving components.
7. Extends the lifespan of machinery.

Examples of parts that may require lubrication

- Bearings.
- Chains.
- Gears.
- Shafts.
- Hinges.
- Moving joints.
- Engine components requiring specified oil.

Procedure for lubrication

1. Identify the parts requiring lubrication.
2. Switch off and isolate the equipment.
3. Clean the lubrication points.
4. Select the correct lubricant.
5. Apply the recommended quantity.
6. Avoid over-lubrication.
7. Wipe away excess lubricant.
8. Record the maintenance activity where necessary.

Types of lubricants

Lubricant	**Description**	**Common application**
Engine oil	Liquid lubricant used in engines	Petrol and diesel engines
Grease	Thick lubricant	Bearings and selected joints
Gear oil	Lubricant formulated for gears	Gearboxes and transmissions
Chain lubricant	Lubricant for chains	Suitable chain-driven equipment

4.2.4 Replacement of worn-out parts

Part replacement involves removing damaged, worn or defective components and fitting suitable new ones.

Examples include:

- Replacing worn chaff cutter blades.
- Replacing damaged electrical cables.
- Replacing worn milking machine liners.

- Replacing damaged drill bits.
- Replacing worn drive belts.
- Replacing faulty spark plugs.
- Replacing damaged safety guards.

Importance of replacing worn-out parts

1. Restores equipment performance.
2. Prevents further damage to other components.
3. Improves safety.
4. Reduces unexpected breakdowns.
5. Maintains the quality of agricultural operations.

Procedure

1. Identify the defective component.
2. Switch off and isolate the equipment.
3. Obtain the correct replacement part.
4. Remove the defective part using suitable tools.
5. Fit the replacement correctly.
6. Tighten and secure all relevant fasteners.
7. Test the equipment safely.
8. Record the replacement in the maintenance logbook.

4.2.5 Adjustment of machine parts

Adjustment involves changing the position, tension, clearance or setting of machine components to ensure correct operation.

Examples include:

- Adjusting belt tension.
- Adjusting the depth of a circular saw blade.
- Adjusting the cutting height of a grass cutter.
- Adjusting the feed mechanism of a chaff cutter.
- Adjusting the vacuum level of a milking machine according to specifications.
- Adjusting the position of machine components to reduce unnecessary vibration.

Importance of adjustment

- Ensures correct machine operation.
- Improves the quality of work.
- Prevents excessive wear.
- Reduces vibration and noise.
- Improves safety.
- Reduces energy wastage.

4.2.6 Engine servicing

Fuel-powered agricultural equipment requires regular engine servicing.

Common engine servicing activities

1. Checking and changing engine oil.
2. Cleaning or replacing air filters.
3. Inspecting spark plugs in petrol engines.
4. Checking fuel pipes and fuel filters.
5. Inspecting the cooling system where fitted.
6. Checking for oil and fuel leakages.
7. Inspecting engine mounting bolts.
8. Cleaning external engine surfaces.
9. Checking engine starting and stopping mechanisms.
10. Following the manufacturer's recommended service schedule.

Importance of engine servicing

- Improves engine performance.
- Reduces fuel consumption caused by poor engine condition.
- Prevents overheating.
- Reduces smoke and harmful emissions.
- Extends engine lifespan.
- Reduces the risk of unexpected breakdowns.

4.3 Maintenance schedule for selected powered tools and equipment

A maintenance schedule is a planned timetable showing the activities to be performed on equipment and when they should be carried out.

Equipment	Before use	After use	Periodic maintenance
Soil auger	Inspect bit, handles and power unit	Clean soil from bit	Inspect engine/motor and sharpen or replace bit
Grass cutter	Check blade, guard and fuel/battery	Remove grass and dirt	Sharpen blade, service engine or inspect battery
Chaff cutter	Inspect blades, guards and drive system	Clean cutting chamber	Lubricate bearings and inspect belts
Milking machine	Inspect hoses, liners and vacuum system	Clean and sanitise milk-contact parts	Service vacuum pump and replace worn liners
Power drill	Check bit, chuck and cable/battery	Remove dust and debris	Inspect motor, chuck and electrical connections
Circular saw	Check blade and guard	Clean sawdust	Inspect blade, motor and adjustment mechanism

4.4 Maintenance records

Maintenance records are documents used to show the maintenance activities carried out on farm equipment.

Information recorded includes:

1. Name of the equipment.
2. Identification or serial number.
3. Date of maintenance.
4. Type of maintenance performed.
5. Parts repaired or replaced.
6. Materials and lubricants used.
7. Cost of maintenance.
8. Name of the person who carried out the work.
9. Next scheduled maintenance date.
10. Remarks on the condition of the equipment.

Sample maintenance record

Date	Equipment	Maintenance activity	Parts/materials used	Cost (KSh)	Next service
2/11/2026	Grass cutter	Blade sharpening	Sharpening file	300	As scheduled

5/11/2026	Chaff cutter	Bearing lubrication	Grease	250	As scheduled
8/11/2026	Power drill	Replaced damaged bit	Drill bit	450	As scheduled

Importance of maintenance records

- Help plan future maintenance.
- Provide evidence of repairs and servicing.
- Help determine the total cost of maintaining equipment.
- Assist in identifying frequently failing components.
- Help farmers plan for replacement parts.
- Improve accountability among farm workers.
- Support budgeting and decision-making.

5.0 Safety in the use of powered tools and equipment

Safety refers to the measures and practices used to prevent accidents, injuries, damage to equipment and environmental harm when operating powered agricultural tools and equipment.

Powered tools can be dangerous because they may contain sharp blades, rotating parts, electrical connections, hot surfaces, fuel systems and high-speed moving components.

5.1 Importance of observing safety measures

1. Prevention of injuries: Safety practices reduce cuts, burns, fractures and other injuries.
2. Protection from electric shocks: Proper handling of electrical equipment reduces the risk of electrocution.
3. Prevention of fires: Correct fuel handling and electrical safety reduce fire risks.
4. Protection of equipment: Safe operation prevents avoidable damage.
5. Reduction of financial losses: Accidents may lead to medical expenses, repairs and loss of working time.
6. Protection of other people: Keeping bystanders away prevents injuries to people who are not operating the equipment.
7. Improvement of productivity: Safe working environments reduce interruptions caused by accidents.
8. Protection of animals: Safe equipment handling prevents injuries to livestock.
9. Environmental protection: Proper handling of fuel, oil and other materials prevents pollution.

5.2 General safety precautions when using powered tools

A. Before operating powered tools

1. Read and understand the manufacturer's instructions.
2. Ensure that the operator has received appropriate training.
3. Inspect the equipment for visible damage.
4. Check that all protective guards are correctly fitted.
5. Ensure that the tool is suitable for the intended task.
6. Confirm that the power source is appropriate.
7. Check fuel and oil levels where applicable.
8. Inspect electric cables and plugs for damage.
9. Ensure that batteries are correctly fitted and undamaged.
10. Clear the working area of unnecessary materials.
11. Keep children, visitors and animals away from the operating area.
12. Wear suitable personal protective equipment.
13. Ensure that the equipment is firmly positioned before starting it.

B. During operation

1. Operate the equipment according to the manufacturer's instructions.
2. Maintain a firm and balanced posture.
3. Avoid distractions while operating machinery.
4. Keep hands and other body parts away from moving components.
5. Do not remove protective guards.
6. Avoid wearing loose clothing or jewellery that may become entangled.
7. Do not overload equipment.
8. Do not allow untrained persons to operate the machine.
9. Stop operation if unusual vibration, noise, overheating or leakage occurs.
10. Never leave running equipment unattended.
11. Keep the work area adequately ventilated when using fuel-powered engines.
12. Do not operate machinery when tired or unable to concentrate.

C. After operation

1. Switch off the equipment.

2. Disconnect it from the electrical supply or remove the battery where appropriate.
3. Allow hot parts to cool before handling.
4. Clean the equipment using the recommended procedure.
5. Inspect for damage or wear.
6. Carry out necessary routine maintenance.
7. Store tools safely.
8. Keep fuel in approved, clearly labelled containers.
9. Record any faults identified.
10. Secure the equipment to prevent unauthorised use.

5.3 Personal protective equipment (PPE)

Personal protective equipment refers to clothing and devices worn to protect a person from hazards during work.

Protective equipment	**Function**
Safety goggles	Protect the eyes from dust and flying particles
Face shield	Protects the face from flying debris
Safety boots	Protect the feet from falling objects and sharp materials
Gloves	Protect hands from cuts, dirt and selected hazards; gloves must not be worn near rotating parts where they could become entangled
Overalls	Protect the body and clothing from dirt and selected workplace hazards
Ear defenders or earplugs	Reduce exposure to excessive noise
Respirator or suitable mask	Protects against selected dusts, fumes and particles when correctly selected
Helmet	Protects the head from falling or striking objects
Reflective clothing	Improves visibility in areas with moving vehicles or machinery

Important: PPE should be suitable for the particular task. It does not replace proper training, machine guards, safe procedures and equipment maintenance.

5.4 Specific hazards associated with powered tools

Hazard	**Possible danger**	**Preventive measure**

Rotating blades	Cuts and amputations	Keep guards fitted and hands away
Flying particles	Eye and face injuries	Wear goggles or a face shield
Electricity	Electric shock and burns	Use sound cables and suitable electrical protection
Excessive noise	Hearing damage	Use appropriate hearing protection
Fuel	Fire and burns	Refuel safely away from ignition sources
Hot engine parts	Burns	Allow the engine to cool before handling
Moving belts	Entanglement	Keep guards fitted and avoid loose clothing
Dust and fumes	Respiratory irritation	Ensure adequate ventilation and use suitable respiratory protection
Vibration	Hand and arm discomfort or injury	Maintain equipment and limit exposure according to guidance
Unstable equipment	Slips, falls and injuries	Position and secure equipment correctly

5.5 Electrical safety precautions

1. Do not operate electrical equipment with wet hands.
2. Avoid using damaged cables, plugs and sockets.
3. Use suitable electrical connections and protective devices.
4. Keep electrical equipment away from water unless specifically designed for wet conditions.
5. Switch off and disconnect equipment before repairs.
6. Do not overload electrical sockets.
7. Avoid pulling a plug out by its cable.
8. Use qualified personnel to repair electrical faults.
9. Ensure electrical equipment is properly earthed where required.
10. Protect cables from sharp objects, heat and moving machinery.

5.6 Fuel safety precautions

1. Store fuel in approved and labelled containers.
2. Keep fuel away from flames, sparks and heat.
3. Refuel outdoors or in a well-ventilated place as directed by the manufacturer.
4. Switch off the engine before refuelling.

5. Allow hot engine components to cool before refuelling.
6. Do not smoke while handling fuel.
7. Clean fuel spills immediately using safe procedures.
8. Avoid inhaling fuel vapours.
9. Keep fuel away from children.
10. Do not store fuel near animal feeds, food or drinking water.

5.7 Safety when using specific equipment

A. Soil auger

- Check the drilling area for buried services.
- Hold the equipment firmly.
- Keep the auger bit away from the body.
- Stop the machine before removing trapped materials.
- Avoid operating near other people.

B. Grass cutter

- Inspect the cutting area for stones and debris.
- Use the correct cutting attachment.
- Keep the guard in place.
- Wear face and hearing protection where appropriate.
- Do not refuel a hot engine.

C. Chaff cutter

- Keep hands away from the feeding chute.
- Use the designed feeding mechanism.
- Do not remove safety guards.
- Isolate the power supply before cleaning.
- Keep children away from the machine.

D. Milking machine

- Ensure the equipment is clean and correctly assembled.
- Check the vacuum system before use.

- Use correct vacuum settings.
- Avoid damaging the animal's teats.
- Clean and sanitise milk-contact parts after use.

E. Power drill

- Secure the workpiece.
- Use the correct drill bit.
- Disconnect power before changing the bit.
- Wear eye protection.
- Keep the drill away from water unless designed for such use.

F. Circular saw

- Ensure the blade guard is functional.
- Secure the material before cutting.
- Use the correct blade.
- Keep hands away from the blade path.
- Disconnect the power supply before blade replacement.

5.8 First aid and emergency response

An emergency may occur when a person is injured while using powered equipment.

General response to an accident

1. Stop the machine if it is safe to do so.
2. Disconnect the power source where possible.
3. Do not touch a person who is still in contact with a live electrical source; isolate the electricity first.
4. Call for assistance and seek appropriate emergency services.
5. Give first aid only within the limits of one's training.
6. Control severe bleeding using appropriate first-aid procedures.
7. Do not move a seriously injured person unless there is immediate danger.
8. Report the accident to the responsible person.
9. Record the incident.
10. Do not restart the equipment until the cause of the accident has been investigated and corrected.

Common injuries and appropriate responses

Injury	Initial response
Minor cut	Clean appropriately and cover with a sterile dressing
Severe bleeding	Apply firm direct pressure and seek urgent medical attention
Burn	Cool the burn with cool running water and seek medical help where necessary
Electric shock	Isolate the power source before touching the casualty; seek urgent medical assistance
Eye injury	Avoid rubbing or pressing the eye; seek medical attention
Suspected fracture	Keep the injured part still and seek medical assistance

6.0 Carrying out selected agricultural tasks using powered tools and equipment

Learners should acquire practical skills in the correct selection, operation, cleaning and maintenance of powered tools and equipment.

Practical activities should be conducted under the supervision of a trained teacher, technician or other qualified resource person.

6.1 Practical activity: Cutting grass using a powered grass cutter

Objective: To develop skills in operating and maintaining a powered grass cutter safely.

Requirements

- Powered grass cutter.
- Appropriate cutting attachment.
- Fuel or charged battery, as applicable.
- Safety boots.
- Overalls.
- Eye and face protection.
- Hearing protection where necessary.
- Gloves suitable for the task.
- First-aid kit.

Procedure

1. Identify the type of grass cutter available.
2. Study the manufacturer's instructions.
3. Inspect the equipment for damage.

4. Check the cutting attachment and guard.
5. Inspect the working area and remove stones, wires and other obstacles.
6. Put on the appropriate PPE.
7. Ensure that people and animals are away from the cutting area.
8. Start the machine according to the manufacturer's instructions.
9. Hold the equipment firmly.
10. Cut the grass using controlled movements.
11. Avoid directing the cutting head towards people or animals.
12. Stop the machine after completing the task.
13. Isolate the power source before cleaning.
14. Remove grass and debris.
15. Inspect the cutting attachment.
16. Store the equipment safely.

Observation table

Observation	**Learner's findings**
Type of grass cutter used	
Source of power	
Type of cutting attachment	
Area cleared	
Safety equipment used	
Maintenance carried out	
Challenges encountered	

6.2 Practical activity: Chopping fodder using a powered chaff cutter

Objective: To acquire skills in preparing livestock fodder using a powered chaff cutter.

Requirements

- Powered chaff cutter.
- Suitable fodder such as Napier grass.
- Suitable collection containers.

- Safety boots.
- Overalls.
- Eye and hearing protection where necessary.

Procedure

1. Identify the main parts of the chaff cutter.
2. Read the operating instructions.
3. Inspect the blades, guards and feeding mechanism.
4. Ensure the machine is firmly positioned.
5. Prepare the fodder by removing unsuitable foreign materials.
6. Put on the required PPE.
7. Start the machine according to instructions.
8. Feed the fodder using the approved feeding mechanism.
9. Avoid inserting hands into the feeding chute.
10. Collect the chopped fodder safely.
11. Switch off and isolate the machine.
12. Clean the cutting chamber.
13. Inspect the blades and other components.
14. Store the equipment safely.

Observation table

Observation	**Learner's findings**
Type of fodder used	
Source of power	
Main parts identified	
Nature of chopped fodder	
Safety measures observed	
Maintenance practices performed	

6.3 Practical activity: Drilling holes using a power drill

Objective: To develop skills in using a power drill for agricultural construction and repair.

Requirements

- Power drill.
- Suitable drill bits.
- Timber or another suitable workpiece.
- Clamps or vice.
- Safety goggles.
- Appropriate PPE.

Procedure

1. Identify the main parts of the power drill.
2. Select a suitable drill bit.
3. Inspect the drill for damage.
4. Ensure the workpiece is firmly secured.
5. Fit the drill bit correctly.
6. Wear safety goggles.
7. Position the drill at the required point.
8. Hold the drill firmly.
9. Start drilling using the appropriate speed and technique.
10. Avoid forcing the drill.
11. Stop the drill after making the hole.
12. Disconnect the power or remove the battery.
13. Remove the drill bit safely.
14. Clean and store the equipment.

6.4 Practical activity: Screwing using a power drill

Objective: To develop skills in using a power drill as a screwdriver during the assembly of farm structures.

Procedure

1. Select the correct screw and screwdriver bit.
2. Inspect the drill and the battery or cable.

3. Fit the screwdriver bit firmly.
4. Position the materials to be joined.
5. Make a pilot hole where necessary.
6. Place the screw at the correct position.
7. Hold the drill firmly.
8. Set the appropriate torque.
9. Drive the screw into the material.
10. Stop when the screw is correctly seated.
11. Avoid over-tightening.
12. Disconnect the power source.
13. Clean and store the equipment.

6.5 Practical activity: Milking using a milking machine

Objective: To understand the operation of a milking machine and observe hygienic milk production.

Requirements

- Healthy dairy animal.
- Milking machine.
- Clean water.
- Approved cleaning and sanitising materials.
- Clean towels.
- Strip cup.
- Milk container.
- Appropriate protective clothing.

Procedure

1. Prepare the milking area.
2. Wash hands thoroughly.
3. Ensure the milking machine is clean and correctly assembled.
4. Bring the dairy animal calmly into the milking area.
5. Restrain the animal appropriately without causing unnecessary distress.

6. Inspect the udder and teats.
7. Clean and dry the teats.
8. Examine foremilk using a strip cup.
9. Check for abnormal milk and signs of mastitis.
10. Start the machine according to the manufacturer's instructions.
11. Attach the teat cups correctly.
12. Observe the milking process.
13. Remove the cluster correctly when milking is complete.
14. Apply an approved post-milking teat dip where recommended.
15. Filter and cool the milk promptly using appropriate procedures.
16. Clean and sanitise the equipment.
17. Record the quantity of milk obtained and any observations.

Precautions

- Do not use a milking machine on an animal with an injured or infected udder without appropriate veterinary guidance.
- Do not mix abnormal milk with milk intended for sale or consumption.
- Observe veterinary drug withdrawal periods.
- Ensure that milk-contact surfaces are clean.
- Avoid incorrect vacuum settings and poor teat-cup attachment.

7.0 Selecting appropriate powered tools and equipment

Farmers should select equipment according to the task to be performed, available resources and the conditions under which the equipment will operate.

Factors to consider when selecting powered tools and equipment

1. Purpose of the equipment: Choose equipment designed for the intended agricultural task. For example, a chaff cutter is suitable for chopping fodder, while a soil auger is suitable for boring holes.
2. Source of power: Consider whether electricity, solar energy, fuel or another power source is available.
3. Purchase cost: Select equipment that is affordable within the farm's budget.
4. Operating costs: Consider the cost of fuel, electricity, lubricants and other consumables.
5. Size of the farm: Large farms may require higher-capacity equipment than small farms.
6. Amount of work: Equipment should have sufficient capacity to handle the expected workload.

7. Availability of spare parts: Choose equipment whose replacement parts can be obtained easily.
8. Availability of repair services: Consider whether trained technicians are available.
9. Ease of operation: Equipment should be manageable by appropriately trained operators.
10. Safety features: Select equipment with appropriate guards, emergency stops and other safety features.
11. Durability: Choose equipment made from suitable, strong and durable materials.
12. Maintenance requirements: Consider how frequently the equipment requires servicing.
13. Environmental impact: Consider noise, fuel consumption, emissions and possible pollution.
14. Portability: Some farm activities require equipment that can easily be moved from one location to another.
15. Manufacturer's warranty: Consider the warranty and availability of after-sales services.

7.1 Factors affecting the efficiency of powered tools and equipment

Efficiency refers to the ability of equipment to perform its intended task effectively while using resources appropriately.

Factors affecting efficiency include:

1. Condition of the equipment.
2. Availability of sufficient power.
3. Skills and experience of the operator.
4. Correct adjustment of machine components.
5. Sharpness of cutting blades.
6. Quality of maintenance.
7. Suitability of the equipment for the task.
8. Environmental conditions.
9. Availability of spare parts.
10. Quality of materials being processed.

7.2 Common problems experienced when using powered equipment

Problem	Possible cause	Appropriate action
Engine fails to start	Fuel shortage, faulty spark plug or other engine fault	Check according to the manufacturer's instructions
Equipment overheats	Overloading, blocked ventilation or	Stop operation and investigate

	inadequate lubrication	
Blades cut poorly	Blunt or damaged blades	Sharpen or replace where appropriate
Excessive vibration	Loose or damaged components	Switch off and inspect
Power drill fails to operate	Flat battery, damaged cable or faulty switch	Check the power supply and seek repair
Chaff cutter blocks	Excessive or unsuitable fodder feeding	Switch off and isolate before clearing
Milking machine loses vacuum	Leaking hoses or faulty vacuum components	Inspect the system and repair
Unusual noise	Loose parts, worn bearings or other mechanical faults	Stop and inspect the equipment

Important: Learners should not attempt complex electrical, mechanical or engine repairs without appropriate training and supervision.

8.0 Environmental considerations when using powered tools and equipment

Powered tools and equipment can affect the environment through fuel consumption, exhaust emissions, noise, waste materials and accidental leakage of lubricants.

Farmers should adopt environmentally responsible practices when operating and maintaining equipment.

Environmental protection practices

1. Preventing oil spills: Handle lubricants carefully to avoid contaminating soil and water.
2. Proper fuel storage: Store fuel in approved containers to prevent leakage.
3. Responsible disposal of used oil: Collect used engine oil and take it to an authorised collection or disposal facility.
4. Proper disposal of batteries: Avoid throwing used batteries into open fields, rivers or ordinary waste where they can cause pollution.
5. Reducing fuel consumption: Service engines regularly and avoid unnecessary idling.
6. Controlling noise: Operate noisy equipment responsibly and maintain silencers where fitted.
7. Preventing air pollution: Maintain engines to reduce excessive smoke and harmful emissions.
8. Responsible water use: Avoid unnecessary water wastage when cleaning equipment.
9. Proper disposal of damaged parts: Dispose of metal, plastic and electrical waste appropriately.
10. Using renewable energy: Where suitable and affordable, adopt solar-powered equipment to reduce dependence on fossil fuels.

9.0 Agricultural technologies and entrepreneurship

Powered tools and equipment contribute to agricultural entrepreneurship by creating opportunities for farmers and other individuals to provide services and produce goods commercially.

Agricultural entrepreneurship involves identifying and exploiting business opportunities in agriculture through innovation, production, processing, marketing and service provision.

Business opportunities associated with powered agricultural equipment

1. Grass-cutting services: An entrepreneur can purchase a powered grass cutter and provide grass-cutting services to schools, homes, institutions and farms.
2. Fodder-chopping services: A farmer can operate a chaff cutter and charge livestock farmers for chopping Napier grass and other suitable fodder.
3. Milking services: Trained service providers may offer machine-milking services to dairy farmers.
4. Farm equipment hire: Entrepreneurs can hire out soil augers, grass cutters, chaff cutters and other suitable equipment.
5. Equipment repair: Skilled technicians can establish workshops to repair agricultural machinery.
6. Equipment maintenance: Entrepreneurs can provide servicing, lubrication, sharpening and parts-replacement services.
7. Farm construction services: Power drills and circular saws can support businesses involved in constructing poultry houses, livestock shelters and farm stores.
8. Solar installation services: Trained technicians can install and maintain solar-powered irrigation and livestock systems.
9. Sale of spare parts: Businesses can supply drill bits, blades, belts, filters and other replacement parts.
10. Agricultural equipment training: Qualified individuals can offer training on safe equipment use and routine maintenance.

9.1 Benefits of using powered equipment in agricultural enterprises

- Increases the amount of work completed within a given period.
- Enables entrepreneurs to serve more customers.
- Improves the quality and consistency of services.
- Reduces labour requirements.
- Creates employment opportunities.
- Improves the profitability of suitable agricultural enterprises.
- Encourages innovation and technology adoption.
- Supports commercial production and value addition.

9.2 Challenges facing farmers when adopting powered equipment

1. High initial cost: Modern agricultural machines may require substantial investment.
2. High fuel and electricity costs: Operating expenses may reduce profitability.
3. Lack of technical skills: Some farmers may lack the knowledge required to operate and maintain equipment.
4. Limited access to spare parts: Some machines may have parts that are difficult to obtain.
5. Breakdowns: Equipment failure can interrupt agricultural operations.
6. Unreliable electricity supply: Power interruptions may affect electrically operated machines.
7. Environmental pollution: Poorly maintained fuel-powered equipment may release excessive emissions.
8. Safety risks: Improper handling may cause serious injuries.
9. Inadequate repair facilities: Some rural areas may lack qualified technicians.
10. Poor maintenance practices: Failure to service equipment can shorten its lifespan.

Possible solutions

- Farmers can form groups or cooperatives to purchase and share expensive equipment.
- Seek agricultural loans or suitable financing.
- Attend training on operation and maintenance.
- Purchase equipment with accessible spare parts.
- Follow recommended maintenance schedules.
- Employ qualified technicians for complex repairs.
- Observe safety procedures.
- Adopt suitable renewable-energy technologies.
- Keep accurate records of equipment use and maintenance.

10.0 CBE integration

The following competencies, values and pertinent and contemporary issues should be developed as learners engage with this sub-strand.

10.1 Core competencies

1. Self-efficacy

Learners develop self-confidence as they identify, select and operate powered agricultural tools and equipment.

How it is developed:

- Operating a grass cutter under supervision.

- Chopping fodder using a chaff cutter.
- Drilling holes using a power drill.
- Carrying out routine maintenance.
- Demonstrating the correct use of powered tools.

2. Communication and collaboration

Learners develop the ability to communicate and work with others when discussing power sources and carrying out practical activities.

How it is developed:

- Working in groups to identify powered tools.
- Sharing information about different sources of power.
- Discussing equipment maintenance practices.
- Presenting findings from practical activities.

3. Critical thinking and problem-solving

Learners develop the ability to identify problems and select appropriate solutions when using agricultural equipment.

How it is developed:

- Identifying causes of equipment breakdown.
- Selecting suitable equipment for different agricultural tasks.
- Comparing sources of power.
- Suggesting appropriate maintenance procedures.

4. Digital literacy

Learners develop the ability to use digital devices and online resources to obtain information about powered tools and equipment.

How it is developed:

- Searching for information on modern agricultural equipment.
- Watching demonstrations on correct equipment operation.
- Identifying the parts of powered tools using digital images.
- Researching technological developments in agricultural machinery.

10.2 Values

1. Responsibility

Learners demonstrate responsibility by taking care of equipment and carrying out assigned maintenance tasks correctly.

Examples:

- Cleaning equipment after use.
- Returning tools to their storage areas.
- Reporting damaged equipment.
- Following safety instructions.

2. Respect

Learners demonstrate respect by accommodating different opinions when discussing sources of power and equipment.

Examples:

- Listening to other learners' views.
- Respecting the contributions of resource persons.
- Sharing equipment responsibly.
- Working cooperatively during practical activities.

10.3 Pertinent and Contemporary Issues (PCIs)

Safety

Learners develop awareness of safety when carrying out agricultural tasks using powered tools and equipment.

Examples:

- Wearing appropriate PPE.
- Keeping away from moving blades.
- Following equipment operating instructions.
- Keeping unauthorised people away from working areas.
- Isolating equipment before maintenance.

Environmental conservation

Learners understand the importance of reducing pollution associated with powered equipment.

Examples:

- Proper disposal of used oil.
- Preventing fuel spills.

- Reducing unnecessary fuel consumption.
- Using renewable sources of energy where appropriate.

Financial literacy and entrepreneurship

Learners appreciate the costs and business opportunities associated with agricultural equipment.

Examples:

- Comparing the cost of purchasing and hiring equipment.
- Preparing simple maintenance budgets.
- Identifying opportunities for equipment-hire services.
- Calculating the cost of providing grass-cutting or fodder-chopping services.

11.0 Suggested learning activities and assessment opportunities

Learning activity	**Skills developed**	**Possible assessment evidence**
Discussing sources of power	Communication and critical thinking	Oral presentation
Identifying powered tools	Observation and identification	Correct naming of tools and uses
Researching powered equipment online	Digital literacy	Research notes or presentation
Cutting grass using a grass cutter	Practical skills and self-efficacy	Correct and safe operation
Chopping fodder using a chaff cutter	Practical skills	Proper preparation of fodder
Drilling holes using a power drill	Technical skills	Correct selection and use of drill bits
Screwing using a power drill	Assembly skills	Correct fastening of materials
Cleaning and lubricating equipment	Responsibility	Maintenance checklist
Discussing safety measures	Safety awareness	Demonstration and oral responses
Preparing maintenance records	Record-keeping skills	Completed maintenance record

12.0 Summary of the sub-strand

Powered tools and equipment are important in modern agricultural production because they reduce labour, save time, improve efficiency and support commercial farming.

The major sources of power used in agricultural equipment include:

- Solar energy.
- Electrical energy.

- Animal power.
- Fuel power.

Examples of powered agricultural tools and equipment include:

Equipment	**Main agricultural use**
Soil auger	Boring holes in the soil
Grass cutter	Cutting grass and weeds
Chaff cutter	Chopping livestock fodder
Milking machine	Extracting milk from dairy animals
Power drill	Making holes and driving screws
Hand-held circular saw	Cutting timber and suitable materials

Proper maintenance practices include cleaning, sharpening blades, lubrication, replacing worn-out parts, adjusting machine components and engine servicing.

Safety is essential when using powered equipment. Operators should receive appropriate training, wear suitable protective equipment, inspect machines before use and follow the manufacturer's instructions.

Powered agricultural equipment also creates entrepreneurship opportunities in equipment hire, repairs, servicing, grass cutting, fodder preparation and farm construction.

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives given.

1. Which one of the following is a renewable source of power used in agricultural production?

A. Diesel
B. Petrol
C. Solar energy
D. Kerosene

2. A farmer intends to make holes for planting fruit tree seedlings. Which powered tool would be most suitable?

A. Chaff cutter
B. Soil auger
C. Circular saw
D. Milking machine

3. Which component of a powered soil auger penetrates the soil and removes loosened soil from the hole?

A. Handle
B. Throttle
C. Auger bit
D. Safety switch

4. Which one of the following is a major use of a grass cutter?

A. Extracting milk
B. Cutting grass and weeds
C. Drilling holes
D. Chopping livestock fodder

5. A dairy farmer wants to reduce the time spent on manual milking. Which equipment should the farmer acquire?

A. Soil auger
B. Power drill
C. Milking machine
D. Circular saw

6. Which part of a milking machine creates the vacuum needed for milk extraction?

A. Milk filter
B. Vacuum pump
C. Milk receiver
D. Teat cup liner

7. Which one of the following components holds the drill bit in a power drill?

A. Chuck
B. Trigger
C. Handle
D. Motor

8. The main function of a chaff cutter is to:

A. Drill holes in the ground.
B. Cut fodder into smaller pieces.

C. Extract milk from dairy animals.
D. Cut timber into boards.

9. Which one of the following is an example of animal power?

A. Electric motor
B. Solar panel
C. Oxen pulling a plough
D. Diesel engine

10. Which maintenance practice involves applying grease or oil to moving parts?

A. Sharpening
B. Lubrication
C. Cleaning
D. Painting

11. A farmer notices that the blades of a chaff cutter are blunt. Which maintenance practice should be carried out?

A. Lubrication
B. Sharpening
C. Painting
D. Washing

12. Which one of the following is an advantage of using powered agricultural equipment?

A. Increased physical labour
B. Increased time wastage
C. Improved work efficiency
D. Increased manual effort

13. Which component of a circular saw protects the operator from accidental contact with the blade?

A. Base plate
B. Blade guard
C. Motor
D. Trigger switch

14. Which one of the following is an appropriate safety practice when operating a power drill?

A. Holding the workpiece loosely.
B. Using a damaged drill bit.
C. Securing the workpiece before drilling.
D. Changing the drill bit while the machine is running.

15. Which of the following is the most appropriate practice before cleaning a powered chaff cutter?

A. Increase the machine speed.
B. Switch off and isolate the power source.

C. Insert hands into the feeding chute.
D. Remove the protective guards while the machine is running.

16. Which one of the following is an example of preventive maintenance?

A. Repairing a machine after a breakdown.
B. Replacing a broken machine frame.
C. Servicing equipment at planned intervals.
D. Disposing of damaged equipment.

17. Which component of a milking machine alternates vacuum and air admission during machine milking?

A. Pulsator
B. Milk filter
C. Milk receiver
D. Milk tube

18. Which one of the following is a limitation of solar-powered equipment?

A. It produces exhaust fumes during operation.
B. It depends on sunlight for energy generation.
C. It always requires diesel fuel.
D. It cannot be used for water pumping.

19. A farmer operates a machine with loose and exposed moving belts. Which safety measure has been ignored?

A. Proper storage
B. Fitting and maintaining protective guards
C. Record keeping
D. Fuel conservation

20. Which one of the following is an agricultural entrepreneurship opportunity associated with powered equipment?

A. Avoiding equipment maintenance
B. Hiring out powered agricultural equipment
C. Operating damaged machines
D. Storing used oil in open fields

Section B: Structured questions

21.

a) Define the term powered agricultural tools and equipment. (2 marks)

b) State four reasons why powered tools and equipment are important in agricultural production. (4 marks)

c) Identify four sources of power used in agricultural tools and equipment. (4 marks)

22.

a) Explain five applications of solar energy in agricultural production. (10 marks)

b) State four limitations of solar-powered agricultural equipment. (4 marks)

23.

a) Describe five uses of electrical energy in agricultural production. (10 marks)

b) Explain four advantages of fuel-powered equipment in agriculture. (8 marks)

24.

a) Describe the construction and operation of a powered soil auger. (8 marks)

b) Explain four uses of a soil auger in agricultural production. (8 marks)

c) State four maintenance practices carried out on a soil auger. (4 marks)

25.

a) Describe the main parts of a powered grass cutter. (10 marks)

b) Explain five safety precautions observed when operating a grass cutter. (10 marks)

26.

a) Explain five uses of a chaff cutter in livestock production. (10 marks)

b) Describe five maintenance practices carried out on a chaff cutter. (10 marks)

27.

a) Describe the main components of a milking machine. (10 marks)

b) Explain five advantages of machine milking over hand milking. (10 marks)

28.

a) Describe five maintenance practices carried out on a milking machine. (10 marks)

b) Explain five hygiene and safety measures observed when using a milking machine. (10 marks)

29.

a) Describe the main parts of a power drill. (10 marks)

b) Explain five uses of a power drill in agricultural construction and maintenance. (10 marks)

30.

a) Describe the main parts of a hand-held circular saw. (10 marks)

b) Explain five safety precautions observed when operating a circular saw. (10 marks)

31.

a) Differentiate between the following maintenance practices:

i. Routine maintenance. (2 marks)

ii. Preventive maintenance. (2 marks)

iii. Corrective maintenance. (2 marks)

iv. Predictive maintenance. (2 marks)

b) Explain five importance of maintaining powered agricultural tools and equipment. (10 marks)

32.

a) Explain five maintenance practices carried out on powered agricultural equipment. (10 marks)

b) State five pieces of information recorded in an equipment maintenance record. (5 marks)

c) Give five examples of equipment parts that may require replacement during maintenance. (5 marks)

33.

a) Explain five safety precautions observed before operating powered agricultural tools. (10 marks)

b) Explain five safety precautions observed during the operation of powered agricultural equipment. (10 marks)

34.

a) Explain five environmental problems associated with the use of powered agricultural equipment. (10 marks)

b) Suggest five measures farmers can adopt to reduce environmental pollution from agricultural equipment. (10 marks)

35.

A farmer in a dairy-producing area intends to start a business providing fodder-chopping services to neighbouring farmers.

a) Identify five requirements needed to establish the business. (5 marks)

b) Explain five benefits of using a powered chaff cutter in the business. (10 marks)

c) State five challenges the entrepreneur may experience. (5 marks)

Glossary of important terms

Term	Meaning
Agricultural technology	Application of scientific knowledge, skills and equipment to improve agricultural production
Powered tool	A tool operated using an external or stored source of energy
Equipment	A device or machine used to perform a particular task

Solar energy	Energy obtained from sunlight
Electrical energy	Energy associated with electric charges
Animal power	Energy obtained from the muscular strength of animals
Fuel power	Energy obtained from burning fuel
Soil auger	A tool used to bore holes into the soil
Grass cutter	A powered tool used to cut grass and weeds
Chaff cutter	A machine used to chop fodder into smaller pieces
Milking machine	Equipment used to extract milk from dairy animals
Power drill	A powered tool used to make holes and drive screws
Circular saw	A powered cutting tool fitted with a rotating circular blade
Maintenance	Activities carried out to keep equipment in good working condition
Lubrication	Application of a suitable lubricant to reduce friction
Sharpening	Restoring the cutting edge of a blade
Preventive maintenance	Planned maintenance intended to prevent equipment failure
Corrective maintenance	Repair work carried out after equipment develops a fault
Routine maintenance	Regular basic maintenance performed before or after use
Predictive maintenance	Monitoring equipment condition to anticipate possible failure
PPE	Personal protective equipment worn to reduce exposure to hazards
Entrepreneurship	Identifying and exploiting business opportunities through innovation and enterprise
Safety guard	A protective component that reduces accidental contact with dangerous machine parts
Pulsator	A component that controls alternating vacuum and air admission in a milking machine
Auger bit	The rotating spiral component that penetrates the soil
Maintenance record	A document showing maintenance activities performed on equipment

STRAND 3.0: AGRICULTURAL TECHNOLOGIES AND ENTREPRENEURSHIP

SUB-STRAND 3.2: MANAGEMENT OF AGRO-BY-PRODUCTS

1.0 INTRODUCTION TO AGRICULTURAL BY-PRODUCTS

Agricultural production involves growing crops, keeping livestock, harvesting, processing and marketing agricultural products. During these activities, various materials remain after the main useful products have been obtained.

Some of these materials are often discarded as refuse, yet they can be converted into useful products that benefit the farm, generate income and protect the environment.

Agricultural by-products are secondary materials obtained during the production, harvesting, processing or marketing of crops and livestock products. They are not usually the main products for which the agricultural activity was undertaken, but they can be used for other beneficial purposes.

Examples of agricultural by-products

1. Maize stalks, cobs and husks obtained after harvesting maize.
2. Rice husks obtained during rice milling.
3. Groundnut shells obtained after removing the nuts.
4. Sugarcane bagasse remaining after juice extraction.
5. Coffee husks and pulp from coffee processing.
6. Fruit peels and vegetable trimmings from food processing.
7. Sawdust and wood shavings from timber processing.
8. Animal dung and poultry droppings from livestock production.
9. Feathers obtained during poultry processing.
10. Blood and bones from approved meat-processing operations.

Management of agro-by-products refers to the collection, sorting, processing, storage, utilisation and marketing of secondary agricultural materials to obtain useful products and economic benefits while reducing environmental pollution.

1.1 Meaning of agricultural refuse and agricultural waste

Agricultural refuse refers to unwanted materials generated during agricultural activities. Some refuse can be reused, recycled or converted into useful products.

Agricultural waste refers to materials from agricultural production and processing that are discarded or have no immediate intended use. Some agricultural waste may become a valuable resource when properly managed.

Difference between agricultural by-products and agricultural waste

Agricultural by-products	Agricultural waste
Secondary materials that can be used beneficially.	Materials that are discarded or require disposal.
Often have an identifiable alternative use or market.	May have no immediate use or market.
Can be processed into useful products.	May require treatment before safe utilisation or disposal.
Examples include rice husks, bagasse and maize cobs.	Examples include contaminated packaging and spoiled materials unsuitable for reuse.

Note: A material may be regarded as waste in one situation and a by-product in another, depending on its quality, safety, availability and intended use.

1.2 Sources of agricultural by-products

Agricultural by-products originate from different agricultural activities.

A. Crop production

These are materials remaining after growing, harvesting and processing crops.

Examples include:

1. Maize stalks and cobs.
2. Wheat and rice straws.
3. Bean and pea haulms.
4. Groundnut shells.
5. Potato and cassava peels.
6. Sugarcane bagasse.
7. Banana leaves and stems.
8. Coffee pulp and husks.
9. Tea prunings.
10. Vegetable trimmings.

B. Livestock production

These are secondary materials obtained from keeping and processing livestock.

Examples include:

1. Cattle dung.
2. Goat and sheep droppings.
3. Poultry droppings.
4. Pig manure.
5. Animal bedding mixed with manure.
6. Feathers from poultry processing.
7. Bones and blood from approved slaughter and processing facilities.
8. Wool clippings and other suitable animal-fibre remnants.

C. Agro-processing industries

These are materials produced when agricultural raw materials are processed into finished products.

Examples include:

1. Rice husks from rice milling.
2. Wheat bran from flour milling.
3. Maize bran from maize milling.
4. Oilseed cakes from oil extraction.
5. Sugarcane bagasse from sugar processing.
6. Fruit pulp from juice processing.
7. Coffee husks from coffee processing.
8. Sawdust from timber processing.

1.3 Characteristics of agricultural by-products

Agricultural by-products have different physical, chemical and biological properties depending on their sources.

1. **Organic nature:** Many by-products originate from plants and animals and contain organic matter.
2. **Biodegradability:** Many can be broken down by microorganisms into simpler substances.
3. **Nutrient content:** Some contain nutrients such as nitrogen, phosphorus and potassium.
4. **Fibre content:** Crop residues such as maize stalks and rice straw contain considerable amounts of fibre.
5. **Moisture content:** Fruit and vegetable remains may contain high amounts of water.

6. **Variable nutritional value:** Some by-products can be used in livestock feeds, while others have low nutritional value or contain harmful substances.
7. **Seasonal availability:** Their availability may depend on harvesting and processing seasons.
8. **Different storage requirements:** Dry materials may be stored for longer than wet, easily decomposing materials.
9. **Potential economic value:** Some can be processed and sold as manure, fuel, feed or other useful products.
10. **Potential environmental impact:** Poor management may lead to bad odours, pests, disease risks and pollution.

1.4 Importance of managing agricultural by-products

Proper management of agricultural by-products is important to farmers, agro-processors, consumers and the environment.

1. **Generation of additional income:** Farmers can sell processed by-products such as compost, briquettes and animal feed.
2. **Reduction of environmental pollution:** Proper utilisation reduces uncontrolled dumping and burning.
3. **Improvement of soil fertility:** Organic by-products can be converted into compost and manure.
4. **Reduction of production costs:** Farmers can use available materials instead of purchasing every farm input.
5. **Provision of livestock feeds:** Suitable crop residues and processing by-products can supplement livestock diets.
6. **Provision of fuel:** Some dry agricultural residues can be converted into briquettes and other fuels.
7. **Creation of employment:** Processing, packaging and marketing by-products create business opportunities.
8. **Promotion of sustainable agriculture:** Recycling nutrients and materials reduces unnecessary resource wastage.
9. **Improvement of farm hygiene:** Regular collection and appropriate treatment of residues reduces breeding places for pests.
10. **Promotion of innovation:** Farmers develop new ways of converting locally available materials into useful products.
11. **Conservation of natural resources:** Agricultural residues can reduce dependence on some materials obtained from forests and other natural resources.
12. **Support for a circular economy:** Materials that would otherwise be discarded are returned to productive use.

2.0 AGRICULTURAL BY-PRODUCTS AND THEIR USES

Agricultural by-products can be converted into different useful products depending on their nature, availability, quality and processing requirements.

The main uses covered in this sub-strand include:

1. Production of organic manure and compost.
2. Production of animal feeds.

3. Production of fuels.
4. Preparation of animal bedding.
5. Mulching and soil improvement.
6. Mushroom production.
7. Biochar production.
8. Production of crafts and other useful products.

2.1 Use of agricultural by-products in manure and compost production

Organic manure is a material obtained from decomposed plant and animal materials and used to improve soil fertility and soil physical properties.

Compost is decomposed organic material produced through controlled biological decomposition of suitable organic residues.

Agricultural by-products such as maize stalks, vegetable remains, fruit peels, dry leaves and animal manure can be used to prepare compost.

2.1.1 Agricultural by-products used in compost preparation

A. Crop residues

- Maize stalks.
- Bean haulms.
- Wheat straw.
- Rice straw.
- Dry grass.
- Banana leaves.
- Vegetable remains.

B. Animal by-products

- Cattle dung.
- Goat droppings.
- Sheep manure.
- Poultry droppings.
- Bedding materials mixed with manure.

C. Food and processing remains

- Fruit peels.
- Vegetable trimmings.
- Coffee pulp.
- Suitable tea residues.
- Other untreated biodegradable food-processing materials.

2.1.2 Materials required for compost preparation

- **Green materials:** Fresh grass, vegetable remains and other materials rich in nitrogen.
- **Dry materials:** Dry leaves, straw, maize stalks and other materials rich in carbon.
- **Animal manure:** Provides nutrients and microorganisms that assist decomposition.
- **Water:** Maintains suitable moisture for microbial activity.
- **Soil or mature compost:** May be added to introduce microorganisms and help inoculate the heap.

- **Composting site:** A suitable location for preparing and managing the compost.
- **Covering materials:** Dry grass, sacks or suitable covers help conserve moisture and protect the heap from excessive rain.

2.1.3 Factors to consider when selecting materials for compost

- **Biodegradability:** Select materials that can decompose naturally.
- **Nutrient composition:** Combine materials with suitable carbon and nitrogen content.
- **Moisture content:** Use materials that can be managed to maintain appropriate moisture.
- **Availability:** Select materials that are locally available in sufficient quantities.
- **Safety:** Avoid contaminated materials, plastics, treated timber and chemical containers.
- **Particle size:** Chop bulky materials into smaller pieces to facilitate decomposition.
- **Absence of harmful substances:** Avoid materials containing persistent chemicals or substances harmful to soil organisms and crops.

2.1.4 Procedure for preparing compost from agricultural by-products

Step 1: Selecting a suitable site

- Choose a well-drained location.
- Ensure the site is accessible for transporting materials.
- Avoid areas where runoff can carry compost into rivers and water sources.
- Select a shaded or appropriately protected location to reduce excessive drying.

Step 2: Collecting materials

- Collect crop residues such as maize stalks, dry leaves and straw.
- Collect suitable vegetable and fruit remains.
- Obtain animal manure.
- Remove plastics, stones, glass and other unwanted materials.

Step 3: Preparing the materials

- Chop bulky crop residues into smaller pieces.
- Separate materials according to their nature.
- Remove diseased or chemically contaminated materials.
- Mix materials appropriately.

Step 4: Arranging the compost heap

- Place a layer of coarse plant materials at the bottom where suitable.
- Add a layer of green materials.
- Add animal manure.
- Add a layer of dry materials.
- Repeat the layering process.
- Sprinkle water to maintain suitable moisture.

Step 5: Covering the heap

- Cover the heap with suitable materials.
- Covering helps conserve moisture.
- It also reduces excessive exposure to rainfall and direct sunlight.

Step 6: Turning the heap

- Turn the heap periodically to improve aeration.
- Mix the materials to promote more uniform decomposition.
- Add water if the heap becomes too dry.
- Avoid waterlogging.

Step 7: Monitoring decomposition

Observe changes in temperature, smell, colour and texture.

A well-decomposed compost should generally:

- Have a dark brown to black appearance.
- Have a crumbly texture.
- Have an earthy smell rather than a strong rotting smell.
- No longer contain easily recognisable fresh materials in most of the heap.
- Be sufficiently mature before application to sensitive crops.

Step 8: Using or marketing the compost

- Apply mature compost to crop fields, gardens and nurseries.
- Package suitable compost in bags.
- Label and market the product where it meets relevant quality requirements.

2.1.5 Importance of compost prepared from agricultural by-products

- Adds organic matter to the soil.
- Improves soil structure.
- Improves water-holding capacity in suitable soils.
- Encourages beneficial soil organisms.
- Supplies plant nutrients gradually.
- Reduces the amount of agricultural refuse requiring disposal.
- Reduces dependence on some purchased fertiliser inputs.
- Can generate income when processed and marketed.
- Helps improve soil condition over time.
- Supports sustainable crop production.

Important: Compost does not always supply nutrients in the same quantities as manufactured fertilisers. Its nutrient content depends on the materials used and the quality of the composting process.

2.2 Use of agricultural by-products in animal feed production

Some agricultural by-products can be used as livestock feeds or feed ingredients. They provide nutrients and help reduce feed costs when properly selected, processed and incorporated into balanced rations.

Examples include:

- Maize bran.
- Wheat bran.
- Rice bran.
- Groundnut haulms.
- Bean haulms.
- Sweet potato vines.
- Sugarcane molasses.

- Oilseed cakes.
- Suitable fruit-processing residues.
- Brewers' spent grains from properly managed processing.

2.2.1 Types of agricultural by-products used in livestock feeds

A. Cereal by-products

These are obtained during the processing of cereal grains.

Examples:

- **Maize bran:** Obtained during maize milling. It can provide energy and fibre in livestock rations.
- **Wheat bran:** Obtained during wheat milling. It provides fibre, energy and some protein.
- **Rice bran:** Obtained during rice milling. It contains energy, protein and other nutrients, but its quality and storage condition should be checked.
- **Maize germ:** Obtained during maize processing. It contains energy and fat and can be used in suitable feed formulations.

B. Legume crop residues

Examples:

- Bean haulms.
- Groundnut haulms.
- Pea haulms.
- Cowpea residues.

Uses:

- They can be dried and stored as roughage.
- They can provide fibre to ruminant animals.
- Some legume residues contain relatively high levels of protein compared with many cereal straws.
- They can supplement other fodder materials.
- They can reduce the cost of purchasing some livestock feeds.

C. Oilseed processing by-products

Examples:

- Sunflower seed cake.
- Cottonseed cake.
- Groundnut cake.
- Soybean meal.

Uses:

- They provide protein for livestock.
- They can be incorporated into balanced animal rations.
- They support growth and tissue development.
- They help meet protein requirements in dairy and other livestock diets.

Important: Oilseed cakes and meals differ in nutritional quality. Some, such as cottonseed products, may contain substances that require special consideration. Their inclusion must follow appropriate livestock feeding recommendations.

D. Fruit and vegetable processing by-products

Examples:

- Citrus pulp.
- Pineapple residues.
- Banana peels.
- Vegetable trimmings.
- Fruit pomace.

Uses:

- Some provide energy.
- Some supply fibre.
- They can supplement livestock feeds.
- They reduce the quantity of organic materials discarded during food processing.

E. Sugar industry by-products

Examples:

- Molasses.
- Sugarcane tops.
- Sugarcane bagasse.

Uses:

- Molasses provides readily available energy and can be included in suitable rations.
- Sugarcane tops may be used as roughage after appropriate preparation.
- Bagasse may have limited nutritional value and is not a complete livestock feed. It requires appropriate treatment and ration formulation if used as a feed ingredient.

2.2.2 Factors to consider before using agricultural by-products as animal feed

- **Nutritional value:** Determine the energy, protein, fibre, mineral and moisture content.
- **Palatability:** Animals should be willing to consume the material.
- **Digestibility:** Consider how easily animals can digest the material.
- **Safety:** Ensure the material does not contain harmful chemicals, toxins or foreign objects.
- **Mould contamination:** Reject mouldy feed materials that may contain harmful mycotoxins.
- **Processing requirements:** Some materials require drying, chopping, grinding or other treatment.
- **Species of livestock:** Different animals have different digestive systems and nutritional requirements.
- **Age and production stage:** Growing, pregnant and lactating animals have different feed needs.
- **Storage conditions:** Materials should be stored in clean, dry and well-ventilated places.
- **Cost and availability:** Use materials that are affordable and consistently available.
- **Balanced ration:** By-products should be combined with other ingredients to meet the animals' nutritional requirements.
- **Presence of anti-nutritional factors:** Some materials contain substances that reduce nutrient utilisation or may be toxic if not properly processed.

2.2.3 Preparation of animal feeds from agricultural by-products

Example: Preparation of supplementary feed using maize bran and other suitable ingredients.

Materials required

- Maize bran.

- Suitable protein supplement.
- Mineral supplement.
- Other recommended feed ingredients.
- Weighing scale.
- Mixing container.

Procedure

- Identify the nutritional requirements of the animals.
- Select safe and suitable feed ingredients.
- Check the ingredients for mould and contamination.
- Weigh the ingredients according to a balanced ration formulation.
- Grind materials where necessary.
- Mix the ingredients uniformly.
- Check the final feed for foreign materials.
- Store the feed in clean, dry and labelled containers.
- Feed animals according to their requirements.
- Monitor animal response and adjust the ration when necessary.

Advantages of using agricultural by-products in livestock feeds

- Reduces feed costs when suitable materials are available.
- Makes use of locally available resources.
- Reduces agricultural refuse.
- Provides alternative sources of nutrients.
- Supports livestock production during periods of fodder scarcity.
- Creates opportunities for feed-processing businesses.

Limitations

- Nutritional quality may vary.
- Some by-products may be difficult to digest.
- Some may contain anti-nutritional substances.
- Wet materials may spoil quickly.
- Mouldy materials may cause serious health problems.
- Some require additional processing before use.

2.3 Use of agricultural by-products in fuel production

Some agricultural by-products can be converted into fuel for cooking, heating and other energy requirements. This reduces dependence on some conventional fuels and provides an alternative use for materials that would otherwise be discarded.

Examples of agricultural by-products used in fuel production include:

- Maize cobs.
- Rice husks.
- Coffee husks.
- Groundnut shells.
- Coconut shells.
- Sugarcane bagasse.

- Sawdust.
- Dry crop stalks.
- Dry grass and other suitable crop residues.

2.3.1 Forms of fuel obtained from agricultural by-products

A. Direct biomass fuel

Biomass fuel is fuel obtained from organic materials of plant or animal origin.

Dry agricultural residues can be used directly as fuel in suitable stoves and heating systems.

Examples:

- Dry maize cobs.
- Dry crop stalks.
- Coconut shells.
- Dry sugarcane bagasse.
- Dry coffee husks.

Uses of direct biomass fuel

- Cooking in suitable stoves.
- Heating water.
- Heating in selected agricultural processing operations.
- Providing heat in suitable industrial boilers.
- Drying agricultural products in appropriately designed systems.

Limitations of direct biomass fuel

- Some materials produce considerable smoke when burned inefficiently.
- Loose residues may burn quickly.
- Some produce ash that requires proper disposal.
- Uncontrolled burning causes air pollution.
- Wet biomass burns inefficiently.

B. Biomass briquettes

Biomass briquettes are compact blocks of fuel produced by compressing suitable dry agricultural residues, often with the help of a binder.

Materials used include:

- Sawdust.
- Charcoal dust.
- Rice husks.
- Groundnut shells.
- Coffee husks.
- Maize cobs.
- Other suitable dry biomass materials.

Advantages of biomass briquettes

- They make loose agricultural residues easier to handle.
- They reduce the volume of materials requiring storage.

- They provide an alternative source of fuel.
- They can be packaged and sold for income.
- They can improve fuel handling and transport.
- They encourage recycling of agricultural materials.
- Their quality can be made more uniform through controlled production.

Materials and equipment required

- Dry agricultural residues.
- Grinder or crusher.
- Suitable binder where required.
- Mixing container.
- Briquette press or mould.
- Drying area or suitable dryer.
- Packaging materials.

Procedure for preparing biomass briquettes

- Collect suitable agricultural residues.
- Sort the materials to remove stones, metals, plastics and other contaminants.
- Dry the materials to an appropriate moisture level.
- Crush or grind them into smaller particles.
- Prepare a suitable binder if the process requires one.
- Mix the particles uniformly with the binder.
- Place the mixture in a briquette press or mould.
- Compress the mixture into the required shape.
- Remove the formed briquettes carefully.
- Dry them thoroughly.
- Inspect the briquettes for strength and quality.
- Package and store them in a dry place.

Factors affecting the quality of briquettes

- Type of raw material.
- Particle size.
- Moisture content.
- Pressure applied during compression.
- Type and quantity of binder.
- Drying conditions.
- Density of the finished briquette.
- Storage conditions.

C. Biogas production

Biogas is a combustible gas produced when microorganisms break down organic materials in the absence of oxygen. This process is called **anaerobic digestion**.

Suitable agricultural materials include:

- Cattle dung.

- Pig manure.
- Poultry manure, when appropriately managed.
- Food-processing residues.
- Vegetable and fruit remains.
- Other suitable biodegradable organic materials.

Main components of a biogas system

- **Mixing tank:** Where organic materials are mixed with water to form slurry.
- **Inlet pipe:** Carries the prepared slurry into the digester.
- **Digester:** An enclosed chamber where anaerobic digestion takes place.
- **Gas holder:** Collects the biogas produced.
- **Gas pipe:** Transports gas to the point of use.
- **Gas control valve:** Regulates gas flow.
- **Outlet chamber:** Allows digested slurry to leave the digester.
- **Slurry storage area:** Holds the digestate before it is used or managed appropriately.

Uses of biogas

- Cooking.
- Heating water.
- Lighting using suitable biogas appliances.
- Generating electricity using an appropriate biogas generator.
- Providing energy for selected farm-processing activities.

Benefits of biogas production

- Converts animal manure and organic residues into useful energy.
- Reduces the amount of organic waste requiring disposal.
- Can reduce dependence on firewood and other conventional fuels.
- Produces digestate that can be used as a soil amendment or fertiliser when appropriately handled.
- Supports integrated crop and livestock production.
- Can provide energy for household and farm activities.

Limitations of biogas production

- Initial installation costs may be high.
- The digester requires proper construction and maintenance.
- Gas production depends on the type and quantity of feedstock and operating conditions.
- The system requires a regular supply of suitable organic materials.
- Gas leakage can create safety risks.
- Low temperatures may slow the digestion process.
- Poorly managed digestate may cause pollution.

Safety precautions when using biogas

- Ensure the system is installed by qualified personnel.
- Inspect gas pipes and connections for leaks.
- Keep flames away from suspected gas leakage points.
- Ensure adequate ventilation where biogas appliances are used.
- Do not enter a digester or enclosed tank.

- Keep the system away from unauthorised persons.
- Follow the manufacturer's instructions.

2.4 Use of agricultural by-products in animal bedding

Animal bedding refers to materials placed on the floors of livestock houses to provide a comfortable, dry and relatively clean resting surface for animals.

Some agricultural by-products can be used as bedding materials because they are absorbent, locally available and relatively affordable.

Examples include:

- Rice husks.
- Sawdust from untreated wood.
- Wood shavings.
- Chopped dry straw.
- Dry maize stalks, when suitably prepared.
- Coffee husks, where suitable.
- Other clean, dry and non-toxic plant residues.

2.4.1 Characteristics of good animal bedding materials

- **Absorbent:** Should absorb moisture from animal droppings and spilled water.
- **Dry:** Should not introduce excessive moisture into the animal house.
- **Soft:** Should provide a comfortable resting surface.
- **Non-toxic:** Should not contain harmful chemicals.
- **Clean:** Should be free from harmful contaminants and disease-causing organisms as far as practicable.
- **Low in dust:** Excessive dust may cause respiratory irritation.
- **Readily available:** Should be accessible to farmers.
- **Affordable:** Should not impose excessive costs on production.
- **Easy to handle:** Should be easy to spread, remove and replace.
- **Suitable for the animal species:** Bedding requirements differ between poultry, cattle, pigs and other livestock.

2.4.2 Uses of agricultural by-products as animal bedding

A. Rice husks

- Used as litter in poultry houses.
- Absorb some moisture from droppings.
- Provide a loose surface for poultry movement.
- Can be collected after use and composted where suitable.

B. Sawdust and wood shavings

- Used in poultry houses and some other livestock units.
- Absorb moisture.
- Provide a relatively soft resting surface.
- Should be obtained from clean, untreated timber.

- Excessively dusty materials should be avoided.

C. Straw

- Used as bedding for cattle, sheep, goats and other livestock.
- Provides a soft resting surface.
- Can be combined with manure and composted after use.

D. Chopped dry crop residues

- May be used as bedding where they are clean and suitably prepared.
- Can provide a relatively affordable alternative where commercial bedding is expensive.

2.4.3 Importance of proper animal bedding

- Improves animal comfort.
- Helps keep livestock houses dry.
- Reduces direct contact between animals and wet floors.
- Helps maintain cleanliness in animal houses.
- Reduces the risk of some foot and skin problems associated with persistently wet conditions.
- Provides a suitable resting area.
- Can absorb moisture from animal droppings.
- Used bedding mixed with manure can be composted for crop production.
- Supports good livestock-house management.

2.4.4 Management of used animal bedding

- Remove excessively wet and contaminated bedding.
- Replace bedding when necessary.
- Avoid allowing used bedding to accumulate excessively.
- Handle used bedding carefully to minimise exposure to harmful microorganisms.
- Compost suitable bedding mixed with manure before applying it to crops.
- Prevent runoff from manure and bedding heaps into water sources.
- Do not use bedding contaminated with chemicals for ordinary composting without appropriate assessment.

2.5 Use of agricultural by-products as mulch

Mulching is the practice of covering the soil surface around crops with suitable materials to conserve moisture, control weeds and improve soil conditions.

Agricultural by-products are important sources of organic mulch.

Examples include:

- Dry maize stalks.
- Rice straw.
- Wheat straw.
- Dry grass.
- Banana leaves.
- Sugarcane trash.
- Bean haulms.
- Other clean plant residues.

Uses and importance of agricultural by-products as mulch

- **Conservation of soil moisture:** Mulch reduces direct evaporation of water from the soil surface.
- **Weed suppression:** A sufficiently thick layer of mulch reduces the amount of light reaching germinating weeds.
- **Reduction of soil erosion:** Mulch reduces the impact of raindrops and slows surface runoff.
- **Regulation of soil temperature:** It reduces extreme temperature changes at the soil surface.
- **Addition of organic matter:** Organic mulch gradually decomposes and contributes organic matter to the soil.
- **Improvement of soil structure:** Decomposed plant residues can improve soil aggregation.
- **Protection of soil organisms:** Mulch provides a more favourable environment for some beneficial soil organisms.
- **Reduction of soil crusting:** It protects the soil surface from the direct impact of heavy rainfall.

Procedure for using crop residues as mulch

- Select clean, suitable crop residues.
- Remove seeds of troublesome weeds and diseased plant materials.
- Prepare the field by removing unwanted weeds.
- Water the soil where necessary.
- Spread the mulch evenly around the crops.
- Leave a small space around the plant stems to reduce excessive moisture and rotting.
- Maintain the mulch layer when it decomposes or is displaced.
- Monitor the field for pests and rodents that may shelter under the mulch.

Precautions when using agricultural by-products as mulch

- Avoid using crop residues heavily contaminated with pesticides.
- Do not spread diseased materials where they may spread crop diseases.
- Avoid placing thick mulch directly against plant stems.
- Check for termites, rodents and other pests.
- Avoid introducing weed seeds through contaminated materials.

2.6 Use of agricultural by-products in mushroom production

Some agricultural by-products contain plant fibres that can serve as substrates for growing mushrooms.

Examples include:

- Wheat straw.
- Rice straw.
- Maize stalks.
- Sugarcane bagasse.
- Sawdust from suitable untreated wood.
- Other approved plant residues.

How agricultural by-products are used in mushroom production

- Collect suitable plant residues.
- Sort to remove plastics, stones and contaminated materials.
- Chop the materials into manageable sizes.
- Apply an appropriate treatment, such as pasteurisation, to reduce competing microorganisms.
- Allow the substrate to cool under hygienic conditions.

- Inoculate the substrate with suitable mushroom spawn.
- Place it in clean growing bags or suitable containers.
- Maintain suitable temperature, humidity and ventilation for the mushroom species.
- Monitor for contamination.
- Harvest mature mushrooms carefully.
- Package and market the mushrooms.
- Manage the spent substrate through suitable composting or other approved uses.

Benefits

- Converts crop residues into a food product.
- Creates income opportunities.
- Reduces agricultural refuse.
- Provides employment.
- Spent mushroom substrate can be composted or used as a soil amendment where suitable.

Precautions

- Use only suitable substrate materials.
- Maintain high standards of hygiene.
- Avoid contaminated or chemically treated materials.
- Use healthy mushroom spawn.
- Maintain appropriate environmental conditions.
- Remove contaminated growing bags safely.

2.7 Use of agricultural by-products in biochar production

Biochar is a carbon-rich material produced by heating biomass under limited oxygen conditions through a process known as **pyrolysis**.

Suitable agricultural materials include:

- Maize cobs.
- Rice husks.
- Coconut shells.
- Groundnut shells.
- Sawdust from suitable untreated wood.
- Other suitable dry crop residues.

Uses of biochar

- It can be incorporated into soil to improve certain soil physical properties.
- It may improve water retention in some soils.
- It can provide a habitat for soil microorganisms.
- It can help retain some nutrients in the soil.
- It can contribute to long-term carbon storage when properly produced and managed.
- It can be used as an ingredient in certain composting systems.

Advantages of biochar production

- Provides an alternative use for crop residues.
- Can improve some soil properties.

- May reduce the need to dispose of certain agricultural residues by open burning.
- Can contribute to carbon management.
- Creates opportunities for value addition and marketing.

Limitations and precautions

- Production requires suitable equipment and controlled conditions.
- Poorly produced biochar may contain harmful substances.
- Open burning is not an appropriate substitute for controlled pyrolysis.
- Biochar is not a complete fertiliser.
- Its effects depend on the feedstock, production temperature, soil type and application method.
- It should be used with appropriate soil fertility management.

2.8 Use of agricultural by-products in craft and other products

Some agricultural by-products can be converted into useful household, decorative and commercial products.

Examples of value-added products

Agricultural by-product	Possible value-added product
Banana fibres	Ropes, mats and handicrafts
Coconut shells	Bowls, ornaments and household items
Maize husks	Mats, baskets and decorations
Sisal residues and fibres	Ropes and craft materials
Sawdust	Composite boards and selected craft products
Fruit peels	Natural extracts and other processed products where safe and technically suitable
Waste paper and crop fibres	Recycled paper and craft products

Economic importance

- Creates additional income.
- Provides employment, especially in small-scale enterprises.
- Encourages creativity and innovation.
- Reduces the amount of material discarded.
- Promotes local manufacturing.
- Creates products that can be sold in local and wider markets.
- Supports cultural and artistic skills.

3.0 VALUE ADDITION OF AGRICULTURAL BY-PRODUCTS

Value addition is the process of improving the usefulness, quality, appearance, shelf life or market value of a product through processing, packaging, grading, treatment or other appropriate activities.

Value addition of agricultural by-products involves converting secondary agricultural materials into more useful, marketable and economically valuable products.

Examples

- Maize cobs can be converted into biomass briquettes.
- Animal manure and crop residues can be converted into compost.
- Rice husks can be processed into bedding or fuel briquettes.
- Fruit remains can be processed into suitable animal feed or compost.
- Sugarcane bagasse can be used as biomass fuel or in other suitable processing activities.

3.1 Importance of value addition of agricultural by-products

- **Increases income:** Processed by-products may fetch higher prices than unprocessed residues.
- **Creates employment:** Processing, packaging and marketing provide jobs.
- **Reduces wastage:** More agricultural materials are put to productive use.
- **Improves product quality:** Processing can improve cleanliness, uniformity and usability.
- **Extends shelf life:** Drying and appropriate storage can reduce spoilage in some products.
- **Reduces environmental pollution:** Proper processing reduces uncontrolled dumping and burning.
- **Improves resource utilisation:** Materials generated on farms are used more efficiently.
- **Promotes entrepreneurship:** Farmers can establish small businesses based on locally available materials.
- **Reduces farm input costs:** Some processed by-products can replace or supplement purchased inputs.
- **Promotes innovation:** Farmers develop new products and processing methods.
- **Supports rural development:** Small processing enterprises can stimulate local economic activity.
- **Encourages sustainable production:** It supports the reuse and recycling of agricultural resources.

3.2 General steps in value addition of agricultural by-products

Although processing methods differ, most value-addition activities follow several basic steps.

Step 1: Identification of by-products

- Identify materials generated on the farm or in the processing unit.
- Determine their quantities and availability.
- Identify possible uses.

Step 2: Collection

- Collect materials from farms, markets and processing centres.
- Use appropriate containers and transport methods.
- Avoid mixing useful materials with contaminated refuse.

Step 3: Sorting and grading

- Separate materials according to type and quality.
- Remove stones, plastics, metals and other foreign materials.
- Separate spoiled or contaminated materials.

Step 4: Cleaning and preparation

- Clean materials using suitable methods.

- Chop, crush, grind or separate them according to the intended product.
- Apply any necessary pre-treatment.

Step 5: Processing

- Convert the materials into the intended product.
- Use suitable equipment and procedures.
- Observe hygiene and safety requirements.

Step 6: Quality control

- Inspect the product for cleanliness, consistency and suitability.
- Check for contamination.
- Confirm that the product meets relevant quality requirements.

Step 7: Packaging

- Use appropriate packaging materials.
- Package products in manageable quantities.
- Label the products accurately.

Step 8: Storage

- Store products under conditions that maintain their quality.
- Protect them from moisture, pests and contamination.
- Use appropriate storage containers.

Step 9: Marketing and selling

- Identify potential customers.
- Determine production and selling costs.
- Set a reasonable selling price.
- Promote the product and maintain customer relationships.

3.3 Factors to consider when selecting agricultural by-products for value addition

- **Availability:** The material should be available in sufficient quantities.
- **Cost of collection:** Transporting bulky materials may be expensive.
- **Quality:** The material should be suitable for the intended product.
- **Market demand:** There should be potential customers for the final product.
- **Processing technology:** Appropriate tools and equipment should be available.
- **Skills:** The entrepreneur should have the necessary processing knowledge.
- **Capital:** Funds should be available for equipment, labour and other inputs.
- **Safety:** Processing should not expose workers or consumers to unacceptable risks.
- **Environmental impact:** Processing should minimise pollution and unnecessary resource use.
- **Storage requirements:** The entrepreneur should be able to store raw materials and finished products safely.
- **Legal requirements:** Relevant standards, licences and regulations should be observed.
- **Profitability:** Expected income should justify the costs of processing and marketing.

4.0 PRACTICAL VALUE-ADDITION ACTIVITIES USING AGRICULTURAL BY-PRODUCTS

Learners should participate in practical activities that demonstrate how locally available materials can be converted into useful products.

4.1 Practical activity: Preparing organic compost from fruit and vegetable remains

Objective: To prepare organic compost from suitable fruit and vegetable remains.

Materials required

- Fruit peels.
- Vegetable trimmings.
- Dry leaves.
- Dry grass.
- Animal manure.
- Water.
- Spade or garden fork.
- Composting site.
- Suitable covering materials.

Procedure

- Identify a suitable composting site.
- Collect fruit and vegetable remains.
- Remove plastics, metals and other non-biodegradable materials.
- Chop large pieces into smaller sizes.
- Mix the green materials with dry leaves and other dry plant residues.
- Add animal manure where available.
- Arrange the materials in layers or mix them thoroughly.
- Sprinkle water to maintain appropriate moisture.
- Cover the compost heap.
- Turn the heap periodically to provide aeration.
- Monitor the decomposition process.
- Allow the compost to mature.
- Inspect the finished compost.
- Use it in a school garden or package it for an appropriate market.

Observation table

Observation	Learner's findings
Type of fruit remains used	
Type of vegetable remains used	
Dry materials added	
Animal manure used	
Changes observed during decomposition	
Colour and texture of mature compost	
Possible uses of the compost	

4.2 Practical activity: Making biomass briquettes from agricultural residues

Objective: To demonstrate how suitable agricultural residues can be converted into solid fuel.

Materials required

- Dry maize cobs, sawdust or rice husks.
- Suitable binder, where required.
- Crusher or grinder.
- Mixing container.
- Briquette mould or press.
- Drying area.
- Protective gloves and dust protection.

Procedure

- Collect dry agricultural residues.
- Remove stones, metals, plastics and other foreign materials.
- Dry the residues to a suitable moisture level.
- Crush or grind the materials.
- Prepare the binder according to the chosen method.
- Mix the ground residues and binder uniformly.
- Place the mixture into the mould.
- Compress the mixture using the briquette press.
- Remove the briquettes carefully.
- Dry the briquettes thoroughly.
- Inspect their shape and strength.
- Store them in a dry place.

Safety precautions

- Wear suitable protection against dust.
- Keep hands away from moving parts of the press.
- Operate equipment under supervision.
- Avoid producing briquettes near open flames.
- Ensure adequate ventilation during any fuel-testing activity.
- Do not burn briquettes in poorly ventilated rooms.

Observation table

Observation	Learner's findings
Type of agricultural residue	
Binder used	
Equipment used	
Shape of briquettes	
Drying method	
Strength of finished briquettes	
Potential market	

4.3 Practical activity: Preparing animal bedding from rice husks

Objective: To demonstrate the use of rice husks as bedding material in a poultry unit.

Materials required

- Clean rice husks.
- Poultry house or demonstration unit.
- Suitable containers.
- Protective clothing.
- Cleaning tools.

Procedure

- Collect clean rice husks.
- Inspect them for stones, sharp objects and contaminants.
- Ensure they are sufficiently dry.
- Clean the poultry house before adding bedding.
- Spread the rice husks evenly on the floor to an appropriate depth.
- Observe the distribution of the bedding.
- Monitor moisture levels during use.
- Remove wet or heavily contaminated sections.
- Replace bedding when necessary.
- Collect used bedding for appropriate composting or disposal.

4.4 Practical activity: Using crop residues as mulch

Objective: To demonstrate how agricultural residues can conserve soil moisture and control weeds.

Materials required

- Dry maize stalks or straw.
- Dry grass or banana leaves.
- Hoe.
- Watering can.
- Crop plants in a garden.

Procedure

- Select a crop garden.
- Remove existing weeds.
- Collect clean and suitable plant residues.
- Chop large materials into manageable pieces.
- Spread the residues around the crop plants.
- Leave space around the stems.
- Water the soil where necessary.
- Observe the condition of the soil over time.
- Record changes in soil moisture, weed growth and decomposition.

4.5 Practical activity: Identifying possible business opportunities from agricultural by-products

Objective: To develop creativity and entrepreneurial skills through the identification of value-addition opportunities.

Procedure

- Learners identify agricultural by-products available in their community.
- They classify the materials according to their sources.
- They suggest possible uses for each material.
- They identify equipment required for processing.
- They identify potential customers.
- They estimate the costs of collection and processing.
- They estimate possible selling prices.
- They present their business ideas to the class.

Sample activity table

Agricultural by-product	Proposed product	Potential customer
Maize cobs	Biomass briquettes	Households and institutions
Animal manure	Organic compost	Crop farmers and nurseries
Rice husks	Poultry bedding	Poultry farmers
Fruit peels	Compost	Vegetable and fruit growers
Groundnut haulms	Livestock fodder	Livestock farmers
Banana fibres	Mats and baskets	Households and craft shops
Sawdust	Briquettes or suitable boards	Households and workshops

5.0 FACTORS AFFECTING THE UTILISATION OF AGRICULTURAL BY-PRODUCTS

The successful utilisation of agricultural by-products depends on several factors.

5.1 Availability and quantity

- Some by-products are available only during certain harvesting seasons.
- Large-scale processing may require a continuous supply of raw materials.
- Farmers may need to collect and store residues during periods of high availability.

5.2 Quality of materials

- Materials should be free from harmful contamination.
- Mouldy or rotten materials may be unsuitable for animal feed.
- Contaminated residues may be unsafe for compost, bedding or other uses.
- Quality determines the suitability of the material for processing.

5.3 Processing technology

- Some by-products require grinding, chopping, drying or pressing.
- Appropriate machines improve processing efficiency.

- Lack of equipment may limit the quantity of material processed.

5.4 Skills and knowledge

- Farmers need knowledge of safe processing methods.
- Poor processing may result in low-quality products.
- Training improves the quality and marketability of value-added products.

5.5 Cost of production

- Collection, transport, labour, electricity and equipment contribute to production costs.
- High processing costs may reduce profitability.
- Efficient use of locally available resources helps reduce costs.

5.6 Market demand

- The final product must meet the needs of customers.
- Farmers should identify potential buyers before investing heavily.
- Market demand affects the selling price and profitability.

5.7 Storage facilities

- Some by-products spoil rapidly when stored wet.
- Dry materials require protection against moisture and pests.
- Proper storage reduces losses and maintains product quality.

5.8 Government regulations and quality standards

- Products intended for sale should meet relevant safety and quality requirements.
- Entrepreneurs should observe applicable environmental and public health regulations.
- Animal feeds and other regulated products must be prepared and marketed responsibly.

6.0 CHALLENGES IN THE MANAGEMENT AND VALUE ADDITION OF AGRICULTURAL BY-PRODUCTS

Farmers and entrepreneurs may face various challenges when collecting, processing and marketing agricultural by-products.

Challenge	Explanation	Possible solution
Inadequate capital	Farmers may lack money to buy processing equipment.	Seek suitable financing or form groups.
Seasonal availability	Some materials are available only after harvesting.	Collect and store materials during peak seasons.
High transport costs	Bulky residues may be expensive to transport.	Process materials near their source.
Lack of skills	Farmers may not understand suitable processing methods.	Provide practical training.
Poor storage	Moisture and pests may spoil materials.	Use dry, clean and secure storage.

Challenge	Explanation	Possible solution
Limited markets	Few customers may be available.	Conduct market research and promote products.
Inadequate equipment	Processing may be slow and inefficient.	Acquire suitable equipment or use shared facilities.
Poor-quality raw materials	Contaminated materials may be unsuitable.	Sort and inspect materials before processing.
High energy costs	Processing equipment may consume expensive energy.	Adopt suitable energy-efficient technologies.
Competition	Similar products may already be available in the market.	Improve quality, packaging and customer service.
Environmental concerns	Poor processing may cause smoke, odours or pollution.	Adopt environmentally responsible methods.
Lack of standardisation	Products may differ in quality and composition.	Follow appropriate production standards and quality controls.

7.0 MARKETING AND ECONOMIC UTILISATION OF VALUE-ADDED AGRICULTURAL BY-PRODUCTS

Marketing refers to activities involved in identifying customers, promoting products, determining prices, selling and delivering products to consumers.

Farmers should understand how to market value-added agricultural by-products to earn income.

7.1 Potential markets

- **Crop farmers:** Purchase compost and other soil-improvement products.
- **Livestock farmers:** Purchase suitable processed animal feeds and bedding.
- **Households:** Purchase biomass briquettes and selected craft products.
- **Schools and institutions:** May purchase suitable fuel, compost and other products.
- **Agro-dealers:** May stock approved agricultural inputs and products.
- **Mushroom growers:** Purchase suitable substrates.
- **Nurseries:** Use compost and other suitable growing materials.
- **Craft shops:** Purchase baskets, mats and other handmade products.

7.2 Methods of marketing value-added products

- Direct selling to farmers.
- Selling through agricultural cooperatives.
- Selling through local agro-dealers.
- Participating in agricultural exhibitions and trade fairs.
- Using social media platforms.
- Advertising through posters and brochures.
- Establishing business partnerships.
- Selling through suitable online marketplaces.

7.3 Factors to consider when pricing value-added products

- Cost of collecting raw materials.
- Cost of transport.
- Labour costs.
- Processing costs.
- Packaging costs.
- Storage costs.
- Market demand.
- Competitor prices.
- Quality of the final product.
- Expected profit.

7.4 Simple calculation of profit from compost production

A farmer prepares and sells bags of compost.

Item	Amount (KSh)
Collection of materials	500
Labour	800
Packaging	400
Transport	300
Other costs	200
Total production costs	**2,200**

The farmer sells the compost for KSh 3,500.

Profit is calculated as:

$$\text{Profit} = \text{Total Revenue} - \text{Total Costs}$$

$$= 3{,}500 - 2{,}200$$

$$= \text{KSh } 1{,}300$$

Therefore, the farmer makes a **profit of KSh 1,300**.

Important terms

- **Revenue:** Money received from selling products.
- **Production cost:** Money spent on producing a product.
- **Profit:** The amount remaining after total costs are deducted from revenue.
- **Loss:** Occurs when total costs exceed total revenue.

8.0 ENVIRONMENTAL MANAGEMENT WHEN UTILISING AGRICULTURAL BY-PRODUCTS

Proper utilisation of agricultural by-products contributes to environmental conservation. However, poor processing and disposal practices may cause pollution.

8.1 Environmental benefits of proper utilisation

- Reduces uncontrolled dumping.
- Reduces open burning of crop residues.
- Improves soil organic matter through composting.
- Reduces the amount of biodegradable refuse sent to disposal sites.
- Encourages recycling of agricultural materials.
- Reduces pressure on some natural resources.
- Supports efficient use of nutrients.
- Can reduce greenhouse gas emissions associated with some unmanaged waste practices, depending on the alternative management method.

8.2 Environmental risks associated with poor management

- **Water pollution:** Runoff from manure and decomposing organic materials may contaminate rivers, dams and wells.
- **Air pollution:** Open burning of agricultural residues releases smoke and harmful particles.
- **Soil pollution:** Improper disposal of contaminated residues may introduce harmful chemicals into the soil.
- **Bad odours:** Decomposing materials may produce unpleasant smells.
- **Pest breeding:** Accumulated organic refuse may attract flies, rodents and other pests.
- **Disease transmission:** Poor handling of animal waste may expose people and animals to disease-causing organisms.
- **Methane emissions:** Anaerobic decomposition of some organic materials can release methane.
- **Blocked drainage:** Improperly discarded residues may block water channels.

8.3 Measures for responsible management

- Sort by-products before processing.
- Compost suitable organic residues.
- Avoid open burning.
- Store manure and organic residues appropriately.
- Prevent runoff into water sources.
- Use clean and uncontaminated materials.
- Maintain hygiene during processing.
- Dispose of unsuitable materials through approved methods.
- Control pests around storage and processing areas.
- Use protective clothing when handling manure and other potentially contaminated materials.

9.0 ENTREPRENEURSHIP OPPORTUNITIES ARISING FROM AGRICULTURAL BY-PRODUCTS

Management of agro-by-products creates opportunities for individuals, groups, schools and farming enterprises.

9.1 Compost production enterprise

Description: An entrepreneur collects crop residues, animal manure and suitable organic materials to produce compost for sale.

Requirements

- Reliable supply of organic materials.
- Composting site.
- Labour.
- Water.
- Tools and equipment.
- Packaging materials.
- Suitable storage facilities.

Potential customers

- Vegetable farmers.
- Fruit farmers.
- Flower growers.
- Tree nurseries.
- Home gardeners.
- Landscaping businesses.

9.2 Biomass briquette production enterprise

Description: An entrepreneur collects suitable agricultural residues and processes them into solid fuel briquettes.

Requirements

- Dry agricultural residues.
- Crusher or grinder.
- Briquette press.
- Binder where necessary.
- Drying facilities.
- Packaging materials.

Potential customers

- Households.
- Restaurants.
- Schools.
- Institutions.
- Suitable commercial users.

9.3 Animal feed processing enterprise

Description: An entrepreneur collects safe agricultural processing by-products and prepares them into suitable feed ingredients or balanced feeds.

Requirements

- Safe raw materials.
- Grinding and mixing equipment.
- Weighing scales.
- Suitable storage facilities.
- Knowledge of animal nutrition.
- Packaging materials.
- Compliance with relevant feed safety and quality requirements.

Potential customers

- Dairy farmers.
- Poultry farmers.
- Pig farmers.
- Sheep and goat farmers.
- Livestock feed retailers.

9.4 Poultry bedding supply enterprise

Description: An entrepreneur collects, cleans, prepares and packages suitable bedding materials such as rice husks and wood shavings.

Requirements

- Reliable raw materials.
- Sorting and cleaning facilities.
- Dry storage.
- Packaging materials.
- Transport.
- Appropriate quality control.

Potential customers

- Poultry farmers.
- Hatcheries.
- Poultry-rearing institutions.

9.5 Mushroom substrate preparation enterprise

Description: An entrepreneur prepares suitable crop residues for mushroom production and sells the prepared substrate or grows mushrooms for sale.

Requirements

- Suitable agricultural residues.
- Chopping equipment.
- Treatment facilities.
- Mushroom spawn if producing mushrooms.
- Clean growing space.
- Packaging materials.
- Knowledge of mushroom production.

Potential customers

- Mushroom growers.
- Restaurants.
- Hotels.
- Food retailers.
- Households.

9.6 Factors contributing to the success of agro-by-product enterprises

- Availability of quality raw materials.
- Good processing skills.
- Appropriate technology.
- Adequate working capital.
- Proper business planning.
- Reliable customers.
- Effective marketing.
- Consistent product quality.
- Good record keeping.
- Compliance with relevant regulations.
- Proper storage and transportation.
- Effective waste and environmental management.

10.0 COMPETENCY-BASED EDUCATION (CBE) INTEGRATION

This sub-strand provides opportunities for learners to develop practical agricultural skills, creativity, entrepreneurship and responsible utilisation of available resources.

10.1 Core competence: Creativity and imagination

Learners develop creativity and imagination by generating ideas on how agricultural by-products can be converted into useful products for economic purposes.

How learners demonstrate this competence

- Identifying locally available agricultural by-products.
- Suggesting alternative uses for crop residues.
- Designing simple composting systems.
- Preparing biomass briquettes.
- Identifying new uses for fruit and vegetable remains.
- Developing business ideas from agricultural by-products.
- Designing suitable packaging for value-added products.
- Exploring innovative ways of reducing agricultural waste.

10.2 Value: Responsibility

Learners develop responsibility by demonstrating commitment and accountability when collecting, processing and utilising agricultural by-products.

How responsibility is demonstrated

- Collecting materials carefully.
- Avoiding unnecessary wastage.
- Following instructions during practical activities.
- Observing hygiene during processing.
- Using equipment responsibly.
- Maintaining a clean working environment.
- Handling animal manure and other organic materials safely.
- Completing assigned tasks.
- Ensuring that products are stored properly.

10.3 Pertinent and Contemporary Issue (PCI): Financial literacy

Learners develop financial literacy by carrying out value addition of agricultural by-products that can generate income.

How financial literacy is developed

- Identifying business opportunities from locally available materials.
- Calculating the cost of collecting agricultural residues.
- Preparing simple production budgets.
- Calculating selling prices.
- Determining revenue and profit.
- Comparing the profitability of different products.
- Identifying possible customers.
- Keeping records of business transactions.
- Making informed decisions when purchasing processing equipment.
- Understanding the importance of saving and reinvesting business income.

10.4 Other cross-cutting issues

Environmental conservation

Learners understand the importance of recycling agricultural materials and preventing pollution.

Health and safety

Learners observe hygiene and safety when handling manure, processing residues and operating equipment.

Entrepreneurship development

Learners identify opportunities for establishing small businesses based on locally available agricultural by-products.

Collaboration

Learners work in groups to collect materials, prepare products and present their findings.

11.0 SUGGESTED LEARNING EXPERIENCES AND ASSESSMENT OPPORTUNITIES

Suggested learning experience	Expected learning evidence
Researching the uses of agricultural by-products	Learner identifies different by-products and their uses.
Collecting crop residues	Learner identifies and classifies suitable materials.
Preparing compost	Learner demonstrates compost preparation.
Preparing animal bedding	Learner selects and prepares suitable bedding.
Preparing biomass briquettes	Learner demonstrates basic briquette production.
Using crop residues as mulch	Learner applies mulch appropriately.
Researching mushroom production	Learner explains how crop residues are used as substrates.
Developing business ideas	Learner presents a value-addition business proposal.
Calculating production costs	Learner prepares a simple budget and calculates profit.
Discussing environmental management	Learner proposes appropriate waste-management practices.

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives given.

1. Which one of the following best describes an agricultural by-product?

A. The main product obtained from a farming activity.
B. A secondary material obtained during agricultural production or processing.
C. A manufactured chemical fertiliser.
D. A material that cannot be used for any purpose.

2. Which agricultural by-product is commonly obtained during rice milling?

A. Sugarcane bagasse.
B. Rice husks.
C. Coffee pulp.
D. Groundnut haulms.

3. A farmer wants to improve soil organic matter using locally available agricultural residues. Which product should the farmer prepare?

A. Plastic pellets.
B. Synthetic fertiliser.
C. Compost.
D. Mineral oil.

4. Which one of the following materials is suitable for preparing compost?

A. Plastic bags.
B. Glass pieces.
C. Fresh vegetable remains.
D. Used pesticide containers.

5. The main function of turning a compost heap is to:

A. Remove all nutrients.
B. Improve aeration.
C. Prevent decomposition.
D. Increase contamination.

6. Which one of the following agricultural by-products is a common source of protein in livestock feed formulations?

A. Groundnut cake.
B. Stones.
C. Plastic waste.
D. Glass fragments.

7. Which one of the following is a common use of rice husks in livestock production?

A. Preparing mineral salts.
B. Animal bedding.
C. Manufacturing vaccines.
D. Producing veterinary drugs.

8. Which process produces biogas from organic materials in the absence of oxygen?

A. Photosynthesis.
B. Anaerobic digestion.

C. Transpiration.
D. Germination.

9. Which one of the following is an example of biomass fuel?

A. Maize cobs.
B. Glass bottles.
C. Plastic pipes.
D. Metal sheets.

10. The process of compressing suitable agricultural residues into solid fuel blocks is known as:

A. Pasteurisation.
B. Briquetting.
C. Fermentation.
D. Irrigation.

11. Which one of the following is an advantage of using agricultural by-products as mulch?

A. Increasing soil erosion.
B. Increasing water evaporation.
C. Conserving soil moisture.
D. Preventing all soil organisms from living.

12. Which agricultural by-product can be used as a substrate in mushroom production?

A. Plastic packaging.
B. Wheat straw.
C. Broken glass.
D. Metal shavings.

13. Biochar is mainly produced through:

A. Freezing agricultural residues.
B. Pyrolysis of biomass under limited oxygen.
C. Washing crop residues with water.
D. Mixing plastics with soil.

14. Which one of the following is a characteristic of good animal bedding?

A. High moisture content.
B. Excessive dust.
C. Good absorbency.
D. Presence of harmful chemicals.

15. Which one of the following is an important factor to consider before using agricultural by-products as animal feed?

A. Colour of the packaging only.
B. Nutritional value and safety.
C. Size of the storage building only.
D. Distance from the nearest town only.

16. Which one of the following is an example of value addition?

A. Dumping maize cobs in a river.
B. Burning all crop residues in the open.

C. Converting animal manure and crop residues into compost.
D. Leaving fruit remains to rot in the market.

17. Which one of the following contributes to the success of an agro-by-product enterprise?

A. Poor product quality.
B. Lack of market research.
C. Reliable supply of raw materials.
D. Poor storage facilities.

18. A farmer sells compost worth KSh 5,000 after spending KSh 3,200 on production. What is the profit?

A. KSh 1,200.
B. KSh 1,800.
C. KSh 3,200.
D. KSh 8,200.

19. Which one of the following practices can cause environmental pollution?

A. Composting suitable crop residues.
B. Using clean rice husks as bedding.
C. Open burning of agricultural residues.
D. Applying suitable organic mulch.

20. Which core competence is emphasised when learners develop innovative ways of converting agricultural by-products into marketable products?

A. Creativity and imagination.
B. Memorisation only.
C. Physical fitness only.
D. Competition without collaboration.

Section B: Structured questions

21.

e) Define the term agricultural by-products. (2 marks)

f) Identify five sources of agricultural by-products. (5 marks)

g) State five examples of agricultural by-products obtained from crop production. (5 marks)

22.

h) Explain five benefits of managing agricultural by-products. (10 marks)

i) Differentiate between agricultural by-products and agricultural waste. (4 marks)

23.

j) Explain five agricultural by-products that can be used in the preparation of organic manure. (10 marks)

k) Describe the procedure for preparing compost using crop residues and animal manure. (10 marks)

24.

l) Explain five importance of compost prepared from agricultural by-products. (10 marks)

m) State five factors to consider when selecting materials for compost preparation. (5 marks)

n) Identify five signs of mature compost. (5 marks)

25.

o) Explain five categories of agricultural by-products that can be used in livestock feed production. (10 marks)

p) State five factors to consider before using agricultural by-products as animal feed. (10 marks)

26.

q) Explain five advantages of using agricultural by-products in livestock feeding. (10 marks)

r) Describe five limitations of using agricultural by-products as livestock feeds. (10 marks)

27.

a) Identify five agricultural by-products that can be used in fuel production. (5 marks)

b) Describe the procedure for preparing biomass briquettes from agricultural residues. (10 marks)

c) State five advantages of biomass briquettes. (5 marks)

28.

a) Define biogas. (2 marks)

b) Describe the main components of a biogas production system. (8 marks)

c) Explain five benefits of producing biogas from agricultural by-products. (10 marks)

29.

a) Explain five characteristics of good animal bedding materials. (10 marks)

b) Identify five agricultural by-products that can be used as animal bedding. (5 marks)

c) Explain five benefits of proper animal bedding. (5 marks)

30.

a) Define mulching. (2 marks)

b) Explain five benefits of using agricultural by-products as mulch. (10 marks)

c) State four precautions to observe when using crop residues as mulch. (4 marks)

31.

a) Explain five ways in which agricultural by-products can be used in mushroom production. (10 marks)

b) Explain five advantages of producing biochar from agricultural residues. (10 marks)

32.

a) Define value addition of agricultural by-products. (2 marks)

b) Explain six importance of value addition in agriculture. (12 marks)

c) State six steps involved in the value addition of agricultural by-products. (6 marks)

33.

a) Explain five factors to consider when selecting agricultural by-products for value addition. (10 marks)

b) State five challenges facing farmers in the management and value addition of agricultural by-products. (5 marks)

c) Suggest five solutions to the challenges identified. (5 marks)

34.

a) Explain five environmental benefits of proper utilisation of agricultural by-products. (10 marks)

b) Describe five environmental problems associated with poor management of agricultural by-products. (10 marks)

35.

A group of learners in a school identifies large quantities of maize cobs, animal manure and vegetable remains in their community. They decide to establish a small enterprise to convert these materials into useful products.

a) Identify four products that can be prepared from the materials. (4 marks)

b) Explain five requirements for establishing the enterprise. (10 marks)

c) State three possible markets for the products. (3 marks)

d) Explain four ways the enterprise can contribute to environmental conservation. (8 marks)

GLOSSARY OF IMPORTANT TERMS

Term	Meaning

Term	Meaning
Agricultural by-product	A secondary material obtained during agricultural production or processing.
Agricultural waste	Material discarded or requiring management after agricultural activities.
Agro-by-product management	Collection, processing, storage and utilisation of agricultural by-products.
Value addition	Improving the usefulness, quality or economic value of a product.
Compost	Decomposed organic material used to improve soil condition and fertility.
Organic manure	Decomposed plant and animal materials used to improve soil.
Crop residue	Plant material remaining after harvesting or processing crops.
Animal bedding	Material placed on livestock-house floors to provide a comfortable resting surface.
Mulching	Covering the soil surface with suitable materials to conserve moisture and control weeds.
Biomass	Organic material of plant or animal origin that can be used as a resource.
Biomass briquette	A compact block of fuel made from compressed biomass.
Biogas	Combustible gas produced through anaerobic digestion of organic materials.
Anaerobic digestion	Biological decomposition of organic materials in the absence of oxygen.
Digester	An enclosed chamber in which anaerobic digestion takes place.
Digestate	Material remaining after anaerobic digestion.
Pyrolysis	Heating organic material under limited oxygen to produce useful products such as biochar.
Biochar	Carbon-rich material produced through biomass pyrolysis.
Substrate	Material used as a growing medium for organisms such as mushrooms.
Mushroom spawn	Material containing mushroom mycelium used to inoculate a growing substrate.
Feed formulation	Selection and combination of feed ingredients to meet animal nutritional requirements.
Palatability	The degree to which an animal finds a feed acceptable and willingly consumes it.
Biodegradable	Capable of being broken down by biological processes.

Term	Meaning
Financial literacy	Ability to make informed decisions about money, costs, income, savings and investment.
Revenue	Total money received from selling goods or services.
Profit	Amount remaining after total costs are deducted from revenue.
Market	A place or system where buyers and sellers exchange goods and services.

STRAND 3.0: AGRICULTURAL TECHNOLOGIES AND ENTREPRENEURSHIP

SUB-STRAND 3.3: AGRI-BUSINESS ACCOUNTS

1.0 Introduction to agri-business accounts

Agriculture is not only concerned with growing crops and rearing livestock. It also involves buying and selling agricultural inputs and products, providing agricultural services, processing farm produce and managing money generated from agricultural enterprises.

Examples of agricultural businesses include:

- Dairy farming and milk-selling enterprises.
- Poultry production and egg-selling businesses.
- Horticultural farms dealing with fruits and vegetables.
- Agro-vet shops selling seeds, fertilisers and pesticides.
- Farm machinery-hire businesses.
- Animal feed processing enterprises.
- Grain trading and storage businesses.
- Agricultural transport and produce distribution businesses.
- Beekeeping and honey-processing enterprises.
- Fish farming and fish marketing businesses.

For these businesses to operate successfully, owners need to keep proper records of their financial transactions. These records help them know how much money is received, how much is spent, who owes them money, whom they owe and whether the business is making a profit or a loss.

Agri-business accounts refer to the systematic recording, classification, summarising and interpretation of financial transactions carried out in an agricultural enterprise.

They provide information about the financial activities and position of an agricultural business.

Examples of financial transactions in an agricultural enterprise

1. Buying fertilisers for crop production.
2. Purchasing animal feeds for dairy cattle.
3. Selling milk to a dairy cooperative.
4. Selling eggs to a local retailer.
5. Paying workers' wages.
6. Buying veterinary medicines.
7. Hiring a tractor for land preparation.

8. Receiving payment for harvested maize.
9. Purchasing farm machinery on credit.
10. Paying electricity and water bills.

1.1 Meaning of an agri-business transaction

An agri-business transaction is a financial activity involving the exchange of money, goods or services in an agricultural enterprise.

A transaction may involve cash payment or credit.

Examples

- A farmer buys 10 bags of fertiliser for KSh 45,000 and pays immediately.
- A poultry farmer sells 50 trays of eggs to a retailer for KSh 15,000 on credit.
- A dairy farmer pays KSh 3,000 for veterinary services.
- A horticultural farmer receives KSh 20,000 from selling tomatoes.
- A farmer hires a tractor for KSh 8,000 and pays after the work is completed.

1.2 Types of agri-business transactions

Agri-business transactions can be classified according to the nature of the transaction and the method of payment.

A. Cash transactions

A cash transaction occurs when payment is made immediately when goods or services are bought or sold.

Examples

1. A farmer buys seeds and pays cash.
2. A poultry farmer sells eggs and receives immediate payment.
3. A farmer pays workers their daily wages.
4. A dairy enterprise buys animal feed and pays immediately.

Characteristics of cash transactions

- Payment is made immediately.
- There is no outstanding amount arising from that transaction.
- The transaction is recorded in the appropriate accounting records.
- A receipt or other relevant proof of payment should be issued or obtained.

B. Credit transactions

A credit transaction occurs when goods or services are supplied but payment is made at a later agreed date.

Examples

1. A farmer purchases fertiliser from an agro-vet shop and agrees to pay after harvesting.
2. A retailer receives vegetables from a farmer and promises to pay after seven days.
3. A dairy farmer receives veterinary services and agrees to settle the bill later.

Characteristics of credit transactions

- Payment is postponed.
- The buyer may become a debtor.
- The seller may become a creditor to the buyer.
- The transaction should be supported by appropriate documents.
- The agreed payment period should be observed.

C. Purchases

Purchases refer to goods or services acquired by a business for its operations or for resale.

Examples include:

- Buying seeds.
- Purchasing fertilisers.
- Buying animal feeds.
- Purchasing poultry vaccines.
- Buying packaging materials.
- Purchasing farm tools and equipment.

D. Sales

Sales refer to goods or services supplied by a business in exchange for money or an agreed payment.

Examples include:

- Selling milk.
- Selling eggs.
- Selling maize.
- Selling tomatoes.
- Selling honey.

- Providing tractor-hire services.

E. Income and expenditure transactions

- Income: Money earned by the business through its activities.
- Expenditure: Money spent by the business to support its operations.

Examples of income include milk sales, egg sales, crop sales and machinery-hire charges.

Examples of expenditure include wages, animal feeds, fertilisers, veterinary services, transport and electricity bills.

2.0 Importance of agri-business accounts

Keeping proper accounts is essential for the successful management of an agricultural enterprise.

Roles and importance of agri-business accounts

1. Determining business profitability: Accounts help the farmer establish whether the enterprise is making a profit or a loss by comparing income with expenses.

2. Monitoring income: They help the farmer know the amount of money generated from selling agricultural products and services.

3. Controlling expenditure: Proper records show how money is spent and help identify unnecessary expenses.

4. Supporting budgeting: Accounts provide information that helps farmers prepare realistic budgets for future agricultural activities.

5. Monitoring debts: They help identify customers who owe the business money and suppliers to whom the business owes money.

6. Preventing financial mismanagement: Proper documentation makes it easier to detect missing money, unauthorised payments and inaccurate entries.

7. Supporting decision-making: Farmers use accounting information to decide whether to expand, reduce or change an agricultural enterprise.

8. Facilitating loan applications: Financial institutions may request business records when assessing applications for agricultural loans.

9. Determining production costs: Accounts help calculate the cost of producing a unit of agricultural product, such as a litre of milk or a kilogram of tomatoes.

10. Planning future activities: Past financial records help farmers estimate future income and expenses.

11. Promoting accountability: Records show how business funds are received, spent and managed.

12. Monitoring business growth: Comparing financial records from different periods helps the owner assess whether the business is expanding.

13. Supporting taxation and statutory compliance: Proper records help a business prepare accurate financial information and meet applicable tax and regulatory obligations.

14. Providing evidence of transactions: Documents such as invoices, receipts and delivery notes provide evidence of business dealings.

15. Improving customer and supplier relationships: Accurate records help resolve disagreements about deliveries, payments and outstanding balances.

16. Supporting stock management: Purchase and sales records help the business monitor the movement of agricultural inputs and products.

17. Encouraging financial discipline: Regular recording of transactions encourages careful handling of business money.

18. Facilitating business evaluation: Accounts help the farmer compare the performance of different enterprises, such as dairy farming and poultry production.

3.0 Documents used in agri-business transactions

Business transactions should be supported by documents that provide evidence of what was requested, supplied, received, sold or paid for.

Agri-business transaction documents are written or electronic records used to initiate, authorise, confirm, support and record financial transactions in an agricultural enterprise.

These documents are important because they provide evidence and information required when preparing accounting records.

The main documents covered in this sub-strand include:

1. Quotation.
2. Purchase order.
3. Service order.
4. Delivery note.
5. Invoice.
6. Receipt.
7. Journal.
8. Cashbook.
9. Debtor register.
10. Creditor register.

3.1 Quotation

A quotation is a formal written statement provided by a seller to a potential buyer showing the prices, quantities, descriptions and terms of goods or services that the seller is willing to supply.

It is usually prepared before the buyer makes a purchase.

A quotation helps a buyer understand the expected cost of purchasing goods or obtaining services.

Example in agriculture

A farmer intends to purchase 20 bags of fertiliser from an agro-vet shop. The farmer requests the seller to provide a quotation showing the price per bag, total cost and payment terms.

Information contained in a quotation

1. Name of the seller or business.
2. Business address and contact details.
3. Quotation number.
4. Date of preparation.
5. Name and address of the potential buyer.
6. Description of goods or services.
7. Quantity required.
8. Unit price.
9. Total price.
10. Discounts, if applicable.
11. Transport or delivery charges, if applicable.
12. Applicable taxes, where relevant.
13. Terms and conditions of sale.
14. Period within which the quotation is valid.
15. Name or signature of the authorised person.

Uses of a quotation

- Communicates the prices of goods and services to potential buyers.
- Helps customers compare prices from different suppliers.
- Enables buyers to estimate the cost of purchases.
- Helps businesses plan sales and supplies.
- Provides a basis for preparing a purchase order.

- Clarifies the conditions under which goods or services will be supplied.
- Reduces misunderstandings about prices and quantities.

Sample quotation

GREEN HARVEST AGRO SUPPLIES

P.O. Box 125, Nakuru | Tel: 0700 000 000

QUOTATION

Quotation No.: GH/Q/014
Date: 01/11/2026

Customer: Sunrise Dairy Farm

Address: Nakuru County

Description of goods

Item	Quantity	Unit price (KSh)	Amount (KSh)
Dairy meal	10 bags	2,500	25,000
Mineral supplements	5 packs	800	4,000
Total			29,000

Terms and conditions: Quotation valid for 14 days. Delivery charges, if any, to be agreed.

Prepared by: Sales Officer

Signature: _____

Illustrative quotation prepared for learning purposes.

Important points about a quotation

- A quotation is generally an offer of prices and supply terms.
- It is not proof that goods have been delivered.
- It is not proof that payment has been made.
- The buyer may use it when deciding whether to place an order.

3.2 Purchase order

A purchase order (PO) is a formal document prepared by a buyer and sent to a supplier to request the supply of specified goods at agreed prices and conditions.

It is normally prepared after the buyer has considered the quotation or identified the required goods.

Example in agriculture

A poultry farmer receives a quotation for 30 bags of poultry feed and decides to purchase them. The farmer prepares a purchase order showing the quantity, type of feed, agreed price and delivery location.

Information contained in a purchase order

1. Name of the buyer.
2. Address and contact details of the buyer.
3. Purchase order number.
4. Date of issue.
5. Name and address of the supplier.
6. Description of goods required.
7. Quantity of each item.
8. Unit price.
9. Total amount.
10. Delivery location.
11. Expected delivery date.
12. Payment terms.
13. Authorisation or signature of the buyer.

Uses of a purchase order

- Communicates the buyer's requirements to the supplier.
- Authorises or documents a proposed purchase according to the business's approval procedures.
- Provides evidence of the goods ordered.
- Helps prevent ordering incorrect quantities or products.
- Supports planning for deliveries and stock management.
- Provides a reference when checking delivered goods against the order.
- Helps resolve disagreements between buyers and suppliers.
- Supports the preparation and verification of invoices.

Sample purchase order

SUNRISE DAIRY FARM

P.O. Box 250, Nakuru County

PURCHASE ORDER

PO No.: SDF/PO/008
Date: 01/11/2026

Supplier: Green Harvest Agro Supplies

Delivery location: Sunrise Dairy Farm

Item	Quantity	Unit price (KSh)	Amount (KSh)
Dairy meal	10 bags	2,500	25,000
Mineral supplements	5 packs	800	4,000
Total			29,000

Delivery date: 05/11/2026

Payment terms: As agreed.

Authorised by: Farm Manager

Signature: _____

Illustrative purchase order prepared for learning purposes.

Difference between a quotation and a purchase order

Quotation	Purchase order
Prepared by the seller.	Prepared by the buyer.
Shows prices and terms offered by the seller.	Shows goods or services the buyer wants to purchase.
Usually prepared before an order is placed.	Usually prepared when the buyer decides to order.
Helps the buyer make a purchasing decision.	Communicates and documents the buyer's order.

3.3 Service order

A service order is a document used to request, authorise or record the provision of a particular service by a service provider.

In agriculture, services may involve machinery hire, transport, veterinary services, equipment repairs, spraying and farm maintenance.

Examples of agricultural services

1. Tractor ploughing.
2. Transporting harvested maize.
3. Repairing a milking machine.
4. Spraying crops using suitable equipment.
5. Vaccinating poultry.
6. Repairing a farm water pump.
7. Cutting grass around a farm.
8. Chopping fodder using a chaff cutter.

Information contained in a service order

- Name and address of the customer.
- Name and address of the service provider.
- Service order number.
- Date of request.
- Description of the service required.
- Location where the service will be provided.
- Expected date of service.
- Agreed service charge.
- Materials or equipment required.
- Terms and conditions.
- Authorisation and signatures.

Uses of a service order

1. Communicates the service required by the customer.
2. Provides instructions to the service provider.
3. Specifies where and when the service should be carried out.
4. Helps establish the agreed service charges.
5. Provides a reference for confirming that the service was performed.
6. Supports preparation of invoices.
7. Helps monitor work assigned to employees or contractors.

8. Reduces misunderstandings between the customer and service provider.

Sample service order

SMART FARM SERVICES

Agricultural Machinery and Farm Services

SERVICE ORDER

Service Order No.: SFS/019

Date: 01/11/2026

Customer: Sunrise Dairy Farm

Service required: Chopping Napier grass using a powered chaff cutter

Location: Sunrise Dairy Farm

Quantity: 2 tonnes of fodder

Agreed charge: KSh 3,000

Expected date: 03/11/2026

Requested by: Farm Manager

Authorised signature: _____

Service provider's acknowledgement: _____

Illustrative service order prepared for learning purposes.

3.4 Delivery note

A delivery note is a document prepared by a supplier and sent together with goods delivered to a customer. It shows the description and quantities of goods supplied.

It enables the buyer to inspect and confirm that the goods delivered correspond with the order.

Example in agriculture

An agro-vet shop supplies a farmer with 10 bags of dairy meal and five packs of mineral supplements. The supplier prepares a delivery note showing the goods supplied and their quantities.

Information contained in a delivery note

1. Name of the supplier.
2. Supplier's address and contact details.
3. Delivery note number.
4. Date of delivery.

5. Name of the customer.
6. Customer's delivery address.
7. Purchase order number, where applicable.
8. Description of goods delivered.
9. Quantity of each item delivered.
10. Name and signature of the person delivering the goods.
11. Name and signature of the person receiving the goods.
12. Remarks on damaged, missing or rejected goods.

Uses of a delivery note

- Confirms that goods have been dispatched or delivered.
- Helps the buyer check the quantities supplied.
- Helps identify missing or damaged goods.
- Provides evidence of the physical delivery of goods.
- Supports the preparation and verification of invoices.
- Helps maintain accurate stock records.
- Reduces disputes between suppliers and buyers.

Sample delivery note

GREEN HARVEST AGRO SUPPLIES

DELIVERY NOTE

Delivery Note No.: GH/DN/014

Date: 05/11/2026

Customer: Sunrise Dairy Farm

Purchase Order No.: SDF/PO/008

Description	Quantity ordered	Quantity delivered
Dairy meal	10 bags	10 bags
Mineral supplements	5 packs	5 packs

Delivered by: _____

Received by: _____

Condition of goods: _____

Date received: _____

Illustrative delivery note prepared for learning purposes.

Important points about a delivery note

- It mainly records the physical movement of goods.
- It may not show the prices or total amount payable.
- It is not necessarily proof of payment.
- The customer should check the goods before signing to acknowledge receipt.
- Any shortages, damage or discrepancies should be recorded.

3.5 Invoice

An invoice is a document prepared by a seller and sent to a buyer to request payment for goods supplied or services provided.

It shows the items supplied, their quantities, prices and the total amount payable.

Example in agriculture

A farmer purchases fertiliser on credit from an agro-vet shop. The supplier issues an invoice showing the quantity supplied and the amount the farmer is required to pay.

Information contained in an invoice

1. Name of the seller.
2. Seller's business address and contact details.
3. Invoice number.
4. Date of issue.
5. Name and address of the buyer.
6. Description of goods or services supplied.
7. Quantity supplied.
8. Unit price.
9. Amount for each item.
10. Discounts, if applicable.
11. Applicable taxes, where relevant.
12. Delivery or other charges, if applicable.
13. Total amount payable.
14. Payment terms and due date.
15. Payment instructions.

Uses of an invoice

- Requests payment from a buyer.
- Shows the amount owed by a customer.
- Provides details of goods or services supplied.
- Supports the recording of credit sales.
- Helps the seller monitor outstanding debts.
- Helps the buyer verify the amount charged.
- Provides evidence for accounting and business records.
- Supports the preparation of financial statements.

Sample invoice

GREEN HARVEST AGRO SUPPLIES

P.O. Box 125, Nakuru

INVOICE

Invoice No.: GH/INV/022
Date: 05/11/2027

Bill to: Sunrise Dairy Farm

Description	Quantity	Unit price (KSh)	Amount (KSh)
Dairy meal	10 bags	2,500	25,000
Mineral supplements	5 packs	800	4,000
Total payable			29,000

Payment terms: Payment within 14 days.

Due date: 19/11/2027

Prepared by: _____

Illustrative invoice prepared for learning purposes. Tax treatment depends on the applicable requirements.

Important points about an invoice

- An invoice is a request for payment.
- It may be issued for cash or credit transactions.
- An invoice alone does not prove that payment has been made.
- It should contain accurate quantities, prices and totals.
- The buyer should verify it against the order and delivery records.

Difference between an invoice and a receipt

Invoice	Receipt
Requests payment.	Acknowledges payment received.
Shows the amount payable.	Shows the amount paid.
Usually issued before payment.	Usually issued after payment.
Helps monitor money owed.	Provides proof of payment.

3.6 Receipt

A receipt is a document issued by a seller or a person receiving money to acknowledge that payment has been received.

It is evidence that a specified amount of money has been paid.

Examples in agriculture

- A dairy farmer pays for animal feeds and receives a receipt.
- A customer buys vegetables from a farmer and receives a receipt.
- A farmer pays for tractor-hire services and receives a receipt.
- A poultry farmer pays for vaccines and receives a receipt.

Information contained in a receipt

1. Name of the business receiving the payment.
2. Receipt number.
3. Date of payment.
4. Name of the person making payment.
5. Amount received.
6. Amount in words, where used.
7. Purpose of payment.
8. Payment method, such as cash, bank or mobile money.
9. Invoice number or transaction reference, where applicable.
10. Name or signature of the authorised receiver.

Uses of a receipt

- Provides evidence that payment has been made.
- Helps the buyer prove that an amount was paid.
- Supports the recording of cash received.
- Helps reconcile payments against invoices.
- Reduces disputes about whether payment was made.
- Supports accountability and financial control.
- Helps maintain accurate financial records.

Sample receipt

SUNRISE DAIRY FARM

OFFICIAL RECEIPT

Receipt No.: SDF/R/031

Date: 06/11/2026

Received from: Green Harvest Agro Supplies

Amount received: KSh 29,000

Amount in words: Twenty-nine thousand Kenya shillings only.

Being payment for: Dairy meal and mineral supplements.

Payment method: Bank transfer

Transaction reference: _____

Received by: _____

Signature: _____

Illustrative receipt prepared for learning purposes.

Important points about a receipt

- It should be issued only when payment has actually been received.
- It should show the correct amount paid.
- It should identify the purpose of payment.
- It should be properly numbered for accountability.
- Electronic payment confirmations may also provide evidence of payment, subject to the business's record-keeping procedures.

3.7 Journal

A journal is a book of original entry in which financial transactions are first recorded in chronological order before they are transferred to the relevant ledger accounts.

It is also referred to as the book of original entry or day book.

In agri-business accounting, a journal is used to record transactions that need to be entered into the accounting system, especially transactions that may not be recorded directly in specialised books such as the cashbook.

Examples of transactions that may be recorded in a general journal

1. Recording depreciation of farm machinery.
2. Recording farm equipment bought on credit.
3. Correcting an accounting error.
4. Recording farm produce donated to a community institution.
5. Recording goods taken by the owner for personal use.
6. Recording bad debts written off.
7. Recording opening balances.
8. Recording adjustments at the end of an accounting period.

Information contained in a journal

- Date of transaction.
- Account to be debited.
- Account to be credited.
- Amount debited.
- Amount credited.
- Narration or brief explanation of the transaction.
- Reference number, where applicable.

Basic accounting terms

Before preparing a journal, learners should understand the following terms:

A. Debit (Dr)

Debit is an entry made on the left-hand side of an account.

B. Credit (Cr)

Credit is an entry made on the right-hand side of an account.

C. Account

An account is a record used to collect and organise transactions relating to a particular item, person or activity.

Examples include:

- Cash account.
- Sales account.
- Purchases account.

- Fertiliser account.
- Machinery account.
- Wages account.
- Debtors account.

D. Narration

Narration is a brief explanation written below a journal entry to describe the transaction being recorded.

Basic double-entry principle

Every financial transaction affects at least two accounts. The total debit entry must equal the total credit entry.

For example, a farmer buys farm tools worth KSh 5,000 and pays cash.

- Farm tools account is debited because the business acquires an asset.
- Cash account is credited because cash leaves the business.

Sample general journal

GREEN HARVEST FARM — GENERAL JOURNAL

Date	Particulars	Debit (KSh)	Credit (KSh)
01/11/26	Farm tools	5,000	
	Cash		5,000
	Being farm tools purchased and paid for in cash.		
03/11/26	Animal feeds	8,000	
	Creditor – Feed Suppliers		8,000
	Being animal feeds purchased on credit.		
05/11/26	Cash	12,000	
	Sales		12,000
	Being agricultural produce sold for cash.		

Illustrative journal entries. Each transaction has equal total debit and credit amounts.

Uses of a journal in agri-business

1. Records financial transactions in chronological order.
2. Provides a basis for transferring entries to ledger accounts.
3. Provides a record of transactions that require adjustments.

4. Helps correct accounting errors.
5. Provides an audit trail for financial activities.
6. Supports preparation of trial balances and financial statements.
7. Helps explain the nature of each transaction through narration.
8. Promotes accuracy and accountability in accounting.

3.8 Cashbook

A cashbook is an accounting record used to record all money received and all money paid out by a business.

It records cash transactions and, depending on its design, bank and mobile-money transactions.

In an agricultural enterprise, a cashbook helps the farmer monitor the movement of money into and out of the business.

Examples of money received

- Cash from selling milk.
- Money from selling eggs.
- Payments for tractor-hire services.
- Money received from selling maize.
- Capital introduced by the owner.
- Payments received from debtors.

Examples of money paid out

- Buying fertilisers.
- Purchasing animal feeds.
- Paying workers' wages.
- Paying electricity bills.
- Buying veterinary medicines.
- Paying transport charges.
- Settling debts owed to suppliers.

Information contained in a cashbook

1. Date of transaction.
2. Details or description of the transaction.
3. Receipt or payment reference.

4. Amount received.
5. Amount paid.
6. Running cash or bank balance.
7. Relevant account or classification, depending on the cashbook format.

Uses of a cashbook

1. Records all money received by the business.
2. Records all money paid out.
3. Shows the available cash balance.
4. Helps control unnecessary expenditure.
5. Supports budgeting and financial planning.
6. Helps identify cash shortages.
7. Provides information for financial decision-making.
8. Supports reconciliation of cash and bank transactions.
9. Helps detect errors and irregularities.
10. Provides a record for preparing financial statements.

3.8.1 Types of cashbooks

A. Single-column cashbook

This cashbook has one amount column for receipts and one amount column for payments. It is mainly used to record cash transactions.

B. Two-column cashbook

This cashbook has two amount columns on each side, commonly for cash and bank transactions.

C. Three-column cashbook

This cashbook has three amount columns on each side, usually for:

- Cash.
- Bank.
- Discounts.

The appropriate format depends on the needs and accounting system of the enterprise.

3.8.2 Sample cashbook

A farmer records the following transactions during the first week of November:

- 1 November: Started the business with KSh 50,000 cash.
- 2 November: Sold vegetables for KSh 8,000 cash.
- 3 November: Bought seeds for KSh 5,000 cash.
- 4 November: Paid workers KSh 3,000.
- 5 November: Sold eggs for KSh 6,000 cash.
- 6 November: Paid transport charges of KSh 2,000.

SUNRISE FARM — CASHBOOK

Date	Details	Receipts (KSh)	Payments (KSh)	Balance (KSh)
Nov 1	Capital	50,000	–	50,000
Nov 2	Vegetable sales	8,000	–	58,000
Nov 3	Seeds	–	5,000	53,000
Nov 4	Workers' wages	–	3,000	50,000
Nov 5	Egg sales	6,000	–	56,000
Nov 6	Transport	–	2,000	54,000
	Totals	64,000	10,000	54,000

Illustrative simplified cashbook. Opening capital is included as money introduced into the business.

Calculation of the closing cash balance

Total receipts = KSh 64,000

Total payments = KSh 10,000

Closing balance} = 64,000 - 10,000

KSh 54,000

The business has a cash balance of KSh 54,000 at the end of the recorded period.

Important points when preparing a cashbook

- Record transactions on the correct dates.
- Enter money received on the receipts side.
- Enter money paid out on the payments side.
- Avoid recording the same transaction twice.
- Calculate the balance after each transaction.

- Keep supporting receipts, invoices and other documents.
- Separate business money from personal money.

3.9 Debtor register

A debtor register is a record used by a business to keep details of customers who have received goods or services on credit and have not yet paid the full amount owed.

A person or business that owes money to the enterprise is known as a debtor.

Examples in agriculture

1. A farmer supplies milk to a hotel on credit.
2. A poultry farmer supplies eggs to a retailer who will pay at the end of the week.
3. A farmer supplies maize to a cereal trader on credit.
4. A farm machinery-hire business provides tractor services and allows the customer to pay later.

Information contained in a debtor register

1. Name of the debtor.
2. Address and contact details.
3. Date of the credit transaction.
4. Invoice number.
5. Description of goods or services supplied.
6. Amount charged.
7. Amount paid.
8. Outstanding balance.
9. Payment due date.
10. Remarks on the payment status.

Uses of a debtor register

1. Identifies customers who owe the business money.
2. Shows the amount owed by each customer.
3. Helps the business monitor outstanding payments.
4. Helps identify overdue debts.
5. Supports follow-up and collection of payments.
6. Helps control credit sales.

7. Provides information for cash-flow planning.
8. Helps reduce the risk of bad debts.
9. Supports customer account reconciliation.
10. Promotes accountability in credit transactions.

Sample debtor register

A dairy farmer supplies milk to three customers on credit.

SUNRISE DAIRY FARM — DEBTOR REGISTER

Date	Debtor	Invoice No.	Amount owed (KSh)	Amount paid (KSh)	Balance (KSh)
1/11/26	Green Hotel	011	8,000	3,000	5,000
2/11/26	Town Retailer	012	5,500	2,500	3,000
3/11/26	Valley School	013	7,000	0	7,000
	Totals		20,500	5,500	15,000

Illustrative debtor register.

Calculation of outstanding debt

Outstanding balance = Amount owed - Amount paid

20,500 - 5,500 = KSh 15,000

The customers still owe the dairy farm KSh 15,000.

Important points when maintaining a debtor register

- Record every credit sale.
- Use the correct invoice reference.
- Update the register whenever payment is received.
- Record the amount and date of each payment.
- Follow up overdue accounts professionally.
- Keep customer details confidential.
- Reconcile balances with invoices and receipts.

3.10 Creditor register

A creditor register is a record used by a business to keep details of suppliers and other persons or organisations to whom the business owes money for goods or services received on credit.

A creditor is a person or business to whom the enterprise owes money.

Examples in agriculture

1. A farmer buys fertilisers from an agro-vet shop on credit.
2. A dairy farmer receives animal feeds and agrees to pay later.
3. A poultry farmer receives chicks from a hatchery on credit.
4. A farmer receives tractor-hire services and agrees to pay after harvesting.

Information contained in a creditor register

1. Name of the supplier or creditor.
2. Address and contact details.
3. Date of the transaction.
4. Invoice number.
5. Description of goods or services received.
6. Amount owed.
7. Amount paid.
8. Outstanding balance.
9. Payment due date.
10. Remarks on the payment status.

Uses of a creditor register

1. Identifies suppliers to whom the business owes money.
2. Shows the amount owed to each supplier.
3. Helps the business plan payments.
4. Prevents forgetting outstanding debts.
5. Helps avoid late-payment penalties where applicable.
6. Supports cash-flow management.
7. Helps maintain good supplier relationships.
8. Provides evidence of credit purchases.
9. Helps verify supplier statements and invoices.
10. Promotes financial accountability.

Sample creditor register

A poultry farmer purchases supplies on credit from different suppliers.

SUNRISE POULTRY FARM — CREDITOR REGISTER

Date	Creditor	Invoice No.	Amount owed (KSh)	Amount paid (KSh)	Balance (KSh)
1/11/26	Feed Suppliers Ltd	021	18,000	8,000	10,000
2/11/26	Agrovet Centre	022	6,500	2,500	4,000
3/11/26	Hatchery Supplies	023	12,000	0	12,000
	Totals		36,500	10,500	26,000

Illustrative creditor register.

Calculation of outstanding creditors

Outstanding balance = Amount owed - Amount paid

36,500 - 10,500 = KSh 26,000

The poultry farm still owes its suppliers KSh 26,000.

3.11 Difference between a debtor register and a creditor register

Debtor register	Creditor register
Records customers who owe the business money.	Records suppliers to whom the business owes money.
Relates mainly to credit sales.	Relates mainly to credit purchases.
Helps monitor money expected from customers.	Helps monitor money payable to suppliers.
Debtors are expected to pay the business.	The business is expected to pay creditors.
Supports collection of outstanding debts.	Supports settlement of outstanding obligations.

Memory aid

- Debtor: Owes the business.
- Creditor: The business owes them.

4.0 Relationship between documents used in agri-business transactions

The documents used in agri-business transactions are connected. One document may lead to the preparation of another as a transaction progresses.

For example, when a farmer buys animal feeds on credit, the transaction may involve a quotation, purchase order, delivery note, invoice, journal entry and creditor register entry.

4.1 Sequence of documents when purchasing agricultural inputs

Example: A dairy farmer purchases fertiliser from an agro-vet supplier.

1. Request for quotation: The farmer requests prices for the required fertiliser.
2. Quotation: The supplier provides a document showing the price, quantity and terms of supply.
3. Purchase order: The farmer prepares an order specifying the fertiliser required.
4. Delivery note: The supplier delivers the fertiliser with a document showing the quantity supplied.
5. Inspection and acknowledgement: The farmer checks the quantity and condition of the goods delivered.
6. Invoice: The supplier issues an invoice showing the amount payable.
7. Journal or other accounting entry: The transaction is recorded in the appropriate accounting records.
8. Creditor register: If the purchase is on credit, the amount owed to the supplier is entered in the creditor register.
9. Payment: The farmer settles the amount due.
10. Receipt: The supplier issues a receipt to acknowledge the payment.
11. Updating the creditor register and cashbook: The payment is recorded, and the outstanding balance is reduced or cleared.

4.2 Sequence of documents when selling agricultural produce on credit

Example: A poultry farmer supplies eggs to a supermarket on credit.

1. The customer places an order for eggs.
2. The farmer confirms the order and supply terms.
3. The eggs are delivered with a delivery note.
4. The customer checks and acknowledges receipt of the eggs.
5. The farmer issues an invoice.
6. The credit sale is recorded in the relevant accounting records.
7. The customer is entered in the debtor register.
8. The customer pays the amount due.
9. The farmer issues a receipt.
10. The debtor register and cashbook are updated.

4.3 Comparison of the main transaction documents

Document	Prepared or issued by	Main purpose
Quotation	Seller	Provides prices and supply terms
Purchase order	Buyer	Requests specified goods
Service order	Customer or authorised business representative	Requests or authorises a service
Delivery note	Supplier	Shows goods delivered
Invoice	Seller	Requests payment
Receipt	Person or business receiving payment	Acknowledges payment
Journal	Business accountant or responsible record keeper	Records transactions in chronological order
Cashbook	Business record keeper	Records money received and paid
Debtor register	Business record keeper	Tracks money owed by customers
Creditor register	Business record keeper	Tracks money owed to suppliers

5.0 Basic principles of good agri-business record keeping

Proper record keeping involves recording financial transactions accurately, consistently and systematically.

The following principles should be observed when preparing agri-business accounts.

5.1 Accuracy

All financial information should be recorded correctly.

- Record the correct quantities of goods purchased or sold.
- Calculate totals correctly.
- Avoid entering incorrect prices.
- Confirm amounts against supporting documents.
- Correct errors using appropriate accounting procedures.

5.2 Completeness

All business transactions should be recorded.

For example, a dairy farmer should record milk sales, animal feed purchases, veterinary expenses, wages and transport charges.

5.3 Timeliness

Transactions should be recorded as soon as possible after they occur.

This prevents forgetting important financial information and reduces errors.

5.4 Consistency

The business should use a consistent method of recording transactions.

For example, the same cashbook format should be used throughout an accounting period unless there is a justified change.

5.5 Accountability

Every transaction should have appropriate supporting evidence and authorisation.

This helps establish who received money, who made payments and who approved purchases.

5.6 Confidentiality

Financial information should be protected from unauthorised access.

Customer details, supplier information, business income and financial records should only be accessed by authorised persons.

5.7 Proper filing and storage

Documents should be organised and stored safely.

They may be filed:

- According to dates.
- According to transaction types.
- According to suppliers.
- According to customers.
- According to document numbers.

Electronic records should be backed up to prevent loss of information.

6.0 Common errors and challenges in agri-business accounting

Agricultural entrepreneurs may experience difficulties when recording and managing financial transactions.

6.1 Common accounting errors

1. Omission: Failure to record a transaction that has taken place.
2. Duplication: Recording the same transaction more than once.
3. Incorrect addition: Making mathematical errors when calculating totals.
4. Wrong classification: Recording an expense under an incorrect account.
5. Incorrect date: Recording a transaction using the wrong date.
6. Incorrect amount: Entering an amount that differs from the supporting document.
7. Failure to update records: Not updating debtor or creditor balances after receiving or making payments.
8. Mixing personal and business finances: Using business money for personal expenses without proper recording.
9. Loss of documents: Misplacing invoices, receipts and other supporting records.
10. Unauthorised transactions: Making purchases or payments without proper approval.

6.2 Challenges facing agricultural entrepreneurs in record keeping

1. Limited accounting knowledge: Some farmers may lack the skills needed to prepare accounting documents.
2. Poor record-keeping habits: Some businesses do not record transactions consistently.
3. Limited access to technology: Some rural enterprises may lack suitable computers or accounting software.
4. High transaction volumes: Businesses with many customers and suppliers may find manual record keeping difficult.
5. Loss of documents: Paper records may be damaged by fire, water, pests or poor storage.
6. Mixing business and personal funds: This makes it difficult to determine the actual financial position of the enterprise.
7. Dishonesty and fraud: Employees or business partners may manipulate financial records.
8. Irregular payments: Customers may delay paying for agricultural products supplied on credit.
9. Seasonal income: Agricultural enterprises may experience irregular cash flows because income often depends on harvesting and production cycles.
10. Unrecorded transactions: Informal cash transactions may be forgotten or deliberately left out.

6.3 Measures for improving agri-business record keeping

1. Train farmers and business workers in basic accounting.
2. Use standard accounting templates.
3. Record transactions immediately.
4. Keep all invoices, receipts and delivery notes.
5. Separate personal money from business money.
6. Carry out regular checks of cash and stock balances.
7. Use spreadsheets or appropriate accounting software.
8. Keep backup copies of electronic records.
9. Assign clear responsibilities for financial recording.
10. Reconcile debtor and creditor balances regularly.
11. Introduce approval procedures for purchases and payments.
12. Restrict access to sensitive financial information.

7.0 Practical application: Preparing agri-business accounting documents

Learners should acquire practical skills in preparing and using documents required in agricultural enterprises.

The following activities can be carried out individually or in groups using templates.

Practical activity 1: Preparing a quotation

Objective: To develop skills in preparing a quotation for agricultural products.

Scenario

A farmer operates an agricultural input shop and receives a request from a customer for the following:

- 5 bags of maize seed at KSh 4,000 per bag.
- 10 bags of fertiliser at KSh 3,500 per bag.
- 4 packs of vegetable seeds at KSh 500 per pack.

Tasks

1. Identify the information required in a quotation.
2. Calculate the amount for each item.
3. Calculate the total quotation value.
4. Prepare a quotation using the information provided.
5. State three uses of the quotation.

Calculation

Item	Quantity	Unit price (KSh)	Amount (KSh)
Maize seed	5	4,000	20,000
Fertiliser	10	3,500	35,000
Vegetable seeds	4	500	2,000
Total			57,000

Expected total: KSh 57,000

Practical activity 2: Preparing a purchase order

Objective: To develop skills in preparing a purchase order for agricultural inputs.

Scenario

Sunrise Poultry Farm wants to purchase:

- 20 bags of chick mash at KSh 3,000 each.
- 10 bags of growers' mash at KSh 2,800 each.
- 5 drinkers at KSh 600 each.

Tasks

1. Identify the buyer and supplier.
2. Prepare a purchase order.
3. Calculate the total purchase cost.
4. Indicate the expected delivery date.
5. State four uses of a purchase order.

Practical activity 3: Preparing a service order

Objective: To develop skills in preparing a service order for agricultural services.

Scenario

A farmer wants to hire a tractor to plough two acres of land at KSh 4,500 per acre.

Tasks

1. Identify the service required.
2. State the location where the service will be provided.
3. Calculate the total service charge.

4. Prepare a service order.
5. State four uses of a service order.

Calculation

2 x 4,500 = KSh 9,000

Practical activity 4: Preparing a delivery note

Objective: To develop skills in documenting the delivery of agricultural inputs.

Scenario

Green Harvest Agro Supplies delivers the following items to a customer:

- 10 bags of fertiliser.
- 5 bags of maize seed.
- 3 packs of vegetable seeds.

Tasks

1. Prepare a delivery note.
2. Indicate the quantities delivered.
3. Provide spaces for the signatures of the supplier and customer.
4. State four uses of a delivery note.

Practical activity 5: Preparing an invoice and receipt

Objective: To develop skills in preparing documents for billing and acknowledging payments.

Scenario

A farmer sells 200 litres of milk at KSh 60 per litre to a local dairy processor.

Tasks

1. Calculate the total value of the milk supplied.
2. Prepare an invoice.
3. Assume the buyer pays the full amount.
4. Prepare a receipt acknowledging payment.
5. Explain the difference between an invoice and a receipt.

Calculation

200x 60 = KSh12,000

Practical activity 6: Preparing a cashbook

Objective: To develop skills in recording money received and paid out.

Scenario

A poultry farmer records the following transactions:

Date	Transaction	Amount (KSh)
1 November	Capital introduced	60,000
2 November	Sold eggs	12,000
3 November	Bought poultry feeds	18,000
4 November	Paid workers	5,000
5 November	Sold manure	3,000
6 November	Paid electricity bill	2,000

Tasks

1. Prepare a cashbook.
2. Identify all receipts.
3. Identify all payments.
4. Calculate total receipts.
5. Calculate total payments.
6. Determine the closing cash balance.

Worked answer

Total receipts:

60,000+12,000+3,000=75,000

Total payments:

18,000+5,000+2,000=25,000

Closing balance:

75,000-25,000 = KSh 50,000

Practical activity 7: Preparing a debtor register

Objective: To develop skills in monitoring amounts owed by customers.

Scenario

A dairy farmer supplies milk to the following customers on credit:

Customer	Amount supplied (KSh)	Amount paid (KSh)
Green Hotel	12,000	5,000
Valley School	8,000	3,000
Town Restaurant	10,000	0

Tasks

1. Prepare a debtor register.
2. Calculate the outstanding balance for each customer.
3. Calculate the total outstanding debt.
4. State four uses of a debtor register.

Worked answer

Customer	Amount owed (KSh)	Amount paid (KSh)	Balance (KSh)
Green Hotel	12,000	5,000	7,000
Valley School	8,000	3,000	5,000
Town Restaurant	10,000	0	10,000
Total	30,000	8,000	22,000

Practical activity 8: Preparing a creditor register

Objective: To develop skills in recording amounts owed to suppliers.

Scenario

A farmer purchases the following items on credit:

Supplier	Amount owed (KSh)	Amount paid (KSh)
Agrovet Centre	15,000	5,000
Feed Suppliers	20,000	8,000
Seed Merchants	12,000	2,000

Tasks

1. Prepare a creditor register.
2. Calculate the outstanding amount for each supplier.
3. Calculate the total outstanding amount.
4. Explain four uses of a creditor register.

Worked answer

Supplier	Amount owed (KSh)	Amount paid (KSh)	Balance (KSh)
Agrovet Centre	15,000	5,000	10,000
Feed Suppliers	20,000	8,000	12,000
Seed Merchants	12,000	2,000	10,000
Total	47,000	15,000	32,000

8.0 CBE integration

8.1 Core competence: Creativity and imagination

Learners develop creativity and imagination when preparing different accounting documents using appropriate formats and templates.

How the competence is developed

1. Designing a quotation for an agricultural input business.
2. Preparing purchase orders using suitable templates.
3. Creating cashbook formats for a dairy enterprise.
4. Developing debtor and creditor registers.
5. Preparing sample invoices and receipts.
6. Using digital tools to design accounting documents.
7. Developing organised systems for filing business documents.

8.2 Value: Integrity

Integrity refers to honesty, fairness and accountability in carrying out responsibilities.

How integrity is developed

1. Recording the correct amount of money received.
2. Avoiding falsification of business documents.
3. Recording all financial transactions.
4. Maintaining accurate cashbook balances.

5. Keeping customer and supplier records confidential.
6. Issuing genuine receipts after receiving payments.
7. Avoiding unauthorised changes to accounting records.
8. Accepting responsibility for errors and correcting them appropriately.

8.3 Pertinent and Contemporary Issue (PCI): Financial literacy

Financial literacy is the ability to understand and manage money and financial information effectively.

How financial literacy is developed

1. Preparing budgets for agricultural enterprises.
2. Recording business income and expenditure.
3. Calculating outstanding debts.
4. Monitoring payments to suppliers.
5. Comparing prices using quotations.
6. Understanding credit transactions.
7. Keeping financial records for business planning.
8. Using accounting information to make business decisions.

9.0 Suggested learning experiences and assessment

Suggested learning experience	Skills developed	Evidence of learning
Visiting an agricultural enterprise	Observation and communication	Identification of accounting documents
Studying quotations and invoices	Interpretation of business documents	Correct description of document contents
Preparing purchase orders	Creativity and imagination	Completed purchase order
Preparing service orders	Communication and documentation	Completed service order
Preparing cashbooks	Numeracy and accounting	Accurate cashbook entries
Preparing debtor registers	Financial management	Correct outstanding balances
Preparing creditor registers	Financial management	Correct supplier balances
Preparing journals	Accounting skills	Correct debit and credit entries
Presenting the uses of documents	Communication	Group presentation

Discussing integrity in financial matters	Ethical decision-making	Demonstration of accountability

9.1 Suggested assessment checklist

The teacher may assess learners using the following checklist during practical activities.

Assessment indicator	**Achieved**	**Not yet achieved**
Identifies a quotation and explains its use	☐	☐
Prepares a purchase order correctly	☐	☐
Prepares a service order correctly	☐	☐
Identifies the contents of a delivery note	☐	☐
Prepares an invoice correctly	☐	☐
Prepares a receipt correctly	☐	☐
Records transactions in a journal	☐	☐
Prepares a cashbook accurately	☐	☐
Prepares a debtor register accurately	☐	☐
Prepares a creditor register accurately	☐	☐
Explains the role of agri-business accounts	☐	☐
Demonstrates integrity when recording financial information	☐	☐

REVISION EXERCISES

Section A: Multiple-choice questions

Choose the correct answer from the alternatives given.

1. Which one of the following documents is prepared by a seller to communicate the prices of goods to a potential buyer?

A. Receipt
B. Quotation
C. Delivery note
D. Cashbook

2. A farmer intends to purchase 20 bags of fertiliser from an agro-vet shop. Which document should the farmer prepare to formally request the goods?

A. Purchase order
B. Receipt
C. Invoice
D. Journal

3. Which document is normally sent together with goods supplied to a customer?

A. Quotation
B. Receipt
C. Delivery note
D. Cashbook

4. A poultry farmer supplies eggs to a supermarket on credit. Which document should the farmer issue to request payment?

A. Purchase order
B. Invoice
C. Quotation
D. Service order

5. Which document provides evidence that payment has been received?

A. Invoice
B. Purchase order
C. Receipt
D. Delivery note

6. Which accounting record is used to record money received and money paid out by a business?

A. Debtor register
B. Cashbook
C. Quotation
D. Delivery note

7. A farmer supplies milk to a hotel on credit. In the transaction, the hotel becomes the farmer's:

A. Creditor
B. Supplier
C. Debtor
D. Employee

8. Which register records amounts owed by a business to its suppliers?

A. Debtor register
B. Creditor register
C. Cashbook
D. Receipt book

9. Which register is used to monitor customers who have purchased goods on credit?

A. Creditor register
B. Cashbook
C. Debtor register
D. Journal

10. Which accounting book records financial transactions in chronological order before they are posted to the relevant ledger accounts?

A. Journal
B. Delivery note
C. Invoice
D. Quotation

11. A farmer buys animal feeds worth KSh 8,000 on credit. Which record should be updated to show the amount owed to the supplier?

A. Debtor register
B. Creditor register
C. Receipt book
D. Sales quotation

12. Which one of the following is a major role of agri-business accounts?

A. Increasing soil erosion
B. Promoting financial accountability
C. Reducing farm production
D. Preventing agricultural marketing

13. Which document is used to request or authorise the provision of a service such as tractor ploughing?

A. Service order
B. Receipt
C. Delivery note
D. Cashbook

14. A farmer receives KSh 15,000 from selling vegetables. In a cashbook, the amount should be recorded as:

A. A payment
B. A liability
C. A receipt
D. A creditor balance

15. Which one of the following is an example of a credit transaction?

A. A farmer pays cash for fertiliser.
B. A farmer buys seeds and agrees to pay after harvesting.
C. A farmer receives cash from selling eggs.
D. A farmer pays workers immediately.

16. A business receives KSh 20,000 from a debtor who owed KSh 35,000. What is the outstanding balance?

A. KSh 55,000
B. KSh 35,000
C. KSh 20,000
D. KSh 15,000

17. Which one of the following values is promoted when a learner records financial transactions honestly and accurately?

A. Integrity
B. Competition
C. Selfishness
D. Discrimination

18. Which one of the following is an appropriate way of improving the safety of financial records?

A. Allowing everyone to alter the records.
B. Destroying all supporting documents.
C. Restricting access to authorised persons.
D. Recording transactions only at the end of the year.

19. A farmer receives an invoice for KSh 12,000 and pays the full amount immediately. Which document should the supplier issue?

A. Quotation
B. Receipt
C. Purchase order
D. Service order

20. Which one of the following documents is most useful when a farmer wants to compare prices offered by different agricultural suppliers?

A. Quotation
B. Receipt
C. Cashbook
D. Debtor register

Section B: Structured questions

21.

a) Define the term agri-business accounts. (2 marks)

b) Explain five reasons why proper accounting records are important in agricultural enterprises. (10 marks)

c) Give four examples of financial transactions in an agricultural enterprise. (4 marks)

22.

a) Define a quotation. (2 marks)

b) Explain five uses of a quotation in an agricultural enterprise. (10 marks)

c) State six items of information contained in a quotation. (6 marks)

23.

a) Define a purchase order. (2 marks)

b) Describe the procedure followed when preparing a purchase order for agricultural inputs. (8 marks)

c) Explain five uses of a purchase order. (10 marks)

24.

a) Define a service order. (2 marks)

b) Explain five uses of a service order in agricultural enterprises. (10 marks)

c) State four examples of agricultural services that may require a service order. (4 marks)

25.

a) Define a delivery note. (2 marks)

b) Explain five uses of a delivery note in agricultural transactions. (10 marks)

c) State six items of information contained in a delivery note. (6 marks)

26.

a) Differentiate between an invoice and a receipt. (4 marks)

b) Explain five uses of an invoice in an agricultural enterprise. (10 marks)

c) State six items of information contained in an invoice. (6 marks)

27.

a) Define a journal. (2 marks)

b) Explain five uses of a journal in agri-business accounting. (10 marks)

c) State four items of information recorded in a journal. (4 marks)

28.

a) Define a cashbook. (2 marks)

b) Explain six uses of a cashbook in an agricultural enterprise. (12 marks)

c) State four examples of money received by a farm business. (4 marks)

29.

a) Define a debtor register. (2 marks)

b) Explain five uses of a debtor register in agricultural enterprises. (10 marks)

c) State six items of information recorded in a debtor register. (6 marks)

30.

a) Define a creditor register. (2 marks)

b) Explain five uses of a creditor register in agricultural enterprises. (10 marks)

c) State six items of information recorded in a creditor register. (6 marks)

31.

a) Differentiate between a debtor and a creditor. (4 marks)

b) Give four examples of agricultural credit transactions. (4 marks)

c) Explain six measures that can be used to improve the accuracy of agri-business accounting records. (12 marks)

32.

A dairy farmer recorded the following financial transactions during one week:

- Opening cash balance: KSh 30,000.
- Sold milk for KSh 12,000.
- Purchased animal feeds for KSh 8,000.
- Paid workers KSh 4,000.
- Sold manure for KSh 3,000.
- Paid transport charges of KSh 2,000.

a) Prepare a cashbook showing the transactions. (8 marks)

b) Calculate the total receipts. (2 marks)

c) Calculate the total payments. (2 marks)

d) Determine the closing cash balance. (2 marks)

33.

A horticultural farmer supplied tomatoes to three customers on credit as shown below:

Customer	Amount supplied (KSh)	Amount paid (KSh)
Green Hotel	15,000	5,000
Valley School	10,000	4,000
Town Restaurant	8,000	0

a) Prepare a debtor register using the information provided. (9 marks)

b) Calculate the total amount owed by the customers. (3 marks)

c) Explain four ways a debtor register helps an agricultural entrepreneur. (8 marks)

34.

A poultry farmer purchased the following supplies on credit:

Supplier	Amount owed (KSh)	Amount paid (KSh)
Feed Suppliers	20,000	10,000
Agrovet Centre	12,000	4,000
Hatchery Services	15,000	5,000

a) Prepare a creditor register. (9 marks)

b) Calculate the total outstanding amount owed to suppliers. (3 marks)

c) Explain four ways a creditor register assists a poultry farmer. (8 marks)

35.

a) Explain five challenges that may affect proper record keeping in agricultural enterprises. (10 marks)

b) Suggest five measures that can be adopted to improve agri-business accounting practices. (10 marks)

Glossary of important terms

Term	Meaning
Agri-business	A business involved in agricultural production, processing, marketing or provision of agricultural services
Agri-business accounts	Systematic recording and management of financial transactions in an agricultural enterprise
Transaction	A financial activity involving the exchange of goods, services or money
Quotation	A document showing prices and terms offered by a seller
Purchase order	A document prepared by a buyer to request specified goods
Service order	A document used to request or authorise a service
Delivery note	A document showing goods delivered to a customer
Invoice	A document requesting payment for goods supplied or services provided
Receipt	A document acknowledging payment received
Journal	A book of original entry used to record transactions chronologically
Cashbook	A record of money received and paid out
Debtor	A person or business that owes money to the enterprise
Debtor register	A record of customers who owe the enterprise money
Creditor	A person or business to whom the enterprise owes money
Creditor register	A record of amounts owed to suppliers and other creditors
Credit transaction	A transaction in which payment is made at a later date
Cash transaction	A transaction in which payment is made immediately
Debit	An entry made on the left-hand side of an account
Credit	An entry made on the right-hand side of an account
Narration	A brief explanation accompanying a journal entry
Income	Money earned through business activities
Expenditure	Money spent by a business
Outstanding balance	The amount that remains unpaid
Financial literacy	The ability to understand and manage financial information and resources
Accountability	The obligation to explain and take responsibility for financial actions

