Book 1

Year 11

Agricultural Science

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GOVERNMENT OF SĀMOA
MINISTRY OF EDUCATION, SPORTS AND CULTURE

Acknowledgements

The Ministry of Education, Sports and Culture would like to thank Gauna Wong for his vision, patience and hard work in putting together this valuable book.

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Designed, edited and typeset by Egan-Reid Ltd, Auckland, as part of the Sāmoa Secondary Education Curriculum and Resources Project for:

Reprinted 2004 with minor amendments.

Funded by the New Zealand Agency for International Development, Nga Hoe Tuputupu-mai-tawhiti.

Printed through Egan-Reid Ltd.

Managing Contractor: Auckland UniServices Limited.

ISBN 982–517–041–7

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Unit 1: AGRICULTURE IN SĀMOA

About this unit
In this unit you will be studying agricultural practices used by farmers trying to improve production and returns. You will investigate trends in local production and production methods used by farmers to maintain or improve their production or returns. You will also evaluate how effective some of the methods practised by farmers are.

Production trends
Every farmer and government would like to optimise production. This is not always possible as we cannot always control the factors of production. For example, we cannot control the weather, diseases, pests and market prices to name a few. So we tend to get fluctuations: *e.g. In crop yields and market prices.*

Methods Of Improving Production

Crop and animal production can be improved by using modern methods of farming. Some of these methods are:

Use of improved varieties and breeds
Improved varieties are normally superior to earlier varieties. Improvements could include: having a higher yield; being more resistant to pests and diseases; maturing faster; being easier to harvest; being a more desirable shape; and so on. Despite having one or more superior characteristics they also often have some undesirable characteristics, which could include a less desirable taste or smell. It is difficult to have all desirable characteristics in one animal or plant. Farmers must be aware of this and select the best crop or animal to suit their farm's objectives.

Use of fertilisers
Fertiliser will improve yield if used wisely. First we must determine the type, amount and frequency of fertiliser to be applied to a crop. We can do this by analysing the soil and finding out the nutrient requirements of plants.

Planting niche crops
Niche crops are high-value produce that are only produced for special markets and fetch high returns. Some examples are hydroponically grown tomatoes that we export to American Sāmoa (see next page) and organically produced crops. Niche crops in Tonga are vanilla and squash. Niche crops are difficult to grow and manage as they require high input and management.

Using crop rotation

Crop rotation is the growing of different crops, one at a time, in a definite sequence on the same piece of land. The advantage of crop rotation is that it helps to maintain soil fertility and controls pests and diseases.

Hydroponics

This is the growing of crops in other media such as water, where factors such as nutrients, water, pests, temperature and light are controlled. Crops can be produced all year round and the quality of the produce is very high.

Planting in greenhouses

Plants grown in a greenhouse can yield more crops than those harvested from open fields because diseases and growing conditions, such as water and light, can be controlled. This provides better growing conditions for plants.

Activity 1 Production Trends

Materials needed:
Year 9 Book 3 student books.

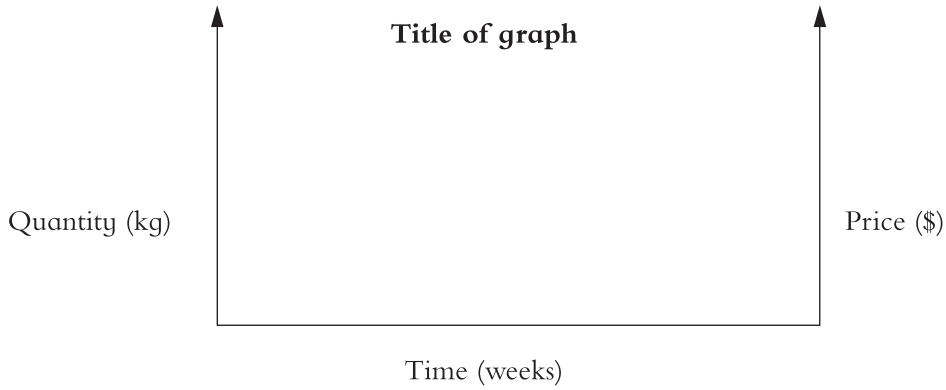
Aim To investigate trends in local production.

1. Divide into groups of four.
2. Discuss and complete Activity B on page 8 of the Year 9 Book 3 student book.
3. Go to a roadside vendor, village store, farmer, supermarket, or local market and collect information on the quantity of one crop sold and its price.
4. Collect information once a week for two months.
5. Record the information you have collected in a table like the one below.
6. Plot the data on a graph like the one on the next page (time on the x-axis, quantity on the left y-axis and price on the right y-axis).

Group:

Crop:

Date	Quantity (kg or bags or bundles or number)	Price	Comments
Week 1 (date)			
Week 2 (date)			
Week 3 (date)			
Week 4 (date)			
Week 5 (date)			
Week 6 (date)			
Week 7 (date)			
Week 8 (date)			



7. You will have one data line for quantity and another for price. Compare the two data lines.
8. Explain the trend shown on the graph.
9. Write a conclusion based on the trend of the graph.
10. Write recommendations based on your conclusion.

Activity 2 Methods For Increasing Production

Aim To investigate a method used to maintain or increase production or return.

1. Divide into groups of four.
2. Select one of the following methods for increasing production:

- Use of new crop varieties.
- Use of new animal breeds.
- Use of fertilisers.
- Planting niche crops.
- Using crop rotation.
- Hydroponics.
- Planting in a greenhouse.

3. Discuss and compare the new method you have selected with old methods. You can get the information you need to make comparisons from farmers, USP Alafua library, Agriculture Department and agricultural extension officers, agriculture teachers, the internet, CDU, FAO office or from background information in this book.
4. Record the results of your discussion and investigation in a table similar to the one on the next page.
5. Present your group's table (written on newsprint or cardboard) to another group.
6. Use the feedback from the other group to make any changes necessary and stick your work on the wall for other students to read.

Method of production Example: The use of fertiliser (poultry manure) when planting Chinese cabbage			
Factors	**Old method** No fertiliser used	**New method** Use of poultry manure	**Benefits**
Farm objectives			
Yield			
Costs			
Environmental impact			
Market			
Time			
Labour			
Other factors			
Conclusion			
Recommendations 1. 2. 3.			

Review

1. What are the best times to sell produce in the local market?
2. Give reasons for your answer to question one.
3. What are the best months for planting vegetables?
4. Name some methods of improving production used by local farmers.
5. List some factors that farmers take into consideration before adopting a new production method.

Unit 2: GENETICS

About this unit
At the end of this unit, you should be able to use genetic charts to identify possible characteristics of the offspring from a simple monohybrid cross, and also relate the principle of variation and genetics to crop and animal production.

Background information
Elephants, ants, trees and people all look different from each other but, like all living things, they contain the same fundamental working parts — cells. All animals and plant cells have three important parts: they are surrounded by a clear flexible covering called a cell membrane; the cell is filled with cytoplasm; in the centre of the cell is the most important part, the nucleus.

Inside the centre is a substance called protein, upon which life depends. The instructions needed to make proteins are stored within a special complex chemical in the nucleus called DNA. DNA is shaped like a twisted rope ladder. The rungs of the ladder are made up of four chemical bases. These bases are called A–adenine, T–thymine, G–guanine and C–cytosine. Each of them has a different shape, just like pieces of a jigsaw puzzle. A and T are shaped so that they fit together, as are C and G. None of the other combinations work. A section of DNA that has the complete code for a single protein is called a gene.

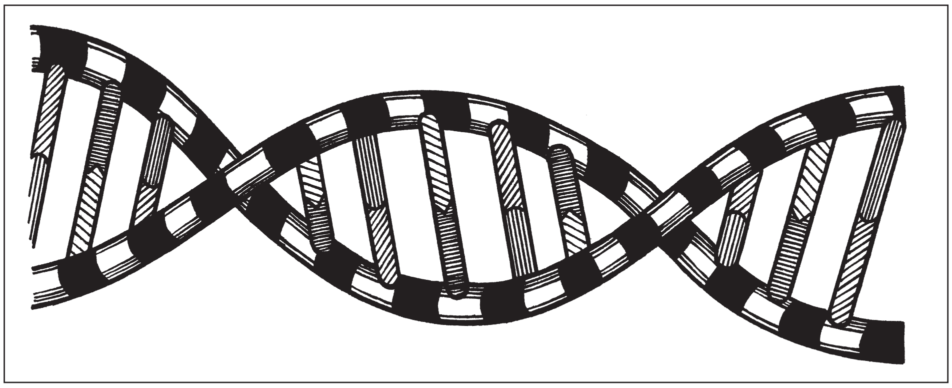


Figure 2.1
A strand of DNA.

Genes determine the type of proteins made, thereby controlling the factors that make unique traits in animals and plants. Genes are not found as separate bits but are strung like beads on long strands of DNA known as chromosomes. Humans have 46 chromosomes arranged in 23 pairs. If all the DNA making up the chromosomes inside one of your cells were stretched out it would be almost two metres long.

Genetics

It has been noted for a long time that offspring resemble their parents. Because there is so much variety in nature it had been difficult to understand the principles of breeding. The first person to discover the basic rules that govern inheritance was a monk, Gregor Mendel. Mendel studied the patterns of inheritance in peas. His work took more than seven years and recorded data about 30 000 plants. He noticed that tall pea plants always produced seeds that became tall plants and short plants did the reverse. From this evolved the rule of pure lines. Pure lines reproduce the same traits as their parents.

- Mendel selected pure line pea plants with contrasting forms as shown in the table below:

DOMINANT		**RECESSIVE**
Tall	STEMS	Short
Side of stem	FLOWERS	End of stem
Smooth	SEEDS	Wrinkled
Yellow		Green
Coloured	SEEDCOATS	White
Inflated	PODS	Narrowed
Green		Yellow

Mendel first experimented with plants that varied in only one characteristic. By breeding one pure line of pea with another pure line, he produced what is now called a hybrid. A hybrid is an offspring produced by breeding two pure lines. Today, it is necessary to use precise names of generations. The notation used is: P_1 generation — pure breed parents; F_1 generation — second generation hybrid offspring; F_2 — generation filial or offspring second generation, and so on.

We used the words *dominant* and *recessive* in the table above. From his experiments Mendel found that the tall factor hid the short factor thus he called it dominant. The short factor was called recessive because it could not be seen. From his results, Mendel concluded that the factors governing dominant and recessive traits are distinct. The three theorems of the law of segregation are:

- For each trait, an individual carries two factors.
- Each parent contributes one of the factors to their offspring.
- If an offspring has two dominant factors or one dominant and one recessive, the offspring will have the traits of the dominant. Only if the offspring has two recessive factors will they carry the traits of the recessive.

Today, the units of heredity are called genes. Genes govern the characteristics of an organism. Two separate forms of the genes are called **alleles**. For example, one allele produces tall plants and another produces short plants. Since each organism carries two alleles per trait, each trait is represented by two letters. A capital letter is used if the trait is dominant and a lower case letter is used if the trait is recessive.

The two letters make up the organism's **genotype**, or set of alleles. The appearance of an organism is called its **phenotype**. An organism that carries two identical alleles is called homozygous. If the alleles are different it is heterozygous. A summary of this can be seen in the chart below, using 'G' = green and 'g' = yellow.

Genotype	GG	Gg	gg
Phenotype	green	green	yellow
Pure or Hybrid	pure	hybrid	pure
Homozygous or Heterozygous	Homozygous dominant	Heterozygous	Homozygous recessive

A helpful way to visualise genetic crosses is using a Punnett square. This is a table devised by Professor Reginald Punnett that shows the number and variety of genetic combinations.

	T	T
t	Tt	Tt
t	Tt	Tt

	T	t
t	Tt	tt
t	Tt	tt

	T	t
T	TT	Tt
t	Tt	tt

	T	T
T	TT	TT
t	Tt	Tt

Each of the four boxes contains a possible combination of alleles. From the Punnett squares you can predict the chance of an occurrence of any genotype or phenotype in an offspring. By doing a test cross you can determine if the lines are pure. If a plant with TT is crossed with Tt the offspring would be TT or Tt, therefore, all the offspring would be tall. If the genotype had been Tt instead of TT then one quarter of the offspring would be short. This way you can test for pure strains.

	T	T
T	TT	TT
t	Tt	Tt

	T	t
T	TT	Tt
t	Tt	tt

All the traits Mendel studied exhibited clear dominance and recessivity. There are some situations called incomplete dominance, for example, the colour of chicken feathers. Birds that are homozygous are either white or black but hybrids appear as a mix of colour. This is called incomplete dominance.

Mendel's studies led to his Law of Independent Assortment. It states that inheritance of alleles for one trait does not affect the inheritance of alleles for another trait. For example, whether a plant is short or tall has no effect upon whether its seeds are smooth or wrinkled.

- There are three ways that populations change — by mutation, selection and migration.

Occasionally there is a change in genetic information that is called mutation. A mutation is an error in the replication of genetic matter. There are certain substances and conditions that can increase the rate of mutations. X-rays and ultra-violet light have been shown to increase the number of mutates. Some chemicals have also been shown to do this.

Animals with certain traits are less likely to survive to an age where they can reproduce and are therefore less likely to pass on their genes. This is called natural selection.

Some animals, such as the panda and the tiger, are facing extinction today because man-made environmental factors have changed the natural selection process.

Migration and isolation are important factors in natural selection. In migration, individuals leave or enter a population. In doing so, the individuals create or remove variety from a population gene pool. Sāmoa was isolated for many years and had a gene pool which gave most people dark hair. With the arrival of the missionaries and other people from different races, variety was introduced to the Sāmoan gene pool. There are now people with lighter-coloured hair in Sāmoa.

Breeding

The human race has learned to use various plants and animals for food, clothing, transportation and protection. The processes used to bring about change are essentially the same as those that operate in nature. Breeding or artificial selection guarantees the survival of those characteristics that humans want for their own purposes. Remarkable success has been achieved in improving domesticated plants and animals. Examples include: sheep with heavier coats; chickens that lay more eggs or have more meat; cows that give more milk; and wheat that yields more grain. Over the last 60 years, the use of genetic modification through various techniques, such as artificial insemination, has become widespread and important to farmers.

Genetic Engineering

People have learned how to alter the code that produces life forms with new traits through genetic engineering. Can you imagine that by creating new plants and animals some of the most crippling diseases can be wiped out? Genes for these diseases can be altered by using viruses. Normally, viruses cause disease. They do this by attacking cells and inserting their own genes into the target's DNA. The infected cell now has instructions to make more copies of the virus. Eventually, those copies burst out and infect other cells.

Specially altered viruses can be valuable in replacing disease-causing genes. Scientists have learned how to use viruses to add missing genes or change defective ones and are finding cures for many genetic disorders.

They have also created transgenic animals and plants by taking genes from one organism and placing them in the DNA of a different one. Animals have been genetically engineered to produce important, rare drugs, such as insulin, in their milk. Researchers have genetically improved tomatoes to reduce the production of the gas ethylene that causes ripening. When the gene is inserted into a tomato plant it slows the ripening process, allowing consumers to have vine-ripened tomatoes all year-round.

Activity 1 Think Pair Share

Materials needed:
Background text;
Pen and paper.

Aim: To get students to read and study a piece of text and share his/her knowledge and understanding within a group.

1. Divide into groups of four.
2. Choose a leader.
3. Each person is to select a paragraph from the background. Start from the beginning of the text.
4. Read your paragraph (five minutes), make notes and share what you have read with your group.
5. Continue until your group completes reading the background text.

Activity 2 Drawing A Family Tree Of Traits In Your Family

Aim: Using family trees to trace a trait.

1. Determine which trait you are interested in.
2. Draw a chart of your family starting with your great-grandparents, if possible, so that you have four generations. Use circles for females and squares for males.
3. Shade the symbol of those people who carry the trait you are studying.
4. Note if the trait is gender-related. The chart should look similar to this:

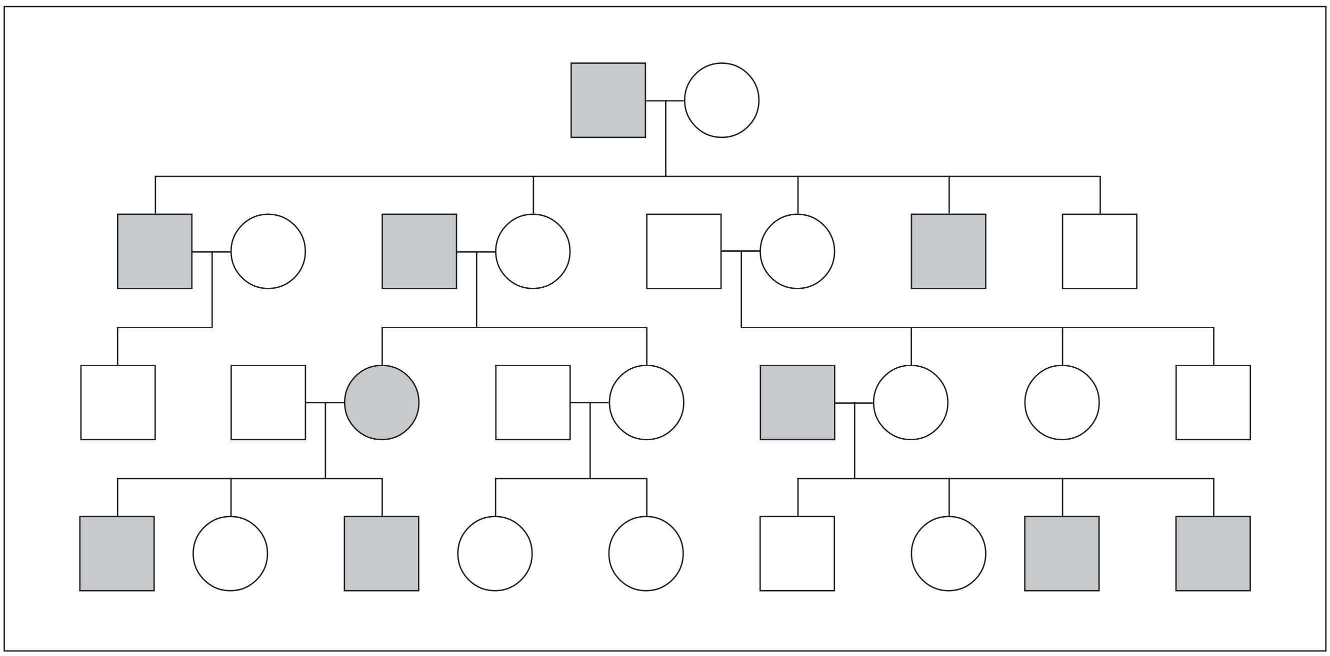


Figure 2.2
Family tree of traits.

Activity 3 Using Punnett Squares

Aim To determine genotype and phenotype of crosses between varieties of water-melon.

1. Work in pairs.
2. Using the example below as a guideline, study and discuss your work.

Example
Cross between a watermelon without seed (Ss) and a watermelon with red flesh (Ff).

Ss — Without seed (S) is dominant over with seed (s).

Ff — Red flesh (F) is dominant over pink flesh (f).

	S	s
F	SF	Fs
f	Sf	sf

Outcome of cross

Genotypes — SF (25%), Sf (25%), Fs (25%), sf (25%).

Phenotypes

- Melon without seeds and red flesh.
- Melon without seeds and pink flesh.
- Melon with red flesh with seeds.
- Melon with seed and pink flesh.

3. Discuss and fill in the Punnett square below for a cross between two melons without seeds (Ss × Ss).
4. Determine the genotype and phenotype of the cross.
5. Determine the percentage of the genotypes.

	S	s
S	?	?
s	?	?

Outcome of cross

Genotypes:

Phenotypes:

Activity 4 Research Topic And Poster For The Science Fair

Materials needed:
Large piece of cardboard;
Pencil;
Coloured pens.

Aim To research a topic and make a poster of it for the science fair.

1. Choose your own topic or choose a topic from the list below.
2. If possible, research your topic in the library or on the internet.
3. Draw a poster describing your research topic and list its pros and cons.

Topic list

- Is cloning of animals useful?
- Causes of mutations.
- Who should have genetic testing before birth?
- Who owns genes?
- Are genetically-modified foods good for us?

Review

1. How do new varieties arise?
2. Describe how a single species might become two species?
3. What are some of the traits that our taro breeders might select?
4. What purely genetic factors and what purely environmental factors contribute to the appearance of a new variety of watermelon or breed of cattle?
5. Determine the genotype and phenotype of a cross between a bull without horns (i.e. Polled) (Hh) and a cow with a black coat (Bb). (Polled is dominant over horns and black coat is dominant over brown coat.)

Unit 3: SOIL PROPERTIES

About this unit
The chemical, physical and biological properties of soil are important factors for plant growth. Its management will determine crop growth and production. In this unit you will describe and investigate the effects of soil properties on plant growth. You will see how and why farmers change soil properties.

Chemical Properties

Soil management in relation to chemical aspects
There are two ways to ensure that plants will not be harmed by pH levels:

- Select plants that grow well at the existing soil pH; or
- Alter the pH of the soil to suit the needs of the plant.

Most soil pH changes are directed towards reducing soil acidity. Adding lime increases soil pH. Agricultural limes, containing calcium carbonate, magnesium carbonate, and other materials, are used to neutralise soil acidity and to provide calcium and magnesium for plant growth. Agricultural lime is usually ground limestone made up of calcium carbonate ($CaCO_3$). This is known as calcitic lime. If the lime also contains a significant amount of magnesium carbonate ($MgCO_3$) the lime is known as dolomitic.

Liming, or altering the acidity of the soil, is usually done by applying ground limestone. To get it right, the purity, neutralising value and fineness of the lime must be taken into consideration.

It takes at least six months for lime to appreciably increase soil pH. Lime may be applied whenever necessary. Calcium hydroxide ($Ca(OH)_2$) is also used as a liming material. It has a greater neutralising value per kilogram and is more soluble than the carbonate form. Wood ash can also be used to increase soil pH.

Acid soils that have been limed are still subjected to the neutralising effects of biological respiration, organic matter mineralisation, and precipitation. Soils must be re-limed to prevent them from becoming acidic again. This must be done every two to five years, depending on variables such as lime application rate, cation exchange capacity, rainfall, crop removal of calcium and magnesium, and fertilisation practices.

Soils containing calcium carbonate are calcareous soils. Calcareous soils have a pH range from 7.5–8.3. Plants growing in such soils are sometimes deficient in iron, manganese, zinc, and/or boron. To reduce soil pH would require the leaching of carbonates, which is impractical. As a result, crops are fertilised with appropriate nutrients to overcome the deficiencies. Alternatively, crops that grow well in calcareous soil are selected.

Significant and dependable increases in soil acidity are achieved through the use of sulphur. Sulphur is slowly converted to sulphuric acid by soil microbes, and the soil slowly becomes more acidic over a period of several months. As with lime, the amount of sulphur required varies with the pH change desired and the soil cation exchange capacity. Sulphur is commonly used in nurseries and gardens.

Physical Properties

Some of the physical characteristics of soil that concern us are texture, structure, consistency, colour, bulk density, particle density and porosity.

Soil texture

The fineness (the clay-like nature) or coarseness (the sandy or gravelly nature) of the soil is determined by the relative size of the soil particles, and to describe it we use the term **texture**. More specifically, texture is determined by the relative proportions of sand, silt and clay.

The rate and extent of many important physical and chemical reactions in soil are governed by texture because it determines the amount of surface on which the reactions can occur. The physical and chemical weathering of rocks and minerals results in a wide range of particles from stones, to gravel, to sand, and to very small clay particles.

When soil is examined you will see that it is made up of particles of varying sizes. These particles have been divided into groups, entirely on the basis of their size, without regard to their other properties.

The following table gives the names of the various soil parts (soil separates) together with their diameters based on the two slightly different systems.

Separate	Diameter mm[a]	Diameter mm[b]	Number of particles per gram	Surface area in 1 gram/cm^2
Very coarse sand	2.00–1.00	–	90	11
Coarse sand	1.00–0.50	2.00–0.20	720	23
Medium sand	0.50–0.25	–	5700	45
Fine sand	0.25–0.10	2.00–0.20	46 000	91
Very fine sand	0.10–0.05	–	722 000	227
Silt	0.05–0.002	0.02–0.002	5 776 000	454
Clay	Below 0.002	Below 0.002	90 260 853 000	8 000 000

[a] United States Department of Agricultural systems (USDA).
[b] International Soil Science System (ISSS).

Once the percentage of sand, silt and clay has been determined, the soil can be placed in one of 12 major textural classes as determined by using the 'Textural Triangle' which was developed by scientists in the USA. See Figure 3.1.

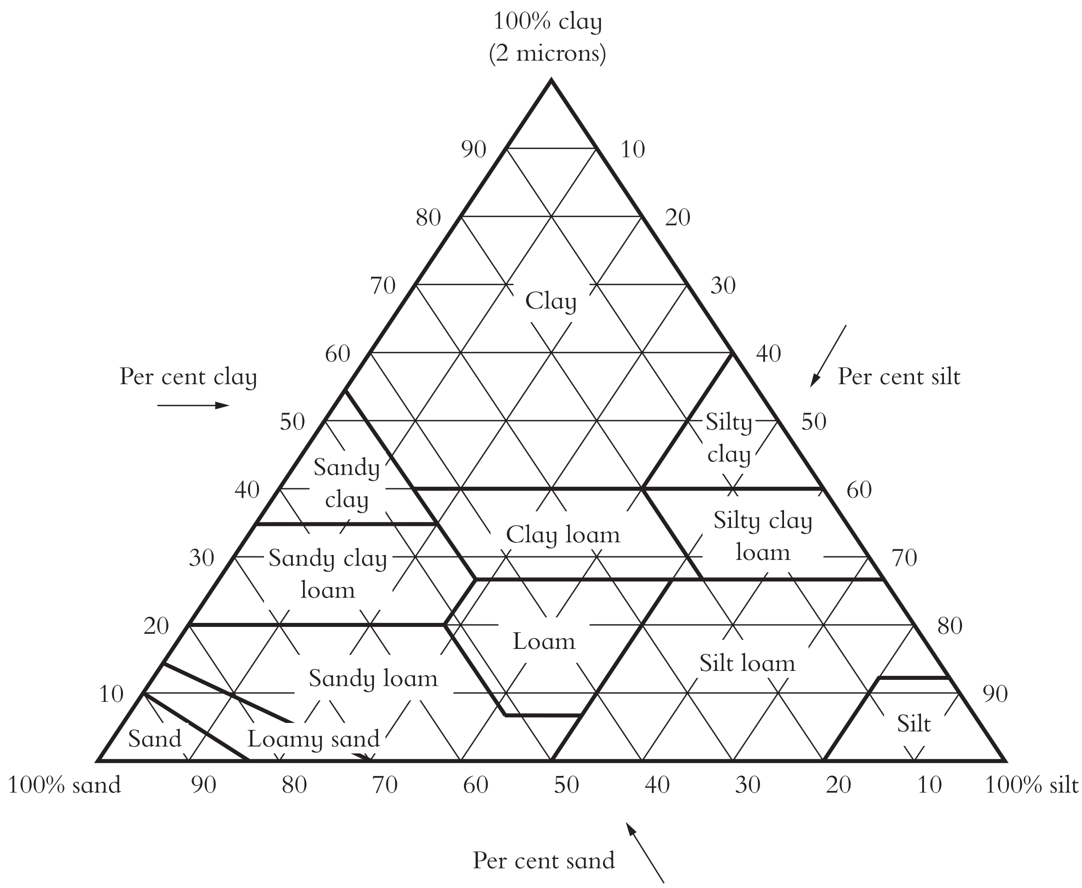


Figure 3.1
Soil texture triangle.

The textural triangle shows the limits of sand, silt and clay contents of the various texture classes.

To find the textural class of a soil, locate a point within the triangle which represents the intersection between two of the three soil separates (sand, silt or clay). The name of the bold box the intersection falls in is the textural class of the soil.

Many of the important soil properties such as fertility, water permeability, plasticity, ease of tillage, droughtiness and productivity are closely related to soil texture. This may be illustrated by referring to clay and sandy soils, which stand in extreme contrast texturally.

Clay soils show high water holding capacity, stickiness and swelling, whereas sandy soils are conspicuous by the absence of these properties. The most important way in which soil texture affects plant growth is water and nutrient supply.

The available water capacity (amount of water available for plant growth) of soil is related to soil texture. Water infiltration (entry of water through soil surface) is more rapid in coarse textured soil, hence plants which require good drainage will thrive well on a coarse textured soil.

Have you heard the terms such as 'light' and 'heavy' soils? In layman's terms light soils are sandy soils. This is used because it is easy to use tools in light soils. Clay soils are termed as heavy because tools need more power. In actual density terms sandy soils are heavier than clay soils.

There are two ways of determining the texture of a soil. The first method is by using the pipette method, which is an accurate determination. The second method is by feel, which is a field method.

The pipette method involves the collection of a soil sample. This soil sample is put into a 500–1000 ml measuring cylinder, mixed with water, shaken and left to settle for a few hours. The percentage of sand, silt and clay are calculated and the soil's texture is determined using the texture triangle.

The feel method involves the mixing of a soil sample with water in your hand. A sticky smooth ribbon of soil is probably a clay-textured type of soil. A rough, coarse ribbon of soil that is difficult to keep together is probably a sandy- or silt-textured type of soil

Soil Structure

The term structure relates to the clumps, grouping or arrangement of soil particles. It describes the gross overall combination or arrangement of the primary soil particles into secondary groupings called aggregates or peds. This arrangement or packing of the particles leads to the existence of pores of various sizes and shapes in soil. The pores may be filled with water, air or both.

Structure can be described as type, class and grade. Type notes the shape and arrangement of peds. Class indicates ped size and grade indicates the distinctiveness and strength of the peds.

The class categories depend on the type as shown in the diagram below. Soil peds are classified on the basis of shape. There are four basic shapes which give rise to seven commonly recognized types as shown in the diagram below. The four basic shapes are plate-like, prism-like, block-like and spheroidal or granular.

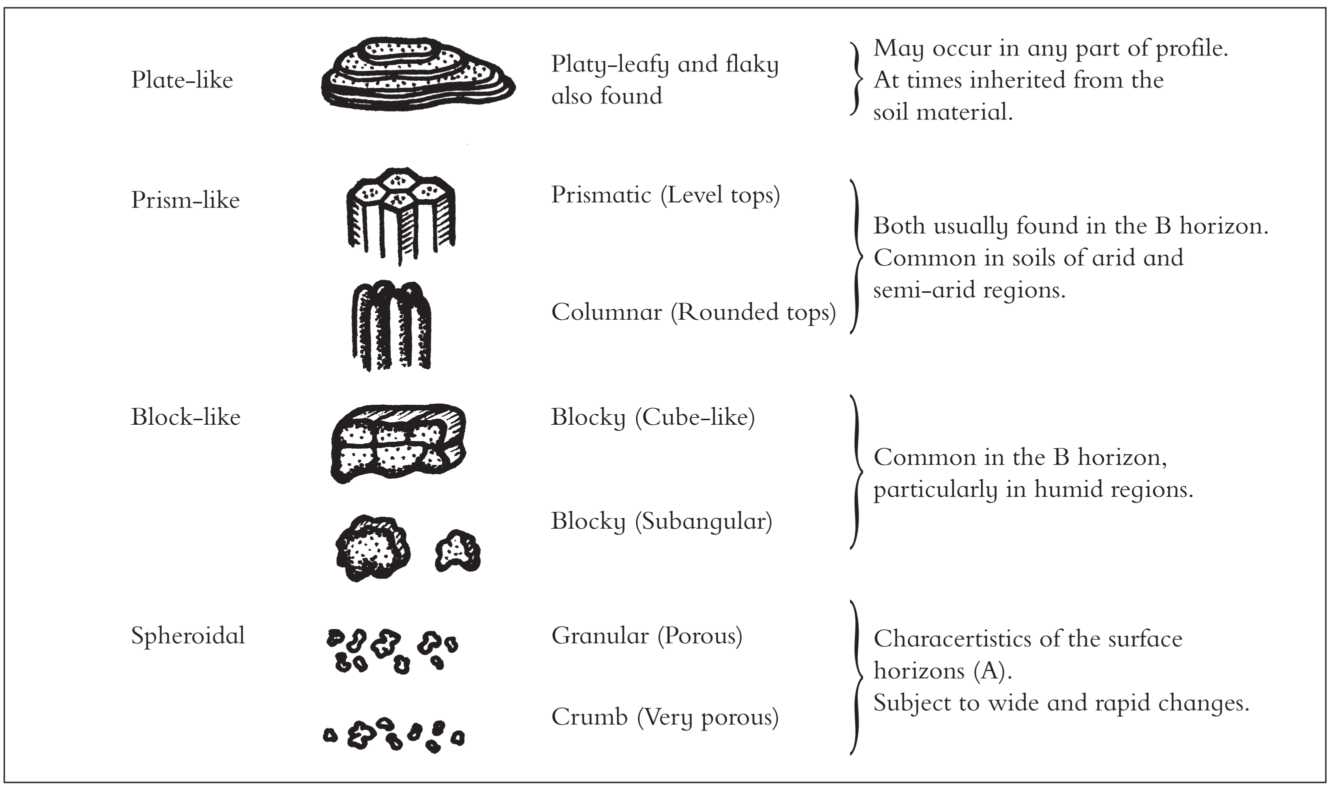


Figure 3.2
Various structural types found in mineral soils. Their location in the profile is suggested. In arable topsoils, a stable granular structure is prized. (Source: Brady, 1990.)

The following terms are used to describe the grade of structure:

- **Structureless** — no observable aggregation (sandy or muddy field).
- **Weak** — poorly-formed aggregates.
- **Moderate** — well-formed distinctive peds.
- **Strong** — durable peds that are of equal size.

When describing a soil's structure, you have to indicate the grade first, then the class and lastly the type.

Soil structure influences plant growth indirectly. The formation of structural units leads to the formation of an array of pores of various shapes and sizes. These pores are important for water retention and movement, for air content and for the temperature of soil which in turn govern plant growth.

Some management practices for crop production that have profound effects on the formation and stability of soil aggregates are:

- Cultivation/tillage operations.
- Crops and cropping practices.
- Manures and fertilisers.

Lowering the level of soil organic matter depletes the soil's structure. Fallowing the land helps in adding organic matter, thereby improving the structural status of soil.

The tillage operations affect the:

- Size distribution of clods.
- Bulk density and packing of soil particles.
- Amount of organic matter.
- Moisture content of soil.

In fine-textured soil that is too dry, the ploughing action will turn over big hard clods but will not break down the clods to smaller sizes. Under very wet conditions, the aggregates will be broken down to very small sizes. This leads to puddled conditions that completely destroy structure. Soil in a puddled condition is desirable for growing rice crops but not for other crops.

Soil structure is affected by both the vegetative canopy of crops above the ground and the branched root system below the ground. The organic matter produced by the roots, along with microbial activity, help produce a soil with an ideal crumb structure. The vegetative canopy protects the soil from the beating action of the raindrops and prevents the destruction of the surface soil structure. This canopy also prevents the soil from crusting.

The soil in which a row crop without much of a vegetative canopy or branched root system is planted soon deteriorates.

Legumes play an important role in building up soil fertility. They are regularly used in crop rotation. Legumes add nitrogen to the soil and improve soil structure.

Under tropical conditions the level of organic matter and the structural improvement of soil can be built up to a varying degree and maintained by adding manure. The degree of improvement depends on three factors:

- The quality and length of application of manure.
- The climatic conditions.
- Nature of the soil.

Aggregate stability is the resistance of aggregates to break down or damage. The stability of aggregates is of great importance. Some aggregates break down easily due to the beating effects of raindrops, ploughing and tilling of the land.

Soil Colour And Consistency

Soil colour
The most obvious physical property of soil is colour. Soil is, still today, described by its colour — black, red or yellow.

Factors affecting soil colour
Organic matter content, iron compounds, poor drainage and other factors such as salt accumulation can all affect the colour of soil.

Organic matter content
The dark colour of soils is generally due to the highly decayed organic matter they contain. In fact, with some practice, the percentage of organic matter in many soils may be judged with reasonable accuracy from their colours. In most mineral soils the organic matter content is usually greatest in the surface soil. The colour of soil becomes darker as the organic matter content increases. Dark soils are fertile soils. Generally, there is a tendency to correlate black-coloured soils with fertile and productive soils.

However, a broad generalisation about soil colour and soil fertility is not always valid.

Grey subsoil indicates a fairly constant water-saturated condition. Such soils are poor building sites. In such conditions, basements tend to be damp or wet and septic tank filters fail to work correctly. Repeated water saturation and drying of the subsoil causes a mixed pattern of soil colours called mottling.

Soil consistency
The best time to prepare your seed beds for planting flowers or vegetables is after a shower of rain. But have you noticed how some soils stick to your tools and some soils do not? These differences are due to the type of clay and organic matter content of the soil. There are two types of clay: kaolinite and montmorillonite.

Soil consistency is expressed by the degree of cohesion and adhesion or by resistance to deformation or rupture. **Cohesion** means sticking to similar particles (*e.g. A water molecule to another water molecule*). **Adhesion** means sticking to dissimilar particles (*e.g. Soils to hand tools*).

Wet, moist and dry consistency
The consistency of a soil is expressed with reference to the water content of soil. Normally, it is described for three moisture levels: wet, moist or dry.

A given soil may be sticky when wet, firm when moist, and hard when dry. A partial list of terms used to describe consistency includes:

- Wet soil — non-sticky, sticky, non-plastic, plastic.
- Moist soil — loose, friable, firm.
- Dry soil — loose, soft, hard.

Plastic soil is capable of being moulded or deformed continuously and permanently, by relatively moderate pressure, into various shapes when wet. Friable soils readily break apart and are not sticky when moist.

Consistency deals with the strength and nature of the forces between the sand, silt and clay particles. This knowledge is important for tillage and traffic considerations. For example, dune sand exhibits minimal cohesive and adhesive properties, and because sand is easily deformed, vehicles can easily get stuck in it. Clay soils become sticky when wet, which makes ploughing difficult.

Consistency limits

The consistency limits are also termed the Atterberg limits. They are indexes of the workability or firmness of artificial mixtures of soil and water as affected by the content of water in the mixture. The limits are defined by the water contents required to produce specified degrees of consistency that are measured in the laboratory. Commonly determined limits are plastic limit and liquid limit.

Plastic limit

Plastic limit is defined as the water content at which soil begins to crumble on being rolled into a thread 3 mm in diameter. It represents the lowest water content at which soil can be deformed readily without cracking.

Liquid limit

Liquid limit is the point at which soil becomes semi-fluid, like softened butter. In operational terms, the liquid limit is defined as the water content at which a trapezoidal groove of a specified shape cut in moist soil in a special cup will flow together for a distance of 10 mm after 25 taps on a hard rubber plate.

Plasticity index

Plastic index is the difference between the liquid and plastic limits. This gives an indication of the 'clayness' or plasticity of clay and is widely employed in engineering classification systems for soils. Clay content and the type of clay are the major factors governing these limits. The other important factors are porous grains, organic matter and drying.

Soil Density And Porosity

Soil is composed of liquid (water), gases (air) and solids. Water and air are contained in a continuous network of irregularly sized and shaped pores or voids.

Voids are distributed throughout the solids like a sponge but with much finer pore sizes. The size and amount of voids influences such things as water movement, aeration, and storage capacity of plant water available and is modified by particle arrangement or structure.

All the factors that affect structure such as organic matter content, tillage, and other soil management practices, influence the amount of air and water in soil.

High bulk density (mg/m^3) means low porosity. Compaction in topsoils causes high bulk density. This causes restricted root penetration, impeded water infiltration and percolation, and low soil aeration, all detrimental to plant growth.

More about particle density

Particle density of inorganic soils depends on mineral composition. The most abundant soil minerals, quartz, feldspars, and clay minerals have densities in the range of 2.5–2.7 mg/m^3.

Factors affecting bulk density
Some of the factors that affect bulk density are: combined volumes of the solids and pore spaces; soil texture; soil compactness; cropping systems and management practices.

Combined solids and pore spaces
Since bulk density relates to the combined volume of the solids and pore space, soils with a high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influences soil pore space will affect bulk density.

Soil Texture

When sandy soils and clay-like soils are compared, which soil has the highest bulk density? Most would say 'clay soil'. However, the correct answer is 'sandy soil'.

The texture of surface soils such as silt loam, clay, and clay loam, generally have lower bulk densities than sandy soils. The arrangement of fine particles, along with organic matter, assures high total pore space and a low bulk density.

Soil compactness
Bulk density may vary depending on the compactness.Very compact subsoils may have bulk densities of 2.0 mg/m^3 or even greater.

In such compact layers there are essentially no macropores and root growth is greatly impaired — the constraint becoming most noticeable at bulk densities of 1.6 mg/m^3 or above.

Bulk density also varies depending on the location in the profile. It is generally higher in lower profile layers.This results from a lower content of organic matter, less aggregation and root penetration, and compaction caused by the weight of the overlying layers.

Cropping systems and management practices
Cropping systems and management practices also influence bulk density. Forest clearing and cultivation tend to increase surface bulk density. The addition of crop residues or farm manure tends to lower it.

Soil Fertility Management

Soil management is the science of tillage, cropping practices, and the treatment of soil for the production of plants. The principal objective of a soil management programme is sustained profitable production. Soil conservation is essentially good soil management and embraces more than just the prevention of soil losses. Soil erosion is a sign of poor management, whether it is inadequate plant nutrients or improper cropping systems. Erosion is a symptom, not a primary cause of soil destruction.

In evaluating a crop and soil management system for its effect on sustainable production, there are several factors to remember including:

- Organic matter and soil tilth.
- Plant nutrient supply.
- Incidence of weeds, insects and disease.

Soils differ in their characteristics, hence in their management requirements. For example, one soil, a silty clay loam high in organic matter, may have excellent tilth and could endure management practices that decrease tilth for some time before problems are encountered. Another soil, a silt loam low in organic matter, might be poor in tilth, and the same management practice would cause trouble immediately. It is important that soil is evaluated carefully in order to establish the necessary management requirements.

Soil evaluation is a process by which nutrient problems are diagnosed and fertility recommendations are made. There are several ways of doing this. The most common ones are:

- Observation of deficiency symptoms.
- Soil tests.
- Plant analysis.
- Biological techniques such as missing element techniques, simple field trials, etc., or a combination of these.

Observation

We can detect plant nutrient deficiencies by simply observing common nutrient deficiency symptoms. For example, mobile nutrients in the plant, such as nitrogen, phosphorus, potassium and magnesium, show deficiency symptoms in old leaves. Immobile elements, such as sulphur, calcium, and micronutrients, first show symptoms in young leaves.

Advantages: cheap and quick; does not require equipment or a laboratory.

Disadvantages: by the time the plant deficiency symptoms become obvious it may be too late in the season to apply fertiliser; care must be exercised because several different deficiencies can produce similar symptoms; symptoms may be mixed with pest and disease conditions.

Soil test

A soil test is a chemical method of estimating the nutrient-supplying power of a soil. It measures a part of the total nutrient supply (available nutrients) in the soil. These values have to be calibrated against nutrient rate experiments in the field and in the greenhouse. One of the weaknesses of this test is that a recommendation to add fertiliser is made from an unrepresentative sample. For example, based on a small sample, fertiliser is perhaps added to 10 000–30 000 tonnes of soil.

Advantages: nutrient deficiencies can be identified before planting a crop; soil testing needs only a small representative sample.

Disadvantages: problem in obtaining a representative sample; a calibration curve, indicating the soil test value and the percentage relative yield, has to be developed for each soil; soil test values do not tell us how much fertiliser needs to be applied; sometimes it is difficult to choose a correct soil extractant; there is no commonly accepted soil test for making nitrogen fertiliser recommendations; soil testing for micronutrients is of little value unless pH levels are taken into consideration; many factors affect crop response to a nutrient — climate, tillage, crop and so on. Even in areas with a soil test very high in phosphorous, a starter is recommended for better performance; services of a testing laboratory are required.

Plant analysis

Plant analysis is based on the premise that the amount of a given element in a plant is an indication of the supply of that particular nutrient and so directly relates to the quality of the soil. Two general types of plant analysis have been used:

- Testing for fresh tissue in the field.
- Total analysis performed in a laboratory with precise analytical techniques.

Biological testing

Biological testing is a technique in which plant growth performance, based on the fertiliser application, is used to measure the fertility status of soils. The two common biological tests are:

- Field test.
- Laboratory and greenhouse tests.

The field-lot method is one of the oldest and best known of the biological tests. The series of treatments selected depends on the particular question the experiment wishes to have answered. The treatments are then randomly assigned to an area of land, known as a replication, which is representative of the conditions. Several such replications are used to obtain more reliable results and to account for variations in soil and management.

These experiments are helpful in the formulation of general recommendations. When large numbers of tests are conducted on soils that are well characterised, recommendations based on such studies can be extrapolated to other soils with similar characteristics.

Laboratory and greenhouse tests are similar to field tests but are more rapid. These tests still involve plants and utilise small quantities of soil.

Biological Properties

Soil organisms

The soil is an environment in which water, air and food materials are found. Hosts of living organisms take advantage of these conditions and live permanently or temporarily in the soil. All these soil organisms are dependent upon one another. In the same way that all animal life above the ground depends on plant life directly or indirectly, so the animals in the soil are dependent on conditions of the soil. Just as different climates support different populations of plants and animals, so do the living things in the soil differ from one soil to another.

Some of the organisms in the soil are large enough to be seen with the naked eye. The larger animals are ants, termites, beetles, earthworms, snails, millipedes, slugs, centipedes and the larvae and pupae of many insects such as cutworms, grubs, wireworms and the larvae of dung beetles. Larger soil fungi may sometimes be seen as masses of fine white or greyish threads in the soil.

By far the most important forms of soil life are those that are microscopic or invisible to the naked eye. Protozoa are single-celled animals that live chiefly on soil bacteria. Soil contains some microscopic green algae which will sometimes be seen as a greenish tinge on the surface when the soil is damp. Fungi or moulds and bacteria are the most important forms of life in the soil.

Soil life is extremely important to all other forms of life. Some soil organisms are the only forms of life on the earth that can make use of nitrogen. Without them no other life could exist, because all living cells must have proteins which contain nitrogen atoms.

Many soil organisms break down or decompose the bodies of other organisms that have fallen onto the soil and become mixed with it. Without these decomposers, dead leaves, stems, fruit or bodies of dead mice, sheep or beetles would never decompose. Eventually all the nitrogen of the air would be locked up in these dead bodies. These soil decomposers convert the bodies of plants and animals into simple substances which can be used again by other plants and animals.

Some soil organisms are important to humans because of the gummy coating of their cells. This sticky substance cements the soil particles together and helps to produce good soil structure.

Activity 1 Growing Plants In Different Soil pH Ranges

Materials needed:
3 pots or cans;
sand;
acidic soil;
6 maize or bean seeds;
Sulphur.

Aim To investigate the effects of pH on plant growth.

1. Divide into groups of three.
2. Discuss and write a hypothesis for this activity.
3. Fill one pot/can half full with sand.
4. Fill the other two pots/cans half full with acidic soil.
5. Mix some sulphur with one pot of acidic soil.
6. Test and record the soil pH in the three pots/cans using a pH meter.
7. Sow two maize/bean seeds 1 cm deep in the pots/cans.
8. Water pots/cans daily.
9. Observe and record germination date, plant height, leaf number and leaf colour for three weeks after germination. Use a table like the one below to record your results.

				Leaf	
Date	Sow	Germinate	Plant height	Number	Colour

10. Take recordings every three days.
11. Compile a report and present it to the whole class for discussion.

Activity 2 — Effects Of Land-Use Systems On Soil Properties

Materials needed:
Year10 Book One.

Aim: To investigate the effects of land-use systems on soil properties.

1. Divide the class into groups of four or five.
2. Each group will select two or more land-use systems.
3. Read the notes on cropping systems and comment on how each system can affect the properties of a soil.

Soil properties	Land-use system	
Chemical — pH, CEC		
Physical — structure, texture, colour, porosity, bulk density		
Biological — soil organisms		

4. Each group presents their table to the whole class for discussion.

Activity 3 — Finding Out The Soil Texture Of The School Garden

Materials needed:
Spades;
Plastic bags;
Cylinders (500 ml);
Bucket;
Magnifying lens.

Aim: To determine the texture of a soil.

1. Divide into groups of four or five.
2. Collect soil sample from the school garden using a ‘Z’ pattern. Collect nine subsamples.
3. Mix the soil samples together.
4. Fill an empty cylinder half full with soil.
5. Add water to fill the cylinder.
6. Shake the cylinder for 1–3 minutes.
7. Leave the solution to settle overnight.
8. Observe and record the level of sand, silt and clay in the cylinder.
9. Calculate the percentage of sand, silt and clay.
10. Determine the soil type using the textural triangle.

Activity 4 Looking At Soil Structure And Consistency

Materials needed:
Soil;
Sand;
Magnifying glass.

Aim To determine the structure and consistency of the school garden soil.

1. Collect some soil from the school garden.
2. Use the magnifying glass to observe the structure of your soil.
3. Draw the soil structure in your exercise book.
4. Compare your soil structure with the soil structure diagrams given in this unit.
5. What structure does your soil belong too?
6. Add some water to the soil and feel how sticky the soil is. Do the same with the sandy soil. Which soil type has a higher consistency (more sticky)?

Activity 5 Looking At Soil Organisms

Materials needed:
Blotting paper;
Saucer or petri dish;
Sugar solution;
Soil.

Aim To determine organisms in soil.

1. Place some blotting paper in a saucer or petri dish and pour some sugar solution over the blotting paper to moisten it.
2. Sprinkle a very small amount of soil over the paper and cover the dish and leave it for several days.
3. What signs of soil organisms can you see?
4. Collect a soil sample from the school garden.
5. List down the soil organisms you find.

Activity 6 Soil Colour And Plant Growth

Materials Needed:
3 pots/cans;
Sample each of black, brown and red soil;
6 maize or bean seeds.

Aim To determine which soil colour plants grow best in.

1. Fill each pot/can half full of black, red and brown soil.
2. Label each pot/can.
3. Sow two maize or bean seeds 1 cm deep in each pot/can.
4. Water the pots/cans and observe the growth of the plants.
5. Record the day of sowing, germination, plant height, leaf number and leaf colour.
6. Record growth once a week for four weeks after germination. Use a table like the one over the page to record your results.
7. Which soil did the maize/bean seeds grow well in?

Date	Soil colour	Sow	Germinate	Plant height	Leaf	
					Number	Colour
Week 1	Red					
	Brown					
	Black					
Week 2	Red					
	Brown					
	Black					
Week 3	Red					
	Brown					
	Black					
Week 4	Red					
	Brown					
	Black					

Activity 7 Porosity And Bulk Density

Materials needed:
Soil;
Water;
Heavy object;
2 beakers.

Aim To find out the effects of compaction on porosity and bulk density.

1. Divide into groups of three or four.
2. Fill the beakers with soil.
3. Use a heavy object to push down the soil in one of the beakers.
4. Pour water into the compacted soil first and record the time it takes for the water to travel from the top to the bottom of the beaker.
5. Do the same with soil that was not compacted using the same volume of water.
6. Discuss and compare the results.
7. Which soil has a higher bulk density?
8. What happens to the structure of the soil when it is compacted?
9. What effect does compact soil have on production?

Review

1. Do you agree with the statement below? Write down reasons for your answer.

   Soil colour is an important way to recognise many important soil properties. It is an indirect measure.

2. Write down three important characteristics that are indicated by soil colour.
3. Why are soil organisms important?
4. How can you improve the soil structure of the school garden?
5. How can you improve the soil texture of the school garden?
6. Is it easier to dig soil when it is dry or wet?
7. Plants grow well only in a certain pH range. How can farmers make sure plants grow in the right soil pH?
8. Find out the bulk density and porosity of a compacted soil.
9. What are some causes of soil compaction in crop and animal farming?

Unit 4: ORGANIC FARMING

About this unit
In this unit you will carry out in groups a short investigation on a management practice that is used in organic farming. You will write a report using a given format and present it to the class for discussion.

Frequently Asked Questions About Organic Farming

What is organic farming?
Organic farming refers to agricultural production systems used to produce food and fibre. All kinds of agricultural products are produced organically, including produce, grains, meat, dairy, eggs, fibres such as cotton, flowers, and processed food products. Organic farming management relies on developing biological diversity in the field to disrupt habitats for pest organisms, and the purposeful maintenance and replenishment of soil fertility. Organic farmers are not allowed to use synthetic pesticides or fertilisers. Some of the essential characteristics of organic systems include: design and implementation of an 'organic system plan' that describes the practices used in producing crops and livestock products; a detailed record-keeping system that tracks all products from the field to point of sale; and maintenance of buffer zones to prevent inadvertent contamination from adjacent conventional fields.

What does certified organic mean?
Certified organic refers to agricultural products that have been grown and processed according to uniform standards, verified by independent state or private organisations accredited by the US Department of Agriculture. All products sold as 'organic' must be certified. Certification includes annual submission of an organic system plan and inspection of farm fields and processing facilities. Inspectors verify that organic practices such as long-term soil management, buffering between organic farms and neighbouring conventional farms, and record keeping are being followed. Processing inspections include review of the facility's cleaning and pest-control methods, ingredient transportation and storage, and record-keeping and audit control. Organic foods are minimally processed to maintain the integrity of food without artificial ingredients or preservatives. To be certified organic requires the rejection of synthetic agrochemicals, irradiation and genetically-engineered foods or ingredients.

Is organic food more nutritious than conventional food?
The definitive study has not been done, mainly because of the multitude of variables involved in making a fair comparison between organically-grown and

conventionally-grown food. These include crop variety, time after harvest, post-harvest handling, and even soil type and climate, which can have significant effects on nutritional quality. A 2002 report indicates that organic food is far less likely to contain pesticide residues than conventional food (13% of organic produce samples versus 71% of conventional produce samples contained a pesticide residue, when long-banned persistent pesticides were excluded).

Is organic food safe?

Yes. Organic food is as safe to consume as any other kind of food. As previously cited, organic produce contains significantly lower levels of pesticide residues than conventional produce. It is a common misconception that organic food could be at greater risk of *E. coli* contamination because of raw manure application although conventional farmers commonly apply tonnes of raw manure with no regulation whatsoever. Organic standards set strict guidelines on manure use in organic farming: either it must be first composted, or it must be applied at least 90 days before harvest, which allows ample time for microbial breakdown of any pathogens.

Is organic food really a significant industry?

In the USA about two per cent of the food supply is grown using organic methods. Over the past decade, sales of organic products have shown an annual increase of at least 20 per cent, the fastest growing sector of agriculture. In 2001, retail sales of organic food were projected to be $9.3 billion (*Organic Consumer Trends 2001.* Published by the Natural Marketing Institute, in partnership with the Organic Trade Association). Organic food is also gaining international acceptance, with nations such as Japan and Germany becoming important international organic food markets.

Why does organic cost more?

The cost of organic food is higher than that of conventional food because the organic price tag more closely reflects the true cost of growing the food. In conventional growing, labour and intensive management is replaced by chemicals, the health and environmental costs of which are borne by society. These costs include the clean-up of polluted water and pesticide contamination. Organically produced foods must meet stricter regulations governing growing, harvesting, transportation, storage and packaging, than conventional foods. The intensive management and labour used in organic production are frequently (though not always) more expensive than the chemicals routinely used on conventional farms. There is mounting evidence that if all the indirect costs of conventional food production were factored into the price of food, organic foods would cost the same as or, more likely, be cheaper than conventional food.

Are organic yields lower?

Analysis of 154 growing seasons' worth of data on various crops, showed that organic crops yielded 95 per cent of crops grown under conventional, high-input conditions (Liebhardt, B. *Get the facts straight: organic agriculture yields are good*. OFRF Information Bulletin #10, Summer). This was by using best organic farming methods. Growers who go through the three-year transition period from conventional to organic management usually experience an initial decrease in yields, until soil microbes are re-established and nutrient cycling is in place, at which point yields return to previous levels.

How do organic farmers fertilise crops? How do they control pests, diseases, and weeds?

Organic farmers build healthy soils by nourishing the living component of the soil, the microbial inhabitants that release, transform, and transfer nutrients. The organic matter in soil contributes to good soil structure and water-holding capacity. Organic farmers feed soil and build soil organic matter with cover crops, compost and biologically-based soil amendments. These produce healthy plants that are better able to resist disease and insect predation. Organic farmers use cover crops and sophisticated crop rotations to change the field ecology, effectively disrupting the habitat for weeds, insects and disease organisms. Weeds are controlled through crop rotation, mechanical tillage, and hand-weeding, as well as through cover crops, mulches, flame weeding and other management methods. Organic farmers rely on a diverse population of soil organisms, beneficial insects and birds to keep pests in check. When pest populations get out of balance, growers implement a variety of strategies such as the use of insect predators, mating disruption, traps and barriers. Under the National Organic Rule, growers are required to use sanitation and cultural practices first before they can resort to applying a material to control a weed, pest or disease problem. Use of these materials in organic production is regulated, strictly monitored and documented. As a last resort, certain botanical or other non-synthetic pesticides may be applied.

How are organic livestock and poultry raised?
Organic meat, dairy products, and eggs are produced from animals that are fed organic feed and allowed access to the outdoors. They must be kept in living conditions that accommodate the natural behaviour of the animals. Ruminants must have access to pasture. Organic livestock and poultry may not be given antibiotics, hormones, or medications in the absence of illness; however, they may be vaccinated against disease. Pesticide use is strictly regulated. Livestock diseases and parasites are controlled primarily through preventative measures such as rotational grazing, balanced diet, sanitary housing and stress reduction.

Organic Matter

Organic matter is the name given to the dead plant and animal materials in the soil which are in the process of being decomposed. The amount of organic matter in soils vary a great deal. Average soils may contain three per cent of organic matter, but sandy soils may have only one per cent and black basaltic loams may have six per cent. Peaty soils may have nearly 100 per cent organic matter. Any soil containing more than 20 per cent organic matter is called an organic soil.

Most organic material in the soil has come from the decay of plant material, especially roots, leaves, stems, flower parts and seed coats. The dense masses of fibrous roots of grasses and dead grass leaves are especially important in adding organic matter to the soil.

Organic matter may be in any stage of decomposition. Some of it will consist of plant parts which have not yet suffered much outward change. Leaves, for instance, may still have their original shape and thickness. Within a short time the pectins cementing the cells together are attacked and decomposed. Shortly afterwards most of the contents of the cells are decomposed by soil organisms. What remains is then a skeleton of the proteins and lignins. These decompose slowly. Eventually even this plant skeleton is attacked and the plant leaf or root then crumbles into small particles, become dark in colour, and form a finely divided powder called soil humus. Enormous numbers of bacterial and fungal cells also die off and become converted into soil humus.

As humus is decomposed slowly by soil organisms, nutrients are released from it. Many of these nutrients will be used as food by the soil organisms, but some of them will be used by the roots of crop plants.

Advantages of organic matter

The chief advantage of soil organic matter is that it serves as a supply of nutrients for crop and pasture plants.

Organic matter has an important effect on the physical nature of the soil. Since it contains bacteria that have gummy coatings on their cell walls, and since organic matter itself becomes colloidal and sticky, it helps to cement soil particles together to form good structure.

Organic matter is also able to absorb soluble nutrients from the soil and prevent them from being washed out of the soil or leached by heavy rain. Since it contains colloidal material which absorbs water, organic matter increases the water holding capacity of soils, especially sandy soils.

Loss of organic matter

A buried leaf passes through many stages of decomposition before it finally becomes humus. The humus also decomposes slowly and in time there is no trace whatever of the original leaf. It is easy to see that unless fresh organic matter is added to the soil, it will eventually disappear.

In nature, as organic matter is decomposed, more is continually being added by plants growing in the soil. The rate of gain and loss is balanced in any particular climate.

If a soil is ploughed up, this operation allows large supplies of air to enter the soil. This stimulates the soil organisms to rapidly grow and they decompose organic matter at an increased rate. Therefore, cultivation is the most important cause of loss of organic matter from soils. It has been discovered that the loss of organic matter through cultivation is rapid at first, but becomes less as time goes on. This is because part of the organic matter is very resistant to decomposition and lasts a long time in the soil.

Over-cropping without pasture rotation causes loss of organic matter, especially if the crop material is removed altogether as hay. The burning of crop residues means that nothing is being added to the soil to take the place of the organic matter used up in growing the crop.

The loss of organic matter from soil is greater with high soil temperatures. That is why soils of cool temperate regions usually have greater amounts of organic matter than soils of hot tropical regions.

Gaining organic matter

In market gardens it is usual to spread animal manure thickly over the soil and to dig it into the ground. Production of vegetables reduces if this practice is not maintained.

One way farmers try to add organic matter to soil is by manure from grazing animals. However, under a hot sun, sheep dung dries up quickly and may later float away with surface rainwater or be powdered and blown away by the wind. Similarly, cow manure is usually left as hard 'cow pats' and these often remain on the surface of the soil.

In cultivated lands the practice of green manuring results in organic matter being added to the soil. If the crop is ploughed under when still young and juicy, the soft tissues rapidly decay and a flood of nutrients is made available in a short time. However, almost all the good effects of this green manure will have disappeared in a short time. If the green manure crop is ploughed under when it is mature, lignins will have formed over the cell walls. Since lignins decompose slowly, the organic matter added to the soil in this way lasts much longer. However, there will be no quick release of nutrients to benefit a quick-growing crop sown soon after plouging. When land has been under cultivation for some time, the organic matter can be replaced by sowing a pasture. The pasture plants will quickly add organic matter to the soil, but a point will soon be reached when there will be no further increase. At this time the pasture should be ploughed up and organic matter be added to the soil. Crops must be planted soon after the green manure is ploughed in if they are to benefit from the added organic matter. It has been shown that the benefits of growing lucerne on wheat lands have disappeared after four years.

We know that legumes are plants with bodies rich in nitrogen. When a leguminous plant is buried under the soil, the benefit to the soil is greater than if grasses were buried. Therefore, whether we add organic matter to the soil by green manuring or by ploughing a pasture, we should use legumes of one kind or another.

Activity 1 Testing Organic Matter

Materials needed:
Test tubes;
Garden soil;
Dried leaves;
Bunsen burner;
Seeds;
Pots;
Sodium hydroxide;
Calcium oxide.

Aim To find out more about organic matter.

1. Heat some garden soil in a test tube. Water is given off first. If the colour then changes to black, this is due to the charring of the organic matter.
2. To show that organic matter contains nitrogen, put some dried leaves in a mortar. Grind them up with a mixture of sodium hydroxide and calcium oxide. Heat strongly in a dry test tube. Carefully smell the gas given off. What is the gas, and what does its presence tell you about the composition of organic matter?

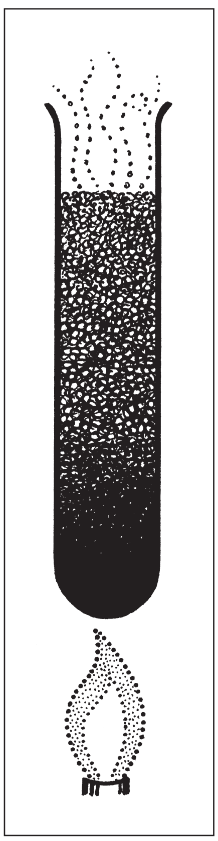


Figure 4.1
Water vapour escaping from heated soil.

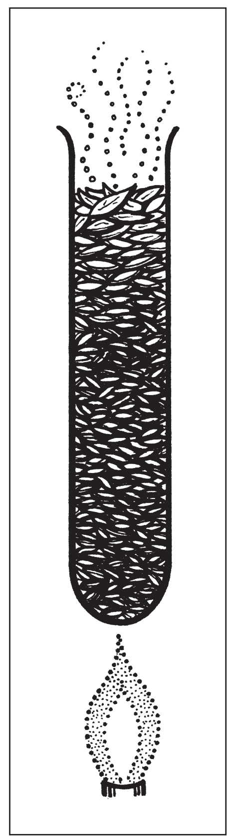


Figure 4.2
Testing for nitrogen in organic matter.

3. Prepare two pots of soil. Dig old plant material or stubble into one, and leave the other untouched. Plant maize or cabbage seeds in both pots and compare the growth of the plants for four weeks after germination. Do not use legume seeds. Record your results in a table similar to the one on the next page.

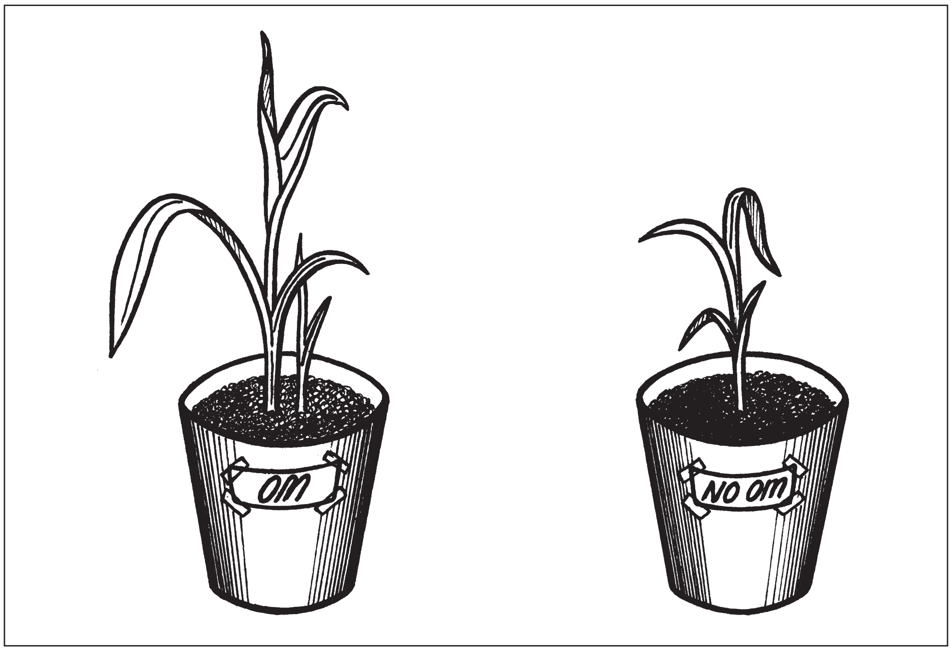


Figure 4.3
Observing the effects of organic material on plant growth.

Date	Growth	Pot		Comments
		Organic matter added	No organic matter added	
Week 1	Leaf colour			
	Leaf size			
	Number of leaves			
	Length of plant			
Week 2	Leaf colour			
	Leaf size			
	Number of leaves			
	Length of plant			
Week 3	Leaf colour			
	Leaf size			
	Number of leaves			
	Length of plant			
Week 4	Leaf colour			
	Leaf size			
	Number of leaves			
	Length of plant			

Activity 2 Short Investigation

Aim To investigate management practices used in organic farming.

1. Divide into groups of three.
2. Choose a topic on organic farming. Each group should work on a different topic. The topics can include: fertilisers; soil building or improving; crop rotation; post-harvest handling; pest control; disease control; weed control; mulching; composting; intercropping; interplanting; organic matter; marketing and any other relevant topics.
3. Find all the information you can about your topic from the Agriculture Department, USP School of Agriculture Alafua, public library, farmers and the internet.
4. Write a report on your topic using the following headings: title or topic; introduction; methodology; body; conclusion; recommendations and bibliography.
5. Present your report to the class for discussion.

Review

1. Define the terms ‘organic farming’ and ‘organic matter’.
2. What are the advantages of organic farming?
3. What are the disadvantages of organic farming?
4. What kind of fertilisers are used in organic farming?

Unit 5: CLASSIFICATION OF CROP PLANTS

About this unit
In this unit you will be collecting, identifying and classifying crop plants into their groups. You will also compare features of monocotyledonous and dicotyledonous crop plants. Both these activities will be done in groups. You will discuss and share your work with other group members.

Introduction
Plants can be classified in a number of ways. These ways separate into two main types:

- Those based on one or a small number of characters: *e.g. Flower colour, use by people*. This type of classification is often termed phenetic or artificial classification, and was the basis of the earliest attempts at classifying plants. Classifying crop plants phenetically has its uses in agriculture, particularly for economic, sociological or land use studies. We will not consider this type of classification any further in this course because it has very little place in plant biology or crop study.
- Those based on the correlation of a large number of characters. This type of classification is often termed phylogenetic or natural classification. It is the most widely used type of plant classification in plant biology or crop agriculture and is subject to change as a result of new discoveries. In a natural classification system, the basic assumption is that plants with the highest number of common characters are the most closely related.

Natural Classification Of Plants

Although no two plants are ever exactly alike, the different individuals belonging to one species usually have so many points of resemblance that it is impossible to doubt their genetic relationships. As well as having many morphological similarities, individuals of a species produce fertile offspring.

The species is the basic unit of classification. Different species of plants having many common features are grouped together in a genus (plural = genera). Both the genus and species names (also called scientific names) of a plant are given in the Latin language. This practice of binomial naming (i.e. Using two words in the scientific name) has long been accepted for ease of universal understanding. For example, there are several species of plant with the genus *Cucurbita*. Some of these species are as follows:

- *maxima* — pumkin, winter or buttercup squash (fruit are round in section).
- *pepo* — summer squash, marrow, zucchini, courgette (fruit are elliptical in section).
- *moschata* — butternut squash (fruit are bell shaped in section).

All plants are named by their genetic (genus) and specific (species) names by convention.The above plants would be named (note italics) as follows if they were written separately — *Cucurbita maxima, Cucurbita pepo, Cucurbita moschata,* or as follows if they were written together *Cucurbita maxima, C. pepo, C. moschata*. It should be noted that some genera have only one species but others have many species.

The scientific (genus and species) name of a crop, along with a detailed description of the distinguishing morphological features ensure that there is no chance of mistaking the identity of a particular crop plant. Detailed descriptions appear in taxonomy or crop botany textbooks.

Among all plants, similar genera are grouped together and classified as families. Understanding and knowing the families of crop plants is important in agriculture, particularly for crop science, but also in weed science and for animal and human nutrition. The important reasons for understanding and knowing about families of crop plants include:

- Crop plants (and possibly more importantly, weed plants) of the same family are likely to respond in the same way to herbicides and other agricultural chemicals.
- Crop plants of the same family have similar demands for particular nutrients.
- Crop plants of the same family are likely to be infected by the same pests and diseases.
- Methods of plant breeding are likely to be the same for crops of the same family.

Larger Grouping Of Plants

Plants and indeed other living things, can be put into larger and larger groups above the basic species level. The numbers in each group decrease from the top down. All plants belong to one kingdom — the plant kingdom. Important segments of large groupings of the plant kingdom relating to crop plants are:

Kingdom	*Plant*.
Sub-Kingdom	*Vascular plants:* i.e. plants with specialised conducting tissues: *e.g. Veins in leaves*. Note that there are other sub-kingdoms of plants: *e.g. Mosses and liverworts*.
Division (of vascular plant)	*Spermatophyta* — seed plants. Note that there are other divisions of vascular plants: *Pteridophyta* — fern plants. *Sphenophyta* — horse tails. *Lycophyta* — club mosses. *Psilophyta* — plants with no leaves.

Classes (of *Spermatophyta*)	*Angiospermae* — flowering plants with enclosed seeds. *Gymnospermae* — cone plant with naked seeds.

The groups continue to be broken down through *Sub-Class*, *Order*, *Family* and *Genus* to *Species* which is the smallest basic unit.

The next topic is perhaps of more interest to agriculturists since it deals with the classification of crop plants. It is essential that we have an understanding of the classification of crops and knowledge of the families and scientific names of crop plants in order to be able to provide the most appropriate production methods for these crops.

Classification Of Crop Plants

Nearly all crop plants are members of the class *angiospermae* (flowering plants). This class of plants has two sub-classes: *dicotyledonae* and *monocotyledonae*. (Note that some fungi [not members of the plant kingdom] such as mushrooms are also grown as crop plants.)

To understand the taxonomy of crop plants we should consider the major differences between dicotyledonous and monocotyledonous plants. In both sub-classes there are many orders in the next layer down of classification.

The names of families and genera within families of crop plants are generally agreed upon by authorities on crop plant classification. There is, however, some argument among pure botanists, and inconsistency between textbooks, as to which families are advanced from an evolutionary point of view, regarding the names of the orders and, in some cases, the families within the orders. The arguments do not, however, have much relevance to tropical crop agriculturists, who are generally concerned with crop values and characters of only about 25 of the over 200 families of flowering plants.

Dicotyledonous Plants

The most important families of dicotyledonous plants (with a few representative crops of each) include the following:

Family	**Representative(s)**
Anacardiaceae	*Mangifera indica* (mango).
Caricaceae	*Carica papaya* (pawpaw).
Convolvulaceae	*Ipomoea batatus* (sweet potato); *I. aquatica*.
Cruciferae	*Brassica chinensis* (Chinese cabbage); *B. oleracea* (head cabbage).
Cucurbitaceae	*Cucurbita maxima* (pumpkin); *C. pepo* (marrow); *C. moschata*. (butternut squash).
	Cucumis melo (melon); *C. sativa* (cucumber).
	Citrillus lanatus (watermelon).
Euphorbiaceae	*Manihot esculenta* (cassava).
Leguminosae	*Phaseolus vulgaris* (common bean).
	Arachis hypogaea (peanut).

Moraceae	*Artocarpus altilis* (breadfruit).
Myrtaceae	*Psidium guajava* (guava).
Passifloraceae	*Passiflora edulis* (passionfruit).
Rubiaceae	*Coffea* spp. (coffee).
Rutaceae	*Citrus aurantifolia* (lime).
Solanaceae	*Solanum melongena* (eggplant); *S. tuberosum* (Irish potato).
	Capsium annuum (sweet pepper).
	Lycopersicon escelenta (tomato).
Sterculaceaae	*Theobroma cacao* (cocoa).
Theaceae	*Camellia sinensis* (tea).

Monocotyledonous Plants

The most important families of monocotyledonous plants (with a few representative crops of each) include the following:

Family	**Representative(s)**
Araceae	*Alocasia macrorrhize* (giant taro); *Cytosperma chamissions* (swamp taro); *Xanthosoma saggittifolium* (tannia); *Colocasia esculenta* (common taro).
Arecaceae	*Cocos nucifera* (coconut palm).
Bromeliaceae	*Anonas coscosus* (pineapple).
Dioscoreaceae	*Dioscorea alata* (greater yam); also other yam species: *D. bulbifea*, *D. nummlaria*, *D.esculenta*, *D. hispida*, *D. trifida*, *D. opposita*, *D.pentaphylla*, *D. dumetorum*.
Gramineae	*Oryza sativa* (rice).
	Zea mays (maize, sweetcorn).
	Saccharum officinarum (sugarcane).
Liliaceae	*Allium cepa* (bulb onion); *A. fistulosum* (spring onion).
Musaceae	*Musa* spp. (banana).
Orchidaceae	*Vanilla fragrans* (vanilla).
Zingiberaceae	*Zingiber officale* (ginger).

Notes:

1. Some generic names are very similar to family names, such as: *Musa, Zinigiber.* Such genera are 'type' genera for families.
2. The use of 'spp.' is used where many species may be involved — some of these may be un-named.

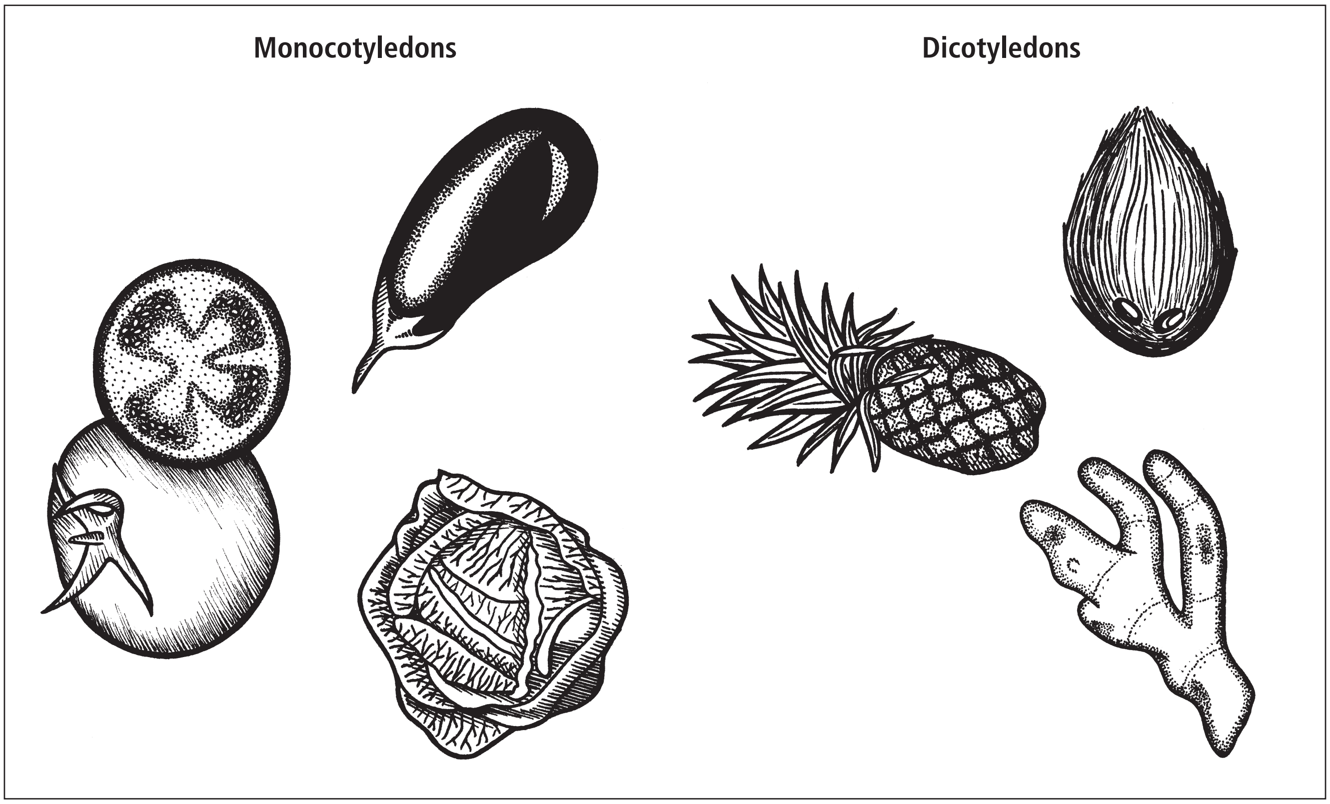


Figure 5.1
Monocotyledonous crops and dicotyledonous crops.

Activity 1 Classification Of Crop Plants

Materials needed:
3 crop plants.

Aim Grouping plants.

1. Divide into groups of three.
2. Go into the school compound and garden and collect three different crop plants. Observe the plants, discuss and classify the plants by using the table below (refer to the background information for hints).

	Crop Plant		
Classification	**1.**	**2.**	**3.**
Kingdom			
Division			
Class			
Family			
Genus			
Species			

3. Present your table to the class for discussion.

Activity 3 Comparing Dicotyledons And Monocotyledons

Materials needed:
Dicotyledonous and monocotyledonous plants (with roots and seeds);
Magnifying glass.

Aim To compare and contrast the features of dicotyledonous and monocotyledonous plants.

1. Divide into groups of two or three.
2. Collect a whole (with roots and seeds) dicotyledonous plant (pawpaw, eggplant, cocoa, green pepper, cabbage) and a whole monocotyledonous plant (pineapple, ginger, maize, taro, banana).
3. Observe, discuss and record the differences between the two plants.
4. Record your observations in a table like the one below:

Part of plant	Dicotyledonous	Monocotyledonous
Root		
Stem		
Leaf		
Flower		
Seed		

5. Discuss your table with another group and let them critique or comment on your work.

Review

1. Do you agree that classification of objects, including plants and animals, into groups is necessary? If you do, explain why. If you do not agree, give reasons to support your view.
2. Why do you think that knowing and understanding crop plant families is important to agriculturalists?
3. What are the major differences between dicotyledonous and monocotyledonous plants?

Unit 6: GROWING AND MANAGING CROPS

About this unit
In this unit you will be required to plan a planting programme. You will also plant, manage and handle eggplants, green peppers, peanuts and watermelon, as well as assist in the growing and management of cocoa, pineapple and pawpaw. You will also investigate plant production in controlled conditions and compare the development of seeds and fruit.

Plant Information

Eggplant (*Solanum melongena* var. *esculentum*)

Figure 6.1
Eggplant with fruit.

Recommended varieties: Chahat; Sigatoka Beauty; Sitara.

Expected yield: 7–10 tonnes/hectare.

Planting time: All year round.

Plant spacing: 60 cm between rows; 60 cm within rows.

Seed rate: 300 g/hectare.

Soil requirements: Well structured, deep alluvial or volcanic loam or sandy loam on river flats.

Method of planting: Transplanting.

Fertiliser requirements: NPK — 200 kg/hectare (apply one week after planting).
Urea — 100 kg/hectare (apply 4–6 weeks after planting).

Plant protection: Weed control — spray with Gramoxone (45 ml in 14 litres of water).
Insect control — spray with orthene or diazinon.
Disease (damping of seedling) — plant seedling in well-drained soils.

Time to maturity: 60 to 90 days.

Harvesting and storage: Pick fruit when still tender, in mature stage.

Capsicum or green pepper (*Capsicum frutescens*)

Recommended varieties: Yolo Wonder B; Yolo Wonder Y; Hybrid new Ace; Hybrid Ace.

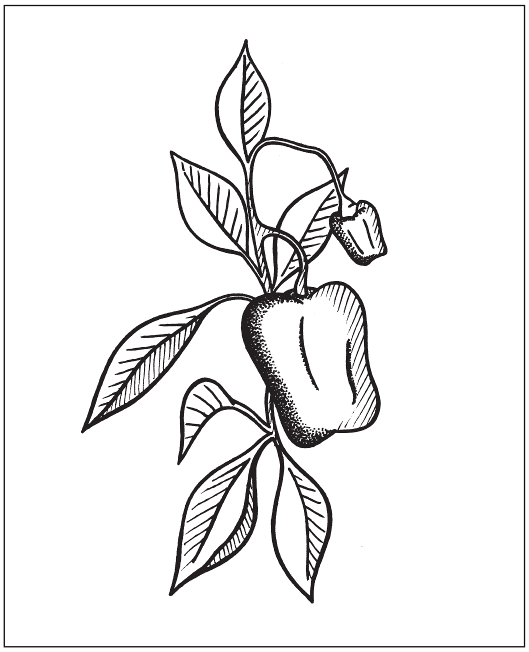


Figure 6.2
Capsicum (green pepper).

Expected yield: 8–10 tonnes/hectare.

Planting time: April–September (may be grown during wet season —needs special care).

Plant spacing: 45 cm between rows; 45 cm within rows.

Seed rate: 300–350 g/hectare.

Soil requirements: Prefers well-structured deep loam with a lot of organic matter.

Method of planting: Transplanting seedlings.

Fertiliser requirements: Basal poultry manure — 2.5–5 tonnes/hectare.
NPK (13:13:13) — 200 kg/hectare.
Urea — 100 kg/hectare applied before flowering.

Plant protection: Weed control — hand-weeding or hoeing.
Insect control (caterpillars, cutworms and birds) — spray with Ambush or orthene.
Disease (rust angular leaf sport, stem rot, soft rot) — use Mancozeb. (Bacteria wilt) — use resistant varieties.

Time to maturity: 3 to 5 months.

Harvesting and storage: Pick when still green or start turning red in colour.

Peanuts (*Arachis hypoqaea*)

Recommended varieties: Local Spanish; Tonga S.

Expected yield: 1.0–1.5 tonnes/hectare.

Planting time: February to April.

Plant spacing: 30 cm between rows; 30 cm within rows.

Seed rate (unshelled): Local Spanish — 126 kg/hectare;
Tonga S. — 228 kg/hectare.

Soil requirements: Prefers loose sandy loam soils.

Method of planting: Direct sowing.

Fertiliser requirements: Single superphosphate — 400 kg/hectare.
Murate of Potash — 100 kg/hectare.

Plant protection: Weed control (pre-emergence, ronstar) — hand or mechanical weeding before pegging stage.
Insect control (spotted bean borer and leaf hopper) — use orthene or lannate.
Disease (peanut rust) — use Mancozeb and Benlate when rust pustules appear on lower leaves at fortnightly intervals.

Time to maturity: 115 to 125 days.

Harvesting and storage: Matures when black lines form on the inside of the pods. Avoid harvesting during wet weather. After the plants are uprooted, remove the pods after a short period of drying. For planting — store unshelled pods.

Watermelon (*Citrullus vulgaris* var. *lanatus*)

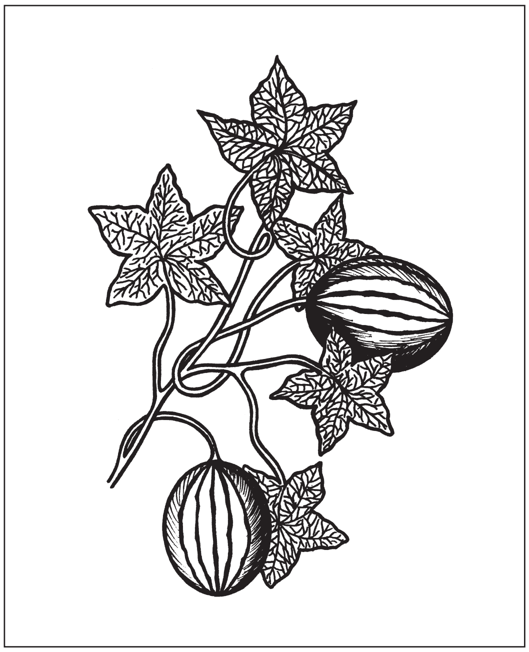


Figure 6.3
Watermelon plant and fruit.

Recommended varieties: Chaleston Gray; Sugar Baby; Beauty Venus; Sugar.

Expected yield: 15–20 tonne/hectare.

Planting time: October to December.

Plant spacing: 150 cm between rows; 30 cm within rows; up to 21 000 plants per hectare.

Seed rate: 3 kg/hectare.

Soil requirements: Prefers fertile alluvial soil with high organic matter.

Method of planting: Direct sowing.

Fertiliser requirements: NPK (2:7:1) — 250 kg/hectare. Poultry manure — 5 tonnes/hectare. Apply poultry manure by working into the soil before planting. Top dress with NPK when vines begin to run and first flowers appear (2 split applications).

Plant protection: Weed control — hand-weeding or hoeing.
Insect control (melon aphid) — apply Ambush 5 g in 14 litres of water.
Disease (downy mildew, powdery mildew, gummy stem blight and Anthrachnose) — apply Mancozeb 28.5 g in 14 litres of water.

Time to maturity: 90 to 120 days.

Harvesting and storage: When watermelon is ripe it gives a hollow sound if tapped gently. The etapor at the base of the melon shrivels and dries when ripe. Watermelon will continue to ripen after picking and has a storage life of up to one month if handled carefully. Care in handling is essential to prevent internal bruising, which is not always noticeable from the outside of the fruit. Store in a cool, dry place.

Pawpaw (Papaya) (*Carica papaya*)

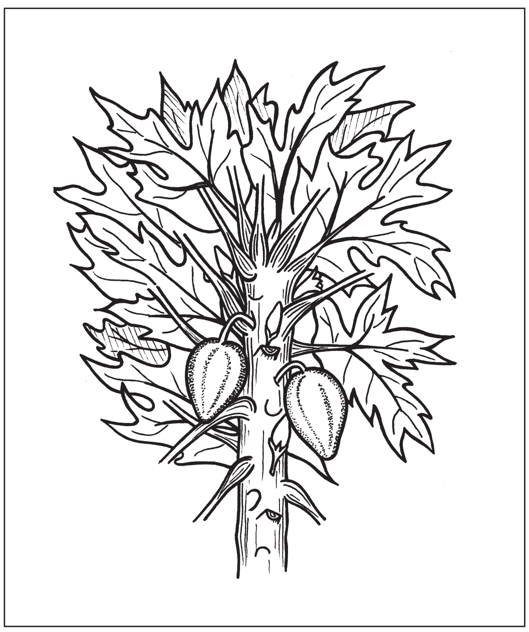


Figure 6.4
Pawpaw plant and fruit.

Recommended varieties: Waimanalo; Sunrise solo; Hawai'ian solo.

Expected yield: 40 tonnes/hectare.

Planting time: All year round.

Plant spacing: 3 m between rows; 2 m within rows; up to 1600 plants per hectare.

Seed rate: 1600 seeds per hectare.

Soil requirements: Prefers well drained, deep soil with good supply of organic matter.

Method of planting: Plant seedlings directly in well prepared soil.

Fertiliser requirements: NPK (2:7:6) 250 kg/hectare. Apply NPK every 3–6 months at the rate of 22 g/plant.

Plant protection: Weed control — hand-weed or spray Paraquat or MSMA or Atrazine Diuron or Glyphosate.
Insect control/disease — no serious pest and disease problems but fruit and corm rot are common in wet areas and poorly drained soil. Control by picking mature fruit and ripen off. Dip after harvest in hot water (166°F) for 20 minutes.

Time to maturity: Nine months before first harvest. Production should continue for 2–3 years, with the second year being the most productive.

Harvesting and storage: Pick before completely ripe (colour starts to show stripes), ripen in dry ventilated conditions. Can harvest fruit from nine months to three years after planting.

Pineapple (*Ananas cosmosus*)

Figure 6.5
Pineapple plant with fruit.

Recommended varieties: Smooth Cayenne; Ripley Queen.

Expected yield: 16 tonnes/hectare.

Planting time: April–May.

Plant spacing: Double staggered rows 120 cm × 60 cm × 30 cm.

Seed rate: 37 000 suckers per hectare.

Soil requirements: Grows on a wide range of soil; essential to have well drained soils.

Method of planting: Suckers are normally planted. Tops can be grown but maturity time is extended.

Fertiliser requirements: Superphosphaste — 250 kg/hectare applied at planting.
Top dress with NPK 13:13:21 — 250 kg/hectare for three applications.

Plant protection: After planting, the following herbicides should be sprayed: Diuron 80 — 4 kg/hectare (85 g/14 litres of water); Krovar — same rate as above. Ploughing in between the double row is preferable for aeration of roots and reducing the amount of chemicals needed, but is not possible after the first year.
Insect control (mealy bugs) — Malathion (28 ml/14 litres of water).
Disease (base rot) — plant during dry weather. Good site drainage will prevent rot.
Rats — control with rat baits as necessary: keep site clear of discarded fruits, etc.

Time to maturity: 9–12 months for slips; 15–18 months for tops.

Harvesting and storage: Properly selected fruits can have a storage life of up to two weeks. Once picked, fruit ripens quickly: better to select fruit according to market demands. Care in handling is essential to prevent bruising.

Cocoa (*Thobroma cacao*)

Figure 6.6
A cocoa plant with fruit. Cocoa trees grow 12–20 m high and 8–10 m in diameter.

Recommended varieties: Amelanado; Trinitario.

Expected yield: Year 4 — 150 kg/hectare; Year 5 — 400 kg/hectare; Year 6 — 650 kg/hectare; Year 7 — 650 kg/hectare.

Climatic requirements: Cocoa grows well in tropical areas with a well distributed rainfall of 1000–2500 mm per year, preferably with 100 mm or more per month and no intense dry seasons.

Planting time: Dry zone mid-September–December; wet zone October–December.

Plant spacing: 2–3 m spacing; 1100 to 2500 plants per hectare.

Seed rate: 50–60 pods for stake planting.

Soil requirements: Prefers deep soil of 1.5 m with good humic layer. Best soils are aggregated clay, loams or sandy loams. Soil to be well drained and well aerated. Optimum pH is around 5. Slope to be less than 15 degrees.

Method of planting: 80 per cent shade should be available where staking plants is to be carried out. Well mix super-phosphate with soil when preparing mounds prior to planting. Include as much of surrounding organic matter as possible in mounds. Plant 2–3 seeds/stake and place seed 5 cm deep in mounds with growing points facing downwards.

Growing Vegetables

Figure 6.7
It is important to know how to plant vegetables correctly.

To grow a good crop it is very important to be able to choose the best available piece of land. Propagate and use strong, healthy seedlings for planting to make sure the young plants start off growing well in the field.

Site Selection

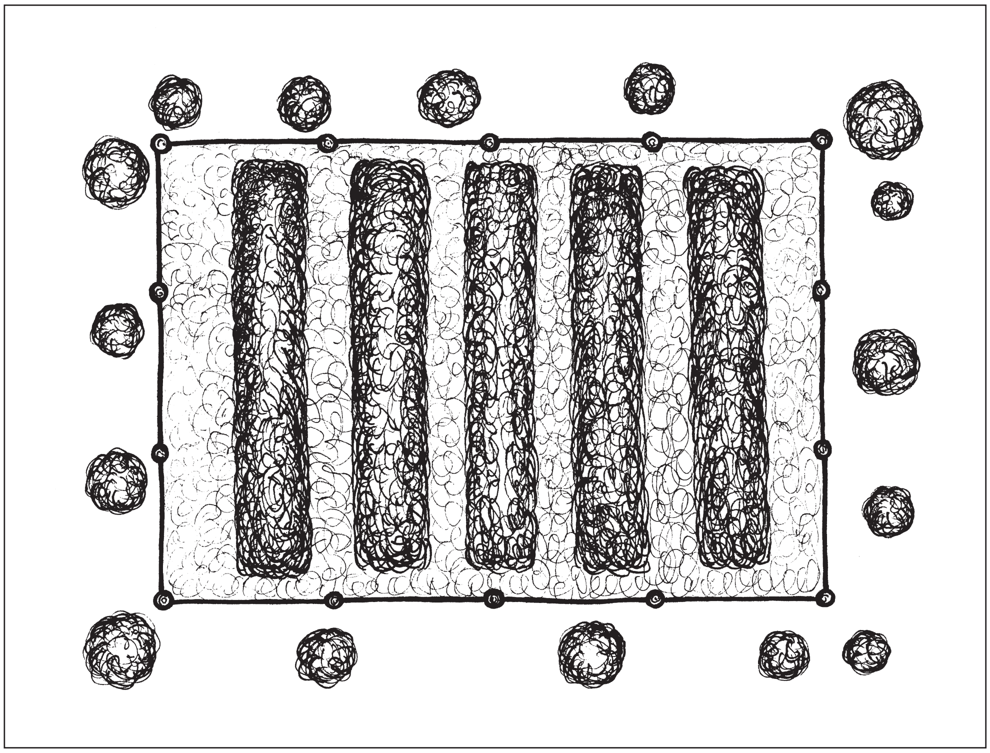


Figure 6.8
A garden site.

Site selection is the process of deciding which is the best area to plant your crops in. If you live in a large country where climatic conditions vary greatly from one region to another, then the site selection process involves two operations. The first part is selecting a region within a country to establish your plantation. The second part is deciding the best land available within that region.

When selecting a region within a country or an area for crop production, it is important to consider the following:

- The climate of the region should meet the climatic requirements of the main crops to be grown on the farm.
- The region should be close to markets or processing facilities.
- The region should not have particular pests nor diseases of the crops you decide to grow.
- Social considerations that may influence the choice of one region over other regions, for example, the availability of cheap labour.

The following factors for site selection are especially relevant and important to small growers in most tropical countries because their farms are most often located within their own districts.

- **Availability of land** — The land must be available for crop production.
- **Soil** — Choose a site with good soil or choose land with soil that has the potential for improvement over time. If the site is newly cleared forest, soil fertility should be high enough to sustain crop production for two or three years before a farmer moves away (this practice is called shifting cultivation). If the site has been continuously cropped, fertiliser may be added and soil pH must be within an acceptable range for the crops. The soil should also have good structure and texture, and salinity levels must be low.
- **Slope of the land** — Use the flattest land or gently sloping land for crops. Land with a steep slope will later create soil erosion problems.
  If sloping land is to be used, you will have to terrace it.
- The site should be close to a reliable water supply for irrigating during the dry season.

Additional factors to consider are:

- **Proximity** — If your farm is close to your home it will be more secure and you can regularly check on it for crop growth and pests and diseases.
- **Sunlight** — Most crops require full sun for at least six hours of the day for reasonable yields. Your cropping area should, therefore, be away from tall trees and tall buildings. If you cannot avoid planting crops away from shaded areas, the sunniest place should be reserved for fruiting vegetables (*e.g. Tomatoes*, *eggplant*, *peppers*) and the shady areas left for leafy vegetables like cabbage and lettuce.

Land Clearing

Once the site for the garden has been selected and acquired, the next step the farmer should take is clearing the land for planting.

Traditional land clearing
In the traditional setting, land clearing is almost always selective and trees of value are left standing. Trees and shrubs are cut down by axes and saws while the underbrush and small trees are cut down with bush knives. After the vegetation has been cut down, farmers resort to burning to remove debris. In fallowed land and grassland regions, land clearing is less tedious: *e.g. Some areas of Fiji*.

Types of trees which may be left standing
You don't have to clear away all trees. There are some trees that are useful for crop production, for example: any economic trees (coconuts, cocoa, timber); slender upright trees which will serve as live stakes for crops such as yams; very large trees that are spared because of the high cost of labour required to fell them.

Modern land clearing
In modern land clearing, particularly in large operations, bulldozers and other types of heavy equipment are used to push down trees and clear the land. This is a popular type of land clearing in Niue for taro production in virgin forests, but there are many disadvantages to using bulldozers for land clearing. These include: heavy machines cause soil compaction; the soil is deprived of organic matter by machines scraping away surface organic matter and pulling plant roots out of the soil which could have contributed to the soil organic matter; machines use expensive fossil fuel; machine use is limited in swampy areas.

Figure 6.9
Clearing a garden with a rake or knife versus using a tractor.

Tillage And Land Preparation

What is tillage?
Tillage is the preparation of land for crop-bearing.

Why is land preparation (tillage) necessary?
Tillage is practised to create favourable conditions for seed germination, seedling establishment, and subsequent management of the crop.

What are the uses of tillage?

- **Control of weeds** — Often weeds are ploughed under. Ploughing prior to cropping may serve to kill weeds in the field. Tillage between rows of growing crops can be an important weed control method.
- **Seed bed preparation** — Tillage loosens the soil and results in a seed bed suitable for seed germination and the development of young seedlings.
- **Incorporation of organic matter into the soil** — Tillage allows organic material to decompose faster. Incorporating plant residues into the soil improves soil structure.
- **Soil and water conservation** — Tillage breaks up the hard surface of the soil improving water infiltration into the soil. This increases the amount of soil moisture and reduces soil erosion due to excessive run-off.
- **Improvement of the soil's physical conditions** — Tillage breaks up hard pans in the soil.

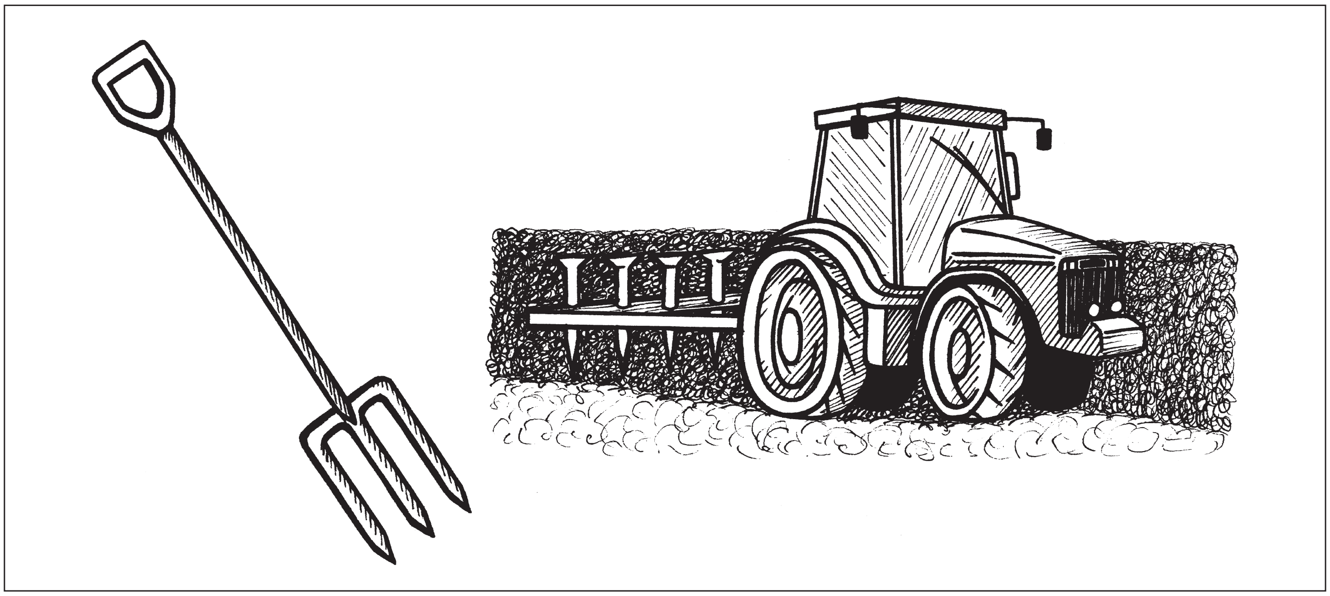


Figure 6.10
Ploughing using traditional methods and modern methods.

Types Of Tillage

- **Ploughing** — This is one of the most ancient and most universal form of tillage. It involves a shear (pulled along by some powered device or animals) slicing its way under the soil, loosening the soil and turning it over. The soil is left in lumps of various sizes and other soil preparation operations may be required to make a suitable seed bed.
- **Harrowing** — If, after ploughing, the soil lumps are still too large they must be broken up by harrowing before planting.
- **Soil collection** — The soil in the field is often collected in various forms before the crop is sown, so that some parts of the field are raised. The three most common forms of soil collection in the tropics are mounding, ridging and bed-making. Soil collection may be done without ploughing or after ploughing and harrowing.
- **Intertillage** — This involves tilling the areas between crop rows to control weeds.
- **Zonal or strip tillage** — Only the planting row is tilled and the inter-row maintained under mulch cover.

Types Of Soil Collections

- **Mounding** — This involves the collection of soil into more or less conical heaps or mounds.
- **Ridging** — This involves the collection of soil into elongated heaps called ridges.
- **Bed-making** — A bed is like a ridge in that it is an elongated portion of the field, but much wider than a ridge. Beds are more often encountered in horticultural and nursery practices than in field crop production. The most convenient bed width is one metre — this makes it easy to reach to the middle of the bed for weeding and so on, and means the grower does not need to walk on the bed.

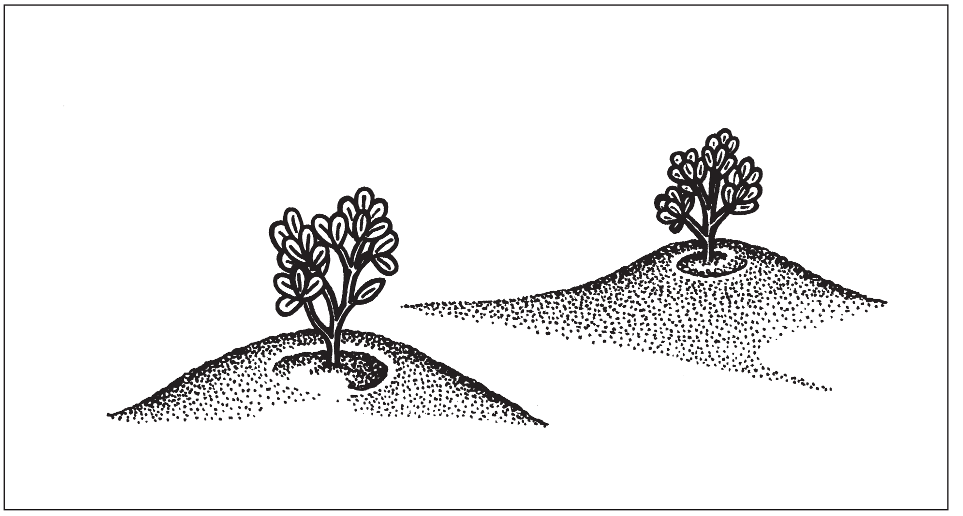


Figure 6.11
Growing plants on soil mounds.

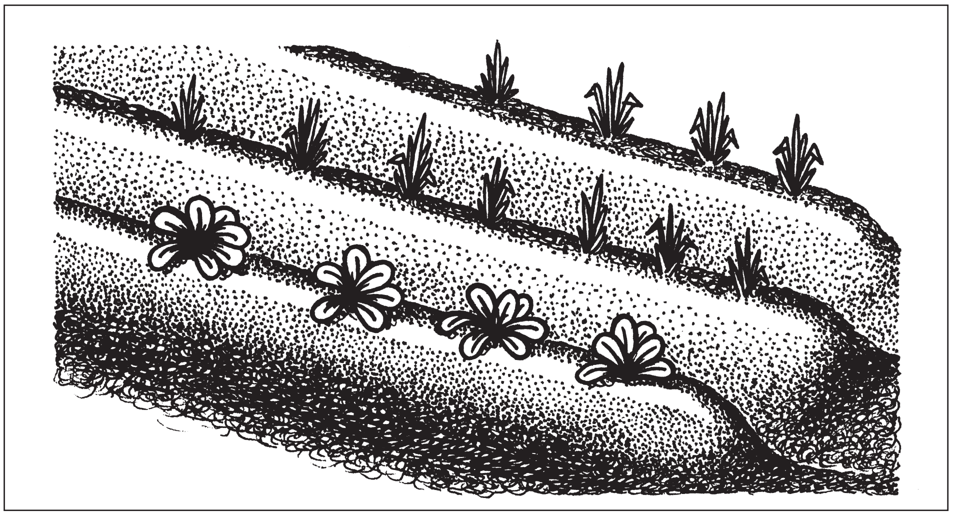


Figure 6.12
Growing plants on soil ridges.

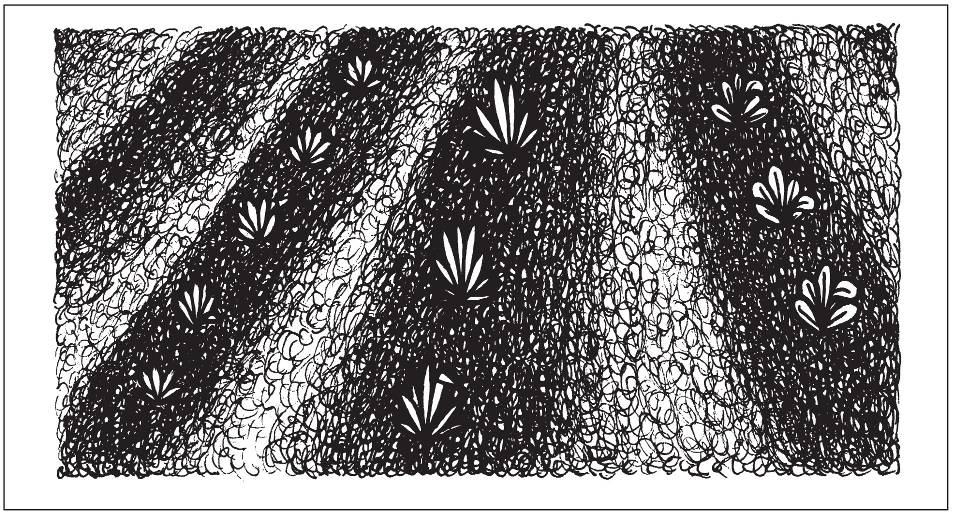


Figure 6.13
Growing plants in soil beds.

Advantages of soil collection

- Provides a deep, loose bed which is particularly suitable for the development of roots and tubers.
- Protects plants from water-logging conditions by elevating the seedbed and plant roots above the water table, particularly in fields with high water tables.
- Provides a variety of seedbed types on the same field, which may be advantageous to intercropping.

Grading And Terracing

Grading and terracing are two ways in which you can prepare the land. Both aim to have an effect on the land's gross topography. Grading is most commonly done if you intend to use any form of surface irrigation. Terracing is one method of managing crop production on land that slopes steeply. It creates a series of relatively flat horizontal portions alternating with vertical portions, very similar to a flight of stairs. It provides erosion control and permits cropping on land that would otherwise have been useless for cropping.

Plant Growth And Environmental Factors

Rainfall

High rainfall areas (greater than 180 mm/year) can be difficult for vegetable production, although some green (*e.g. Amaranthus*) and many tree crops (pawpaw, avocado) do well. The main effect of high rainfall is to encourage the growth of disease organisms. If annual rainfall is less than 1200 mm and the growing season is short, irrigation may be necessary.

Temperature

Temperature is usually the most important factor to consider in deciding what crop to grow in an area because it:

- Influences physiological activities by controlling the rate of reactions.
- Affects flowering and pollen viability and time when fruit sets.
- Affects hormonal balance.
- Affects the rate of maturation and senescence.
- Affects quality, yield and shelf-life of crop produce.
- Affects harvest times.

High temperatures are the main constraint to temperate (cool season) vegetable production in the tropics. There are four approaches to this problem:

1. Plant at higher elevations — there is a 0.6°C decrease in temperature for every 91.5 m rise in elevation.
2. Plant during cool seasons of the year.
3. Select heat-tolerant cultivars.
4. Provide shade — although shade does not have much effect on air temperature, it can decrease soil temperature by 5–6°C. One trial showed that maximum yield for French bean and cucumber was found to be at 20 per cent and 37 per cent shading respectively, but there was no effect on the yield of tomato and sweetcorn at these levels of shading.

There is some variation in heat tolerance among vegetables. Irish potatoes, for example, were originally grown in the cooler part of the high Andes, but are now also grown in highland parts of the tropics.

Some vegetables do best in the cooler seasons of the year, and others which may be adapted to high day temperatures (like some local types of cabbage) prefer a climate where there is a marked difference in temperature between night and day. Such vegetables are most successful when grown at relatively high altitudes above sea level.

For regions around 5° latitude north of the equator, temperate vegetables such as cabbage, garden peas and Irish potatoes are recommended for altitudes higher than 1500 m, while for lowland areas, tropical vegetables such as okra, yam, sweet potatoes and eggplant are recommended. Vegetables equally recommended for both highland and lowland areas are carrots, tomatoes and French beans.

Seed Propagation

Only viable seed should be used for sowing, that is, it must be able to germinate, emerge from the soil and produce a healthy plant. The seeds of most crops will remain viable for a number of years if stored under favourable conditions. Seed in storage can be affected by temperature and moisture. In a tropical environment where it is both hot and humid, the length of time seeds remain viable is often much shorter. So, in the tropics seed should be stored in a cool, dry place such as a refrigerator. Remember that storage temperature is closely related to the moisture content of the seed. In general, the higher the storage temperature the lower the seed's moisture content needs to be. The following table provides you with the estimated maximum safe seed-moisture content for storage for one year at different mean temperatures of storage.

Maximum safe seed-moisture content (%) for average temperature			
Crop	Temperate 4–10°C (refrigerator)	21°C (air conditioning)	Tropical 27°C (ambient)
Bean	15	11	8
Cabbage	9	7	5
Corn	14	10	7
Cucumber	11	9	8
Pepper	10	9	7
Tomato	13	11	9

Life expectancy of some common vegetable seeds under favorable storage conditions:

Crop (seed)	**Number of years viable**
Onion	1
Sweetcorn, Pepper	2
Carrot, Chinese cabbage, Tomato	3
Eggplant, Cabbage, Pumpkin, Squash, Watermelon	4
Cucumber/Melons	5

Seeds And Fruit

Once fertilisation has occurred several changes take place:

1. The zygote starts dividing and develops into an embryo. This consists of a plumule (young shoot), a radicle (young root) and one or two cotyledons (seed leaves).
2. The ovule develops into the seed. The outer layers of the ovule form the tough seed coat or testa.
3. The ovary develops into the fruit. You know that apples, pears and plums are all fruits — but so are nuts, marrows and even peapods and beanpods; for in each case the fruit is a structure that developed from the ovary and surrounds the seeds. The fruit protects the seeds and helps in their dispersal.

The embryo inside the seed needs a supply of food to nourish it until it has germinated and the new leaves start making food by photosynthesis. Food, usually in the form of starch, is stored inside the seed. In many seeds the food is stored in the cotyledons (such as in beans), while in others it is stored in special tissue called endosperm that surrounds the embryo, for example in maize.

Seed Germination

Some crops (*e.g. Carrots*) often have a low germination percentage, while others (*e.g. Cabbage*) frequently give close to 100% germination. To germinate, seeds need the right amount of heat (temperature), water and oxygen. The optimum germination temperature and the maximum temperature above which germination will not occur varies for different crops. This is shown in the table on the opposite page:

Soil temperature (°C)		
Optimum	Maximum	Crops
27	35	Carrot, onion, radish, tomato.
29	35	Beans, beet, cabbage, eggplant.
29	40	Sweetcorn.
35	40	Cucumber, watermelon, squash, okra.

Note: These temperatures refer to germination, not growth of the plant.

Vegetables can be grouped according to the soil moisture requirement needed for each crop's seed to germinate as shown in the following table:

Group	Crop
1. Germination good with dry soil.	Cabbage, pumpkins, radish, sweetcorn, squash, watermelon.
2. Needs soil moisture above 25%.	Beans, carrots, cucumber, onion, pepper, tomato.
3. Needs soil moisture above 50%.	Beet, Chinese cabbage.

Oxygen may only be limited when the soil around the seed is saturated for long periods (i.e. In poorly drained, low-lying areas). Cucurbits are especially sensitive to low levels of oxygen in the soil.

Sowing And Planting

When considering the method of establishment, crops can be divided into three groups. These are:

1. **Direct seeding/sowing** — Seeds are sown at the place where the plant will grow.
2. **Transplanting** — Seeds are sown in beds or containers, and seedlings are planted out after they have 'hardened'.
3. **Vegetative propagation** — Plants are grown from cuttings or plant pieces not seeds.

Some crops are more suitable for transplanting than others, such as legumes and cucurbits, which are most often directly sown, while solonaceous crops and brassicas are most often transplanted.

Direct Seeding/Sowing

Direct seeding or sowing seed directly is normally done by the drill method or broadcast method.

Direct seeding
Direct seeding can be done by (a) drilling in row or (b) broadcasting. What are the general guides to how deep the seeds should be sown?

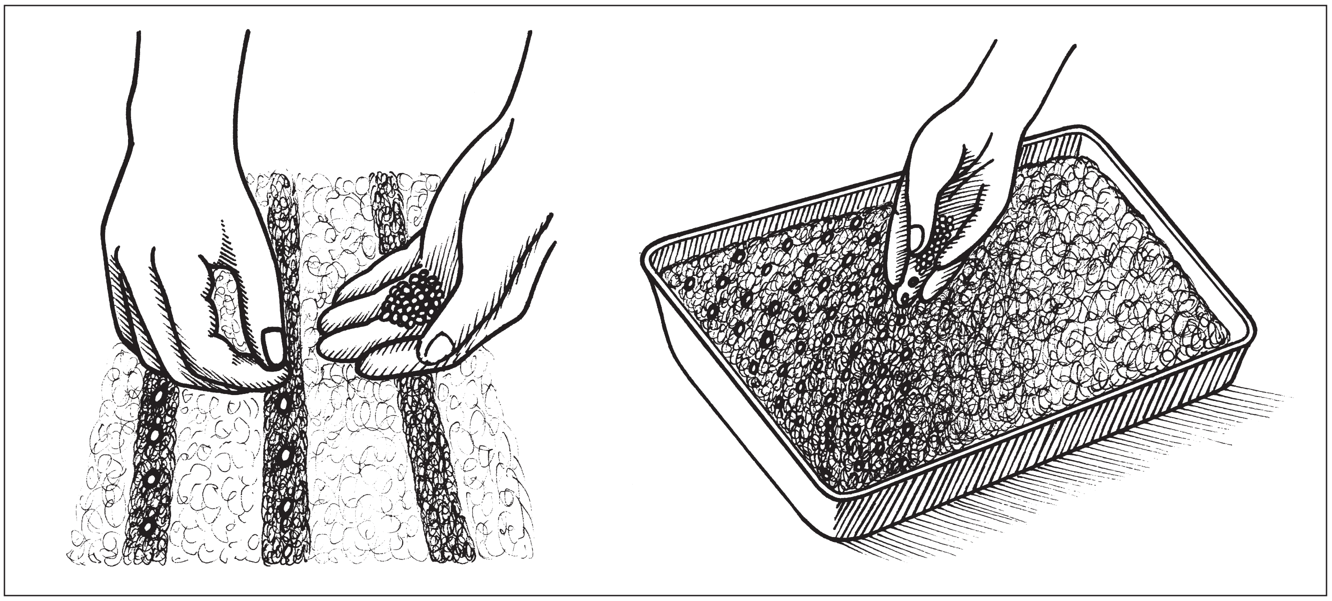


Figure 6.14
Sowing seeds in a row, and spreading seeds evenly.

- Seeds should be planted at a depth equal to about 2–5 times the diameter of the seed.
- Large seeds should be sown 2 cm deep and small seeds 0.5–1 cm deep.
- Some seeds germinate and grow slowly, and if sown too deep, poor establishment may result.

The drill method is suited to:

- Crops such as cucurbits which are widely spaced.
- Long season crops.
- When a weed problem is anticipated and mechanical control will be used.
- When a furrow will be used.
- When seeds are expensive.

The broadcast method involves lightly sprinkling the seeds into a container or on the seed bed. It is rarely used by farmers. Whichever method you choose, the field first needs to be adequately prepared — very finely tilled, weed free and irrigated by sprinklers.

What is seedling emergence?
Emergence is referred to as the time when seedlings break through the soil surface after germination. Seeds may germinate successfully, but emergence may be reduced or not occur due to the soil drying out and the formation of a surface crust. This crust on the soil surface may be hard enough to prevent the emerging seedling breaking through.

To avoid the problem of soil crusting, you can:

- Cover rows of seeds with sand or sawdust. This improves soil structure and reduces crust formation.
- Work the soil gently during seedling emergence by loosening the soil surface to stop any crust formation.

- Mulch and maintain soil organic matter which will reduce the formation of crusts.
- Another solution is to plant strong emerging crops like radishes along the same row as the seeds of the desired crop. They are strong enough to break through most crusts, allowing the seedlings of the desired crop to emerge.

Indirect Sowing/Transplanting/Seedlings

Indirect sowing of seeds is often referred to as growing seedlings or transplants. Seeds should be sown three to six weeks before the seedlings are required for planting out in the garden.

It is very important that seedlings be strong and healthy. Strong seedlings will produce better crops than weak, spindly seedlings. Seedlings are raised in well-prepared seedbeds or containers commonly referred to as 'flats'. Pots or large old cans are also used.

Seedbed method of growing seedlings
This is the cheapest and most commonly used method. The three methods for sowing seeds in the nursery are:

- **Broadcast method** — You lightly sprinkle seeds in a container or in the seedbed.
- **Drill sowing with uniform spacing method** — You sow the seeds in rows at a certain distance from each other.
- **Sowing at high density in lines method** — The seeds are sown in a line at no particular spacing. The seeds are close together and touch each other. The seedlings are later transplanted (pricked) and grown at uniform spacing in other containers or seedbeds.

Some disadvantages of the seedbed method are:

- Damage to roots when pulling out seedlings at transplanting. To minimise damage, seedlings should be pulled out with a ball of soil surrounding the roots.
- This method can be laborious and can cause transport problems.
- It is difficult to control the spread of disease within a seedbed.

Container method
The containers used are usually trays — these are shallow boxes, or 'flats', usually about 45 cm square and 10 cm deep, which can be made from old packing crates.

Preparing Soil For Sowing Seeds

No fertiliser is required if seedbeds are made from new soil just cleared of natural vegetation. If the soil has been used for crop production, it is best to enrich it with compost or old manure at a rate of 0.2 kg/square metre. The compost should be mixed into the soil and the bed soaked with water about one week before sowing seeds.

The seeds are then sowed using one of the methods described earlier. After sowing seeds, the beds should be watered and then covered with coconut leaves, banana leaves, sacks or other similar material to keep the beds moist. When the seedlings appear, the covering should be removed immediately.

In the wet season, it is difficult to grow seedlings in beds because of 'damping off' disease caused by fungi that thrive in hot, wet conditions. These fungi live in the soil and attack seedlings as they germinate and emerge from the soil, causing them to collapse. Some control of this disease can be achieved by adding Captan (which is a chemical available at any agricultural store) to the seedbeds. During the wet season it is best to grow seedlings under a plastic cover.

Container method
The soil mix used for the container method (the **growth medium**) should be one part sand to three parts good topsoil. If well-rotted manure or compost is available, some should be added to the mixture. In developed countries, growth medium consists of ready-to-use mixes of perlite, vermiculite and peat.

Quality Of Growth Medium

The growth medium should have good water-holding capacity and aeration. The use of coconut coir dust, rick husk, mosses and fully decomposed dried manure and river sand improves the water holding capacity of the growth medium.

Any growth medium should have the capacity to supply plant nutrients to plants. Vermiculite/perlite/peat and their tropical counterparts such as coconut coir dust and rick husk supply very little plant nutrients. Nutrient rich materials such as compost, manure or fertile topsoil are used to supply plant nutrients. A small quantity of a compound fertiliser (NPK) should be added to a tray. About 30 grams or one matchbox full per flat should provide sufficient nutrients to get seedlings off to a good start.

The growth medium should be free from soil-borne plant pathogens, so it is very important to sterilise the medium.

Nursery Management

Seedling care
We have already talked about nursery making and sowing, now we will look at thinning, watering, fertilising, hardening and transplanting.

Thinning
Close spacing should be avoided as this will cause plants to compete with each other for light, nutrients and moisture. Plants should be spaced so that the leaves of adjacent plants are not touching. To prevent overcrowding, you should take into account the following thinning guides.

- Seedlings in trays or seedbeds should be thinned out at about the 3–4 leaf stage.
- Seedbed plants should be thinned to about 10 cm apart in the row.

Watering
Seedlings must never be allowed to dry out, but over-watering and wetting leaves in the evening should be avoided as this encourages 'damping off' disease. Water carefully until seedlings emerge, especially when the seeds are small. Water in the

morning and, if it needs to be repeated, in the early afternoon. Watering should be decreased about ten days before transplanting. This practice is important in seedling 'hardening' which we will discuss later.

Clean water must be used for watering, so tap water or water from a deep well must be used. Surface water may carry weed seeds as well as pathogenic micro-organisms.

Fertilisers

Fertiliser applied to the seedbed must be mixed with the soil before, not after, sowing. Seedlings must be able to use the fertiliser immediately after they have developed root systems to absorb nutrients. Also, mixing the fertiliser with the soil before sowing provides an even distribution of the fertiliser and prevents fertiliser injury. Use slow-releasing fertiliser to reduce loss of nutrients through leaching. In the tropics, use well decomposed organic matter.

Liquid fertiliser can be applied as a drench, starter solution or foliar spray. This can be made by dissolving 10 g of urea in five litres of clean water, or 30 g of a compound fertiliser (NPK) in 15 litres of clean water. If organic matter is to be used, only fully decomposed organic matter (compost or manure) should be used because decomposing organic matter contains a lot of micro-organisms which may compete with the seedlings for nutrients. The decomposition process also helps release toxic chemicals.

Hardening seedlings

The hardening process helps plants recover rapidly from the stress of transplanting. A hardened plant will grow more slowly after transplanting but will resume normal growth much sooner than a non-hardened plant.

Seedlings in beds can be hardened by gradually reducing the water supply over a ten day period prior to transplanting and removing shade gradually over the same period. Seedlings in trays or pots can be hardened by placing the containers outside in the sun for a few hours each morning.

Transplanting

The greatest problem with transplanting is that plant growth is temporarily slowed or stopped. This is due to the shock the plant suffers when it is moved — mainly damage to the root system. To reduce transplanting shock:

- Use only healthy and vigorous seedlings.
- Water the tray or seedbed thoroughly before removing seedlings.
- Try to lift plants with a ball of soil around the roots.
- Handle seedlings carefully, and avoid handling the stem if possible.
- Transplant into beds immediately after removing from tray or seedbed.
- Make the hole in the bed large enough so that the roots are not bent upwards.
- Plant the seedlings slightly deeper than they were in the seedbed to ensure the upper roots are not exposed.
- After transplanting, firm the soil around the roots and leave a slight depression.
- Water each seedling with about a cupful of water — this will help to expel air pockets around the roots.
- Transplant late in the afternoon. Cloudy days with little wind are best.

Crop Rotation

Crop rotation is the growing of different crops, one at a time, in a definite sequence on the same piece of land. The advantage of crop rotation is that it helps to maintain soil fertility and controls pests and diseases.

It is impractical to give a definite rotation for every crop, but there are a few principles that should be followed. To fully utilise the resources of the soil, shallow-rooted crops and deep-rooted crops should be alternated.

Average effective root-zone depth of vegetable crops in deep, well-drained soil are shown in the table below:

Crop	Root-zone depth (cm)
Shallow-rooted crops	Less than 50 cm
Bush beans	45
Lettuce	30
Onion	30
Radish	45
Medium-rooted crops	51–100 cm
Cabbage	60
Carrots	90
Cucumber	90
Eggplant	90
Sweetcorn	90
Deep-rooted crops	more then 100 cm
Melon	155
Tomato	120
Snap beans	110

Different crops take different amounts of minerals from the soil, so a rotation based on the nutrient requirements of crops is an important strategy in the total soil management programme.

Crops with a high fertility requirement (heavy feeders), such as tomatoes, should be followed by a fertility restoring crop (heavy giver), such as cowpeas, which in turn should be followed by a crop which depletes the fertility of the soil only slightly (light feeder).

Heavy feeder	Heavy giver	Light feeder
Tomatoes	Beans	Carrots
Eggplants	Peanuts	Sweet potatoes
Green peppers		Radishes
Cabbages		
Corn		
Watermelons		
Cucumbers		
Pumpkins		

Disease And Pest Control

Crop rotation can help contain the spread of pests and disease which are destructive to crops. Insects usually prefer to feed on certain crops or families of crops and most diseases are specific to certain crops or families of crops.

Crop families
Examples are shown on the table below:

Family	Cucurbitaceae	Cruciferae	Solonacae	Leguminosae
Crops	Cucumber Pumpkin Squash	Head cabbage Chinese cabbage Couliflower	Tomato Peppers Eggplant	Beans Peanut

Plants of the same crop family on the same land every year allows insects and diseases to build up in that area. Sometimes rotations are planned to avoid pests and diseases that are known to be a serious problem. In such cases factors such as soil fertility considerations are of less importance, for example, crops can be selected according to whether or not they are included in one of the following five groups:

1. Crops susceptible to bacterial wilt — tomato, potato, eggplant and pepper.
2. Crops susceptible to cabbage moth — head cabbage, Chinese cabbage and radish.
3. Cucurbits — cucumber, pumpkin, squashes, zucchini, melons and watermelons.
4. Legumes — beans and peanuts.
5. Other crops — maize, carrots, lettuce, onions, leeks, garlic, celery, okra, coriander, parsley, pele, sweet potatoes, taro, cassava and yams.

In this rotation, members of one group are not grown successively on the same ground. Ideally, there is a gap of three to four years before a member of the same group occupies the same ground again.

It should be noted that most of the crops in group five are unrelated to each other and are suitable for rotating with crops in the other groups because they have few diseases in common. However, related plants within the group (onions, leeks, garlic) as well as bele and okra, would not be sown in sequence.

Rotations for raised beds
A three bed rotation: bed 1, then bed 2, then bed 3, then bed 1; or bed 1, then bed 2, then bed 3a, then bed 1.

One bed or part of one bed may be kept for perennial crops: *e.g. Ginger*. Other beds may be kept for experiments so that you can try growing unusual crops.

1. Local vegetable bed — amaranthus, purslane, bitter cucumber, comfrey, fern, rungia, pit and sugarcane.
2. Introduced vegetables which are hard to grow — carrots, broccoli, cabbage, cauliflower, celery and beetroot.
3. Some vegetables can be grown in running water — water kumara and watercress.

1	2	3 or	3a
Leafy vegetables	Fruiting vegetables	Legumes or	Climbing legumes
Chinese cabbage Corn (intercrop) Choko (for leaves) Hibiscus cabbage Lettuce Radish Spring onion	Capsicum Chilli or Corn (intercrop) Cucumber Eggplant Melon (bushy) Pineapple Tomato Zucchini	Dwarf bean Peanut	Climbing bean Snake bean Winged bean Yardlong bean

Rotations for fields

Field rotations: 1–2–3–4–1, or 1–3–1–3 or 3–4–3–4. Choose one or more kinds of plant for each field from each column of the table below:

Field 1	Field 2	Field 3	Field 4
Leafy vegetables	Fruiting vegetables	Legumes	Root or grain crops
Chinese cabbage Pumpkin (for leaves) Hibiscus cabbage (aibika, bele, pele) Lettuce Spinach Spring onion	Capsicum or Corn (intercrop) or Pumpkin (fruit) Cucumber Eggplant Melon (trailing) Okra Pineapple Tomato Watermelon Zucchini	Common bean Peanut Dwarf bean Winged bean	Cassava Corn Kumara (sweet potato) Taro Yam

Integrated Pest Management (IPM)

What is plant protection?

Plant protection is the development of programmes for the management of pests (insects, diseases, weeds, etc) to maintain them at levels which are not economically harmful. It includes an understanding of what is a pest and what strategies are available to control them.

What is a pest?

A pest can be described as an organism that causes damage or illness to people, their crops, animals or possessions. The term pest may include insects, mites, fungi, bacteria, viruses, nematodes, crustaceans, rodents, birds, molluscs and weeds.

Different ways in which pests can cause crop damage

Pests can cause damage to crops both directly and indirectly by:

- Destroying the whole plant.
- Damaging the non-saleable part of the plant.
- Damaging the plant by injecting eggs and poisonous fluids.
- Encouraging the growth of moulds on insect secretions.

- Introducing other pests (*e.g. Weeds*).
- Interfering with other management practices.

Modern farming practices increase pest problems

While natural ecosystems have large number of species and suffer few pest problems, modern cropping practices usually consist of crops grown in monoculture which tends to encourage the build–up of pests. The use of intensive management methods often make matters worse because the ecosystem becomes more unbalanced compared to the untouched environment. This means that unnatural measures often have to be taken to ensure that pests remain under control.

In the Pacific Islands, pests have become of major importance. Shifting cultivation with long fallow periods is in decline and cropping areas are no longer small, isolated gardens surrounded by forest. As human communities have grown, so too has the size of cultivated areas and a more unbalanced environment, with a resulting rapid increase of pests. In addition, the isolation of Pacific Island countries from other world regions, which previously served so well to protect agriculture from exotic pests, is no longer an effective barrier. Pests are now common and it is estimated that more than 80 per cent of the pests present today have been introduced, mostly through human intervention.

Humans have also increased the significance of pests in other ways. New crops and new, more susceptible varieties of traditional crops which have been introduced, which have been susceptible to attack by hitherto unrecorded pests.

Why move away from total reliance on pesticides for pest control?

A pesticide is a chemical used to kill pests. In the past, pesticides were seen as the answer to all pest problems. With increasing usage, more 'traditional' cultural control measures received less and less attention.

In the 1970s and 80s, this increasing reliance on chemical pesticides began to be questioned due to a number of factors, including:

- The development of pest resistance to pesticides.
- Greater understanding of pest/crop/environment relationships.
- Concerns about hazards of pesticides to the user, the consumer and the environment.
- Occurrence of pest resurgence (pest populations bouncing back to higher levels following the use of pesticides due to destruction of natural or beneficial enemies).
- Increase in economic pressures forcing farmers to question the value of routine and expensive pesticide applications.

As a result, a more complete approach to pest control, based on a thorough understanding of the crop/pest relationship and the use of a range of complementary control techniques, was advocated. This is commonly referred to as Integrated Pest Management (IPM).

Logical sequence of stages in applied IPM

Where pest problems do occur a rational approach must be taken to manage them.

- Identify the pest and define the area in which control is to be applied.
- Assess the level of infestation and the potential economic losses.

- Study the life cycle and behaviour of the pest.
- Consider the options for control measure(s).
- Apply pesticides only after all other pest control methods have been considered.

Pest Management (Control) Methods

A wide range of pest control options are available and the IPM approach will normally require a combination of these.

A. Varietal control
This can be done by breeding plant varieties with resistance to insect or diseased pests. In addition, new methods are being developed using genetic engineering to create new varieties with resistance to pests. Plant resistance to pests can manifest itself in a number of ways including:

- **Non-preference** — Pests prefer not to attack the plant.
- **Antibiosis** — Pests are not as healthy as on susceptible varieties.
- **Tolerance** — Damage occurs but does not seriously affect plant growth.

B. Cultural control
This includes:

- **Soil cultivation** — Reduce insect populations that live or pupate in the soil by exposing them to the sun and to attack by predators. Frequent turning of the soil, especially in dry weather, is a useful way to reduce nematode populations.
- **Mulching** — This practice smothers the weeds and can reduce drought stress, which tends to make crops more susceptible to sucking pests (*e.g. Planthoppers on taro*). Mulches provide places for predators to hide. However, excessive mulching can also provide ideal conditions for slugs and snails and for the growth of fungi which may then attack the crop.
- **Roguing** — This involves the physical removal of low level weeds to prevent a population build-up, or the removal (and destruction) of infected plants: *e.g. Those known to be infected with a virus*. Roguing may work in small plots. In large areas, it is only practical if the crop is of high value.
- **Pruning** — The removal of infected plant or parts of plants: *e.g. The pruning of cocoa to reduce the spread of diseases such as a pink disease*. Also, the reduction of dense foliage in plantation crops reduces many pests.
- **Fertilising** — Good crop fertilising often reduces losses to pests as rapid growth of the crop shortens the susceptible stage and a healthy crop can better tolerate damage and competition.
- **Irrigation** — This may disturb, drown or suffocate insect pests and weeds: *e.g. In irrigated rice or with diamondback moth on cabbages*.
- **Mixed cropping** — Intercropping increases the diversity in the cropping system and therefore tends to reduce pest problems. This technique is still widely used by village farmers and plantation groups in Pacific Island countries.

- **Crop rotation** — Separating the pest from its host by growing an alternative crop has long been an important element of pest management, especially for pests such as nematodes which are difficult to control by other methods. Breaking continuous cropping of a single crop (*e.g. Sweet potato*) has been shown to result in fewer pest problems.
- **Trap crops** — This involves the planting of a crop that is more attractive to the pest: *e.g. Cabbage can be protected from diamondback moth when strips of Indian mustard are planted within the crop*.
- **Sowing and harvesting practices** — Changing the planting date may avoid the main migration or oviposition period of a pest or get the crops to a resistant stage by the time of the pest attack: *e.g. Yams are planted so that they reach the tops of their supporting poles before the onset of the raining season to avoid Colletotrichum dieback*. Co-ordinating the time of planting nationally can be an effective way to limit the build-up of pests. (e.g. *Cucumber mosaic virus or squat in Tonga*.)
- **Hygiene** — Methods such as keeping field borders free of weeds and cleaning tools before moving them between fields helps to minimise the spread of diseases from field to field.

C. Biological control

This includes the introduction of parasites, predators or diseases (natural enemies) of pests. There is great potential for the increased use of natural enemies in pest control in Pacific Island countries. Natural enemies are:

- Selective.
- Safe (to user, environment and consumer).
- Able to seek out their prey.
- Self-perpetuating.
- Less costly to the farmer.
- Unlikely to result in the development of resistance or in resurgence.

An example of biological control is the control of the rhinoceros beetle in coconut. Some constraints of biological control include:

- It can be expensive to initiate.
- There may be a significant time lag between introduction of the control agent and reduction in pest population.
- It may be incompatible with the use of pesticides.
- Not every pest can be controlled in this way.
- It does not necessarily eliminate pest damage completely.
- Results may be unpredictable.
- Requires monitoring and expert supervision.

Biological control can be applied in three main ways

1. **Inoculative (one-off) releases** — for example, the control of Salvinia water weed in Papua New Guinea by the release of the weevil, *Cyrtobagus salviniae*, in 1983.

2. **Repeat releases (augmentation/inundation)** — natural enemies are laboratory bred on a continuous basis and released repeatedly: *e.g. The use of* Trichogramma *spp. egg parasites to control corn borers in the Philippines*.
3. **Conservation/enhancement** — natural enemies already present can be protected by careful pesticide applications: *e.g. By protecting the natural enemies during spraying* — by careful timing of application, by using selective pesticides and by ensuring a plentiful supply of adult food and shelter: *e.g. The planting of* Coleus blumei *in Western Sāmoa to control the cluster caterpillar*, Spodoptera litura.

D. Interference methods

- **Repellents** — Personal insect repellents are well known (*e.g. Mosquito repellents*), but there have been few successful applications of the same principle in crop protection.
- **Pheromones** — These are chemical substances released by insects to change the behaviour of members of the same species. They can generally be classified as attractants and excitants (to encourage mating).
- **Antifeedants** — These are chemicals that inhibit an insect's biting reflex. Because antifeedants are not absorbed by the plant tissue new crop growth is unprotected. In addition sucking insects are not affected.
- **Insect hormones** — Artificially produced insect hormones have been used to disrupt the development of insect pests.
- **Genetic method** — The sterile male technique, where male flies are sterilised by irradiation and released in large numbers to compete with the natural fertile males in mating with the females, has been effective: *e.g. Fruit flies have been eradicated from the southern islands of Japan using this technique coupled with other methods.* The technique is highly dependent on having favourable conditions and environment.

E. Physical methods

- **Heat treatment** — This is usually applied to the planting material of vegetatively propagated crops: *e.g. The treatment of ginger or banana sets against nematodes and the treatment of sugarcane set against chlorotic streak*.
- **Sound** — This is used in a number of ways to control pests: a) the banging of pots and pans to try to prevent locust swarms landing; b) the use of bird-scarers emitting sharp bangs; c) the production of high frequency sound to deter rats.
- **Traps** — Traps of various descriptions have been used over the ages particularly against vertebrate pests: *e.g. Rats*. Light traps — the use of UV light to attract insects and kill them.
- **Visual objects** — The placement of visual objects in the field to frighten away pests: *e.g. Aluminum foil or reflective strips to frighten birds*.
- **Barriers** — The use of iron sheets around trees to stop rats from attacking coconut fruits.
- **Hand picking**.

F. Regulatory control

This involves the strict control of entry and export of all plant produce and material for food and planting. Legislative controls form an important component of IPM, especially when it is viewed on a regional basis. The main controls are:

- **Eradication** — Campaigns are periodically launched against specific pests in an attempt to eradicate them from an area.
- **Certification** — Under these regulations certain crops at certain times of the year are considered free from pests unless certified.
- **Rotation orders** — In this case the planting of certain crops at certain times of the year is mandatory and/or may be combined with fallow or non-pest host break crop.

G. Exclusion and eradication

Exclusion of pests can take place on many levels. Many pests of the world have not reached Oceania. The most effective method of controlling a pest is to keep it out of a country. This is done by quarantine regulations and inspections. Once a pest gets into a country it may still be prevented from moving from island to island within a country. If the pest is one which moves around slowly, such as a soil borne pathogen, a farmer may be able to prevent the entry of that pest into a specific farm.

Eradication means removing all the individuals of a pest so that it is no longer present. This is usually done at a national level. For certain pests, such as some weed species, it may also be possible to eradicate them from a specific farm.

H. Chemical control

This refers to the use of pesticides. These should be used only when necessary and, where possible, selective products should be used: *e.g. The use of* Bacillus thruringiensis *to control diamondback moth without harming its parasites*.

Activity 1 Record Keeping

Aim To design a garden diary and record sheets to be used in the school garden.

1. Divide into groups of three or four.
2. Within your groups discuss and design:

- A farm diary.
- A record sheet for recording tools and equipment.
- A record sheet for recording money used.
- A production record sheet for a crop.

3. Present your diary and record sheet to the class for discussion.
4. Make changes to your record sheets where necessary.
5. Use your diary and record sheets for recording activities in the garden.

Activity 2 Crop Rotation

Aim To design a crop rotation programme for peanut, green pepper, watermelon and eggplant.

1. Work with your garden plot partner.
2. Read and discuss the information on crop rotation at the beginning of this unit.
3. Discuss and design a crop rotation programme for peanut, green pepper, watermelon and eggplant.
4. Share your crop rotation programme with another group.
5. Use the crop rotation programme in your garden practical periods.

Activity 3 Site Selection

Materials needed:
Pencil and paper.

Aim To select a suitable site for the Year 11 plots in the school garden area.

1. Divide into pairs.
2. Go to the school garden area.
3. Survey the area and draw a map of the area using keys to indicate the location of the school garden area in the school compound, road, taps, slope, rocky area, soil colour, fence, trees in garden area, sunrise-set direction, north, weeds and other features.
4. Discuss the map with your partner and select the best area for planting a garden.
5. Have a class discussion and select the best area for the Year 11 garden.
6. As a class, sketch the plots (1 m × 10 m) for the whole class. Leave a space of 30 cm between plots for a walking/working area.

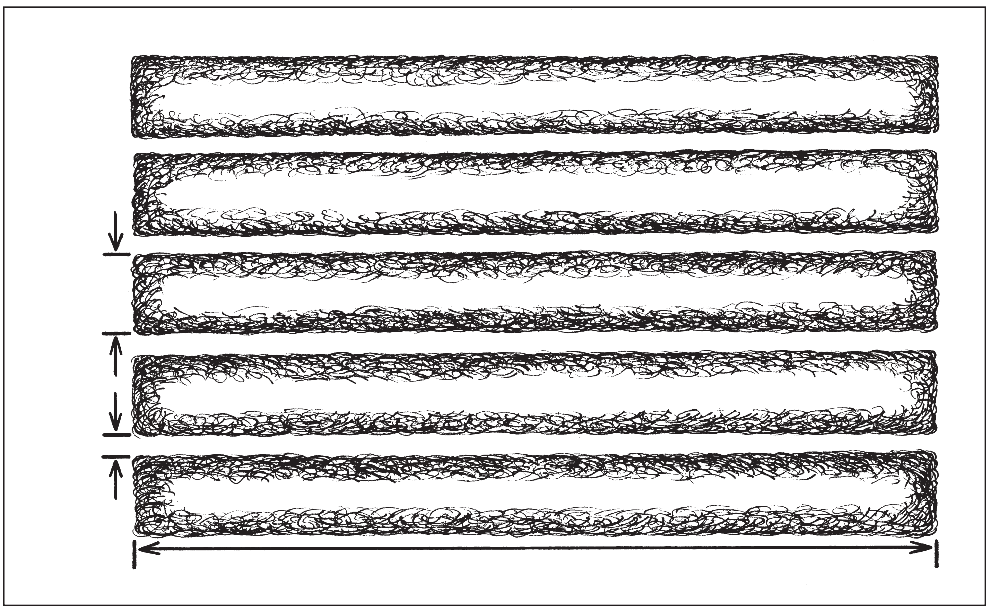


Figure 6.15
Class plots, with space between rows.

Activity 4 Land Preparation

Materials needed:
Tools (bush knife, spade, digging fork, rake);
Measuring tape (50 m);
Sticks.

Aim To clear garden area, mark and divide plots in preparation for planting.

1. As a whole class, clear the area for your class garden using knives and rakes.
2. Measure (1 m × 10 m plots) and mark the plots with sticks.
3. Dig the soil and prepare raised beds. Break up soil to a fine tilth.

Activity 5 Interplanting Green Pepper With Peanuts

Materials needed:
Measuring tape;
Peanut seeds;
Green pepper (capsicum) seedlings;
Trowel or small kitchen knife;
Organic fertiliser;
Watering can;
Garden hose pipe.

Aim Interplant peanut and green pepper using your crop rotation programme.

1. Mix organic fertiliser with soil.
2. Mark rows (10 cm from edge of plot and 45 cm within row) for planting green pepper (two outer rows).
3. Mark middle row for planting peanuts (30 cm between plants).
4. Water green pepper seedlings.
5. Transplant seedling to marked area for planting green pepper.
6. Sow two peanut seeds 1 cm deep into marked area for planting peanut.
7. Water seedlings well. Do this once a day.
8. After peanuts have germinated remove weeds and add mulch.
9. Harvest peanuts after 115–125 days or when you see black lines inside pods (open some pods to check this around 115 days).
10. Harvest green pepper after three months when they are matured.
11. Handle fruits with care to minimise damage to fruits.

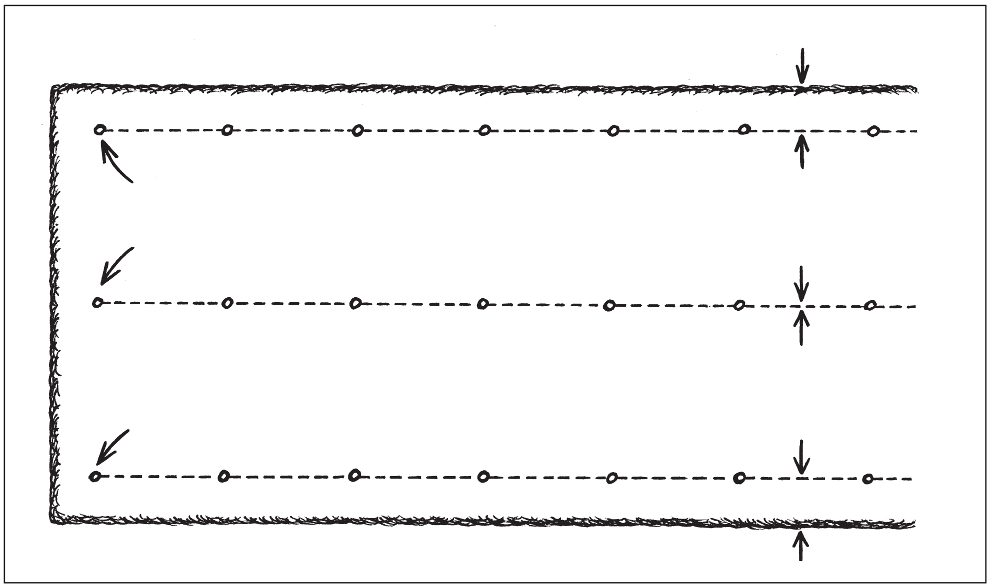


Figure 6.16
Plot planting measurements mentioned in 2 and 3 above.

Activity 6 Planting Cocoa, Pineapple And Pawpaw

Materials needed:
Measuring tape;
30 cocoa and pawpaw seeds;
50 pineapple suckers;
Trowel and spade;
Organic fertiliser;
Bush knife;
Sticks.

Aim To assist in the planting of cocoa, pineapple and pawpaw.

1. As a class, select and prepare an area for planting 10 cocoa plants, 50 pineapple suckers and 10 pawpaw. Use seeds for planting pawpaw and cocoa.
2. Add organic fertiliser.
3. Plant these crops using the recommended spacing. Use three cocoa and pawpaw seeds per hole. Mark area with sticks where seeds were sowed.
4. Prepare a sign board indicating name of crop (local and scientific), spacing date planted. Place sign in front of the row of crops.
5. Water seedlings daily and remove weeds.
6. Mulch seedlings and suckers.

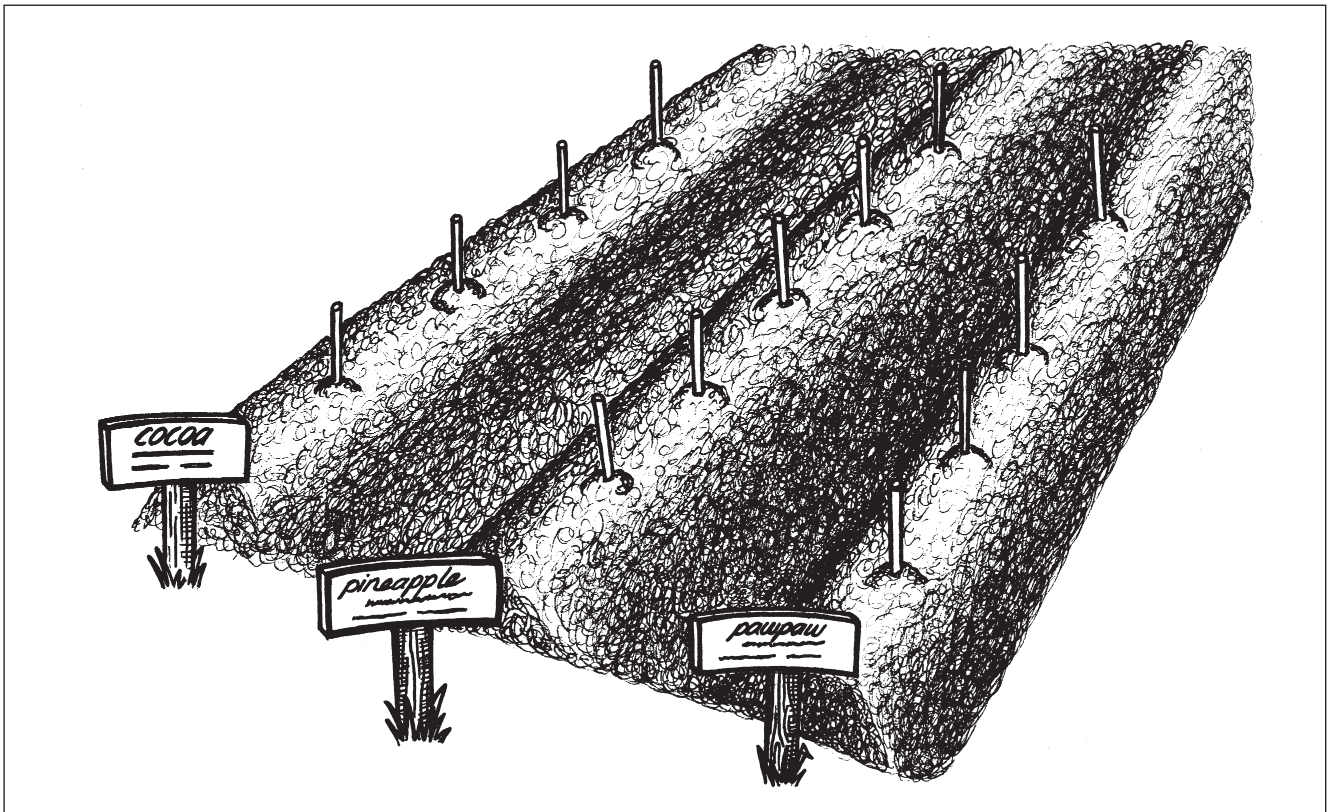


Figure 6.17
Rows of cocoa, pawpaw and pineapple.

Activity 7 Plant Densities

Materials needed:
Newsprint;
Markers.

Aim To investigate plant production at different plant densities.

1. Work in pairs.
2. Study and discuss the data (on the next page) on a spacing trial on taro:
3. Plot and label the data on a graph.
4. Explain the trend shown on the graph.

Spacing (cm)	30 × 30	50 × 50	80 × 80	100 × 100	200 × 200	300 × 300
Yield (tonne/ha)	4.4	6.3	8.9	10.0	9.1	7.2
Average weight per corm (kg)	0.6	1.3	1.5	2.0	2.5	2.6

5. Write a conclusion.
6. Write recommendations based on your conclusion.
7. Present your graph and recommendations to the class for discussion.

Activity 8 Weed Management

Materials needed:
Hoe;
Mulching material (dried grass or leaves).

Aim To use a rational approach to weed management.

1. Put mulch around the plants after the peanuts have germinated.
2. Remove any weeds when they are young or have two to four true leaves, using your hands or a hoe.

Figure 6.18
Mulching and hand-weeding.

Activity 9 Pest And Disease Management

Aim To study a rational approach to pest and disease management.

1. In groups of three or four, read and discuss the background information on integrated pest management
2. Plan a programme for controlling pests and diseases in your plots.
3. Write down the steps you will follow.
4. List the materials you will need and the costs that will be involved.
5. Write down the results you expect.

6. Explain the likely environmental effects your programme will have.
7. Present your programme to the class for discussion.

Figure 6.19
A combination of pest control methods: chemical, biological, cultural and physical.

Activity 10 From Flower To Fruit

Materials needed:
Flowers and fruit of any available plant;
Sharp knife or scalpel;
Bush knife.

Aim To investigate fruit development of plants from flowering fruit.

1. Divide into groups of three or four.
2. Collect flowers and fruit of different ages from a plant.
3. Discuss and identify the parts of the flower.
4. Discuss and try to determine how a flower develops into a fruit.
5. Look at the old fruit and see if you can see how the seeds are released.
6. Draw a series of diagrams showing how your flower develops into a fruit and how the seeds are released.
7. Split open the fruit and count the number of seeds inside. Estimate how many seeds the plant produced.

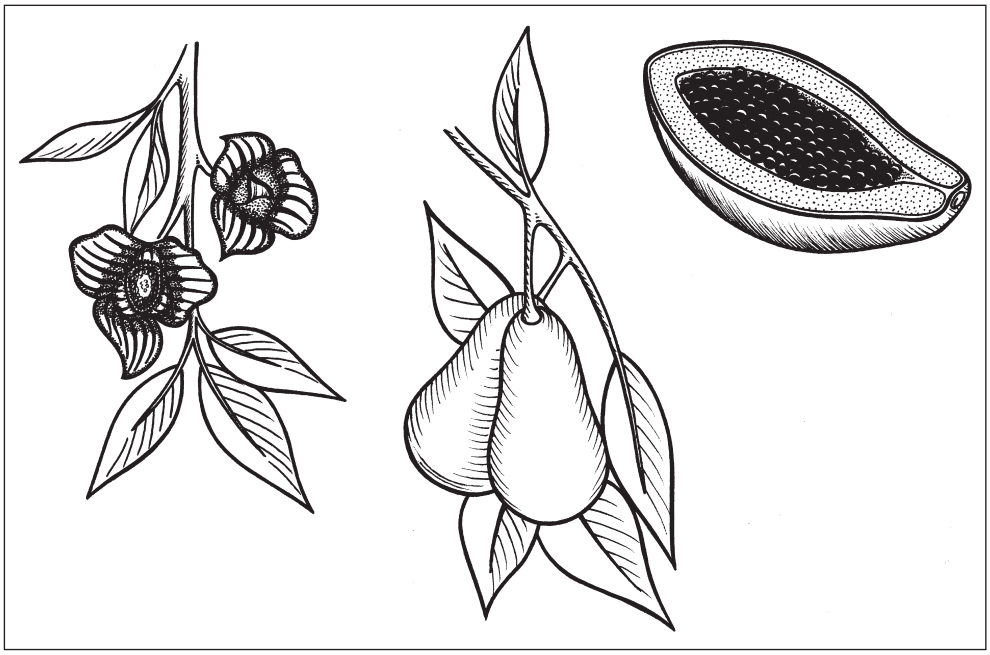


Figure 6.20
Pawpaw flower and pawpaw fruit.

Review

1. List and explain factors associated with successfully selecting lands for crop production.
2. How are plants established?
3. What are methods of sowing seeds in a nursery?
4. What is a good local growth medium mix?
5. What is the main function of river sand in a growth medium mix?
6. Explain the most popular type of land clearing.
7. What are some disadvantages of using heavy machinery for land clearing?
8. What are some of the main reasons for tillage?
9. What are some good management practices that a farmer can use to minimise the occurrence of 'damping off' disease in a nursery?
10. Contact the meterological station and look at any rainfall data for the area where you live. Indicate whether it is a high rainfall area or a low rainfall area.
11. How would you successfully grow temperate crops in the tropics?
12. Define a 'viable seed'.
13. What is the relationship between storage temperature and seed moisture content?
14. How should we store seed in the tropics?
15. Describe the hardening process for seedlings.
16. List some good transplanting practices.
17. Why do plants produce many seeds?

Unit 7: PROCESSES IN PLANTS

About this unit

This unit covers plant processes. It is important for you to have an understanding of plant processes so that you can better assist in improving crop production as well as help in keeping our environment clean. You will be investigating the role of plants in the nutrient cycle and in the carbon and nitrogen cycle.

The Nitrogen Cycle

Nitrogen is an essential element in the making of proteins, which are found in all plants and animals. Plants make proteins using nitrogen in the form of nitrates. Nitrates are inorganic compounds found dissolved in soil water and are taken up by the plant through the roots.

When a plant is eaten by an animal, the proteins are broken down into amino acids which are used by the animal to build animal proteins.

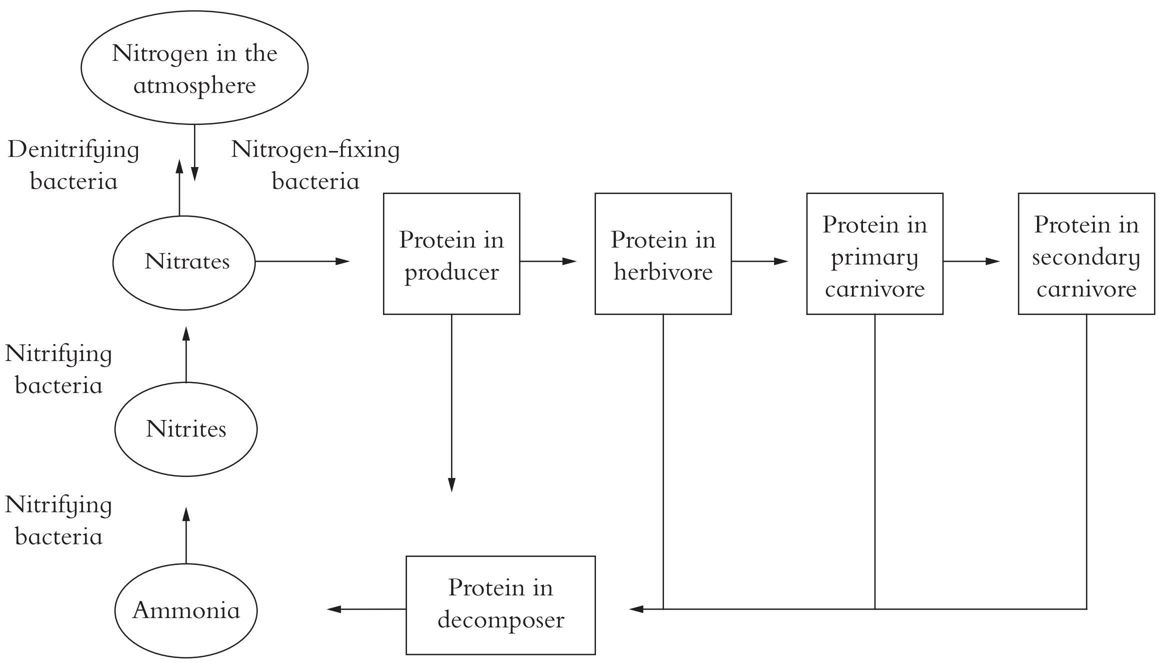


Figure 7.1
The nitrogen cycle.

Proteins from dead organisms and the excreta of living ones are broken down by decomposers into ammonia. This is changed by the soil bacterium Nitrosomonas, into nitrite ions which are oxidised by another bacterium, Nitrobacter, back into nitrates. These bacteria have the effect of increasing the nitrogen available to the plants in the soil and are called nitrifying bacteria. This process is called nitrification.

The greatest pool of nitrogen is the nitrogen gas in the atmosphere. This can be converted directly into nitrates by the action of nitrogen-fixing bacteria. Some of these live in the soil, but others such as the bacteria Rhizobium, live in nodules on the roots of plants such as clover and lupins. Because of this mutual relationship, these plants can grow in soil where the amount of nitrates is low.

The action of another group of bacteria living in the soil, called denitrifying bacteria, converts nitrates in the soil back to the gaseous nitrogen in the atmosphere.

This circulation of nitrogen in the ecosystem is called the **nitrogen cycle** and is illustrated in Diagram 7.1 on the previous page.

The Carbon Cycle

Carbon exists in the atmosphere in the form of carbon dioxide. This is taken into plants during the process of photosynthesis and is used to build complex organic molecules — carbohydrates, proteins, fats and oils and others. These are passed through the food chains as one organism eats another.

During energy release (respiration) in all organisms, organic molecules are broken down into carbon dioxide and water. This is released into the atmosphere.

If plants and animals do not fully decompose after death the organic molecules in their bodies may accumulate under the ground as hydrocarbons, which form the fossil fuels such as coal, oil, and natural gas. When humans burn this fossil fuel, the carbon is finally oxidised to carbon dioxide and released into the atmosphere.

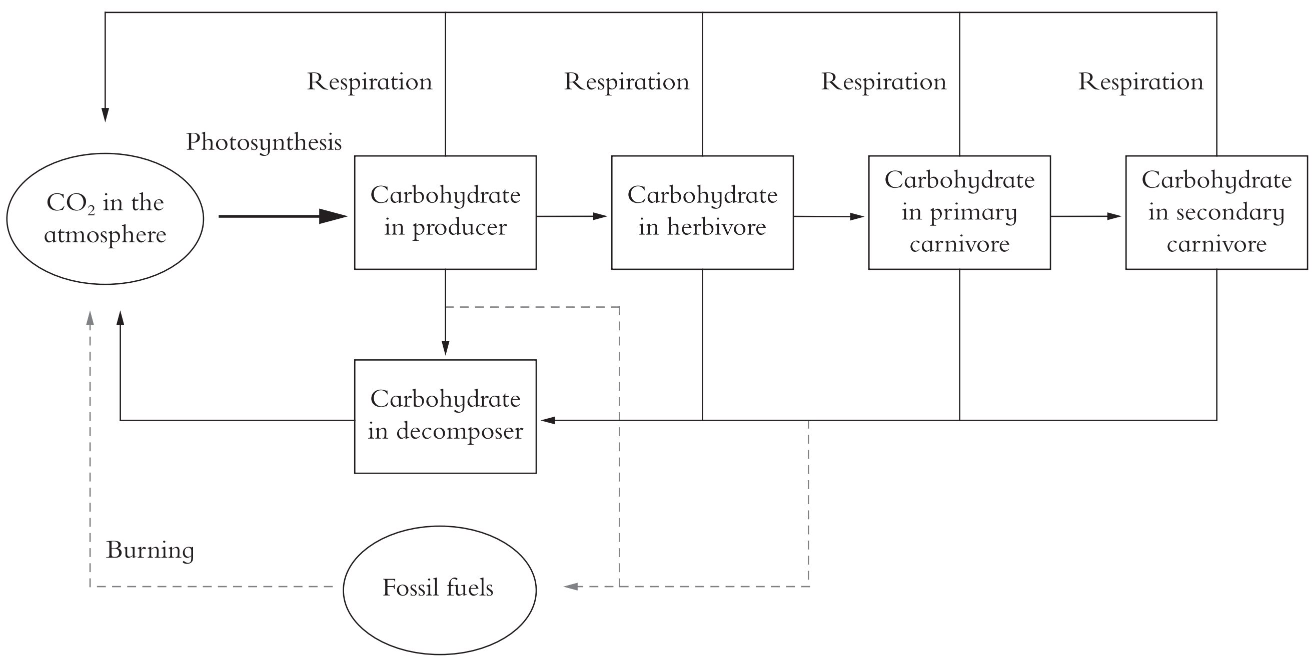


Figure 7.2
The carbon cycle.

Energy

This section studies energy and the cell. It looks at where the energy comes from and the structures and processes that make energy available for use by the cell.

Every living cell needs a regular supply of energy in order to survive and remain active. This energy is needed to carry out a variety of living processes. It is needed to power chemical processes such as manufacturing proteins, building up cell structures, moving chemicals through membranes and around the cells, and many more. It also keeps cell temperatures up and may be used for special functions such as the contraction of muscles.

The energy source

The sources of this energy are the large complex molecules which make up the food supply for the cell. These are often glucose, but may come from other carbohydrates, fats or proteins. The energy is contained in these large molecules as the molecular bonds which hold the atoms together. When the bonds are broken this energy is released.

This is what happens in the process of burning:

fuel	+	air	—fire→	wastes	+	energy
Wood or other complex carbohydrates		Contains a supply of oxygen		In the form of water vapour and carbon dioxide		Energy and light

Unfortunately, the cell cannot obtain its energy as simply as this. The complex food molecules contain so much energy that the cell would be unable to handle it if it was all released at once, as in burning. It has been calculated that there is so much energy in one slice of apple pie that if this energy was all released at once when eaten, it would raise our body temperature by 10°C. This would be enough to kill us.

Cellular respiration

Within the cells, the energy from the food molecules is released by a process called cellular respiration. This is a very complex process controlled by enzymes that break down the complex molecules one step at a time, releasing energy in such small amounts that it can be controlled and used by the cell. In a simplified way we can summarise cellular respiration as follows:

Food (glucose)	+	oxygen	→	carbon dioxide	+	water	+	energy
$C_6H_{12}O_6$		$6O_2$		$6CO_2$		$6H_2O$		

As with burning, the process needs oxygen as a raw material. The food is reduced to simple molecules of carbon dioxide and water. This summary does no more than show the raw materials and end products.

Photosynthesis

In this section the importance of photosynthesis in producing food for all living things is studied.

The chloroplast — food factory

The chloroplast is the site of photosynthesis. Although the two raw materials, water and carbon dioxide, are easy to obtain, the actual process is very complex. What actually goes on in the chloroplast?

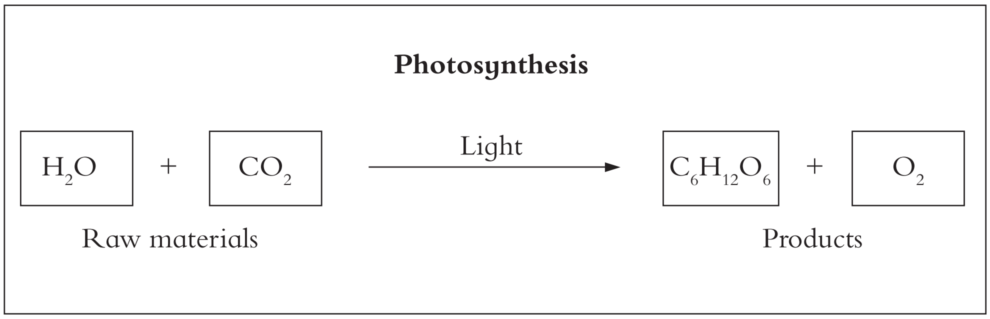


Figure 7.3

Diagram of the details of photosynthesis.

Light

Light is the energy that is used to build up complex food molecules. Only about one per cent of the light falling on the plant is actually used in photosynthesis. This ordinary 'white' light is made up of different wavelengths. The green wavelengths are reflected. This explains the green colour of plants containing chlorophyll. The red and blue wavelengths are absorbed and it is these wavelengths that are used in photosynthesis. Experiments in which plants are grown in light of different wavelengths confirm this.

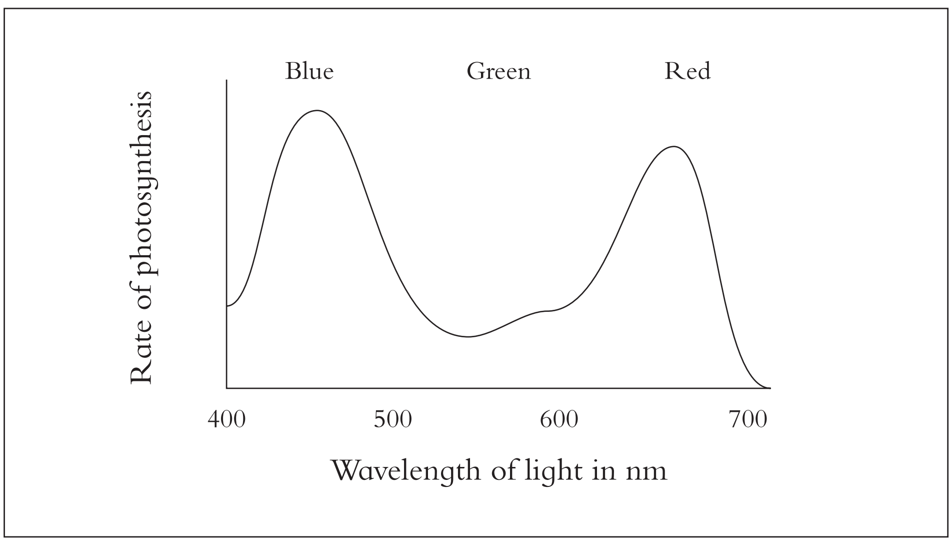


Figure 7.4

Rates of photosynthesis that take place in different wavelengths of light.

Chlorophyll

Chlorophyll is the chemical that plays the vital role of trapping the light energy. There are two types of chlorophyll, as well as several other pigments, such as the yellow carotene, that assist in carrying out this role. Within the chloroplast, large numbers of chlorophyll molecules are arranged over the flat surface of the layers of grana. This arrangement means that as much light as possible is trapped.

The light reactions

The light shining on the chlorophyll causes several reactions to occur. These are quite complex and involve several other chemicals. In simple terms these reactions result in:

- Hydrogen being split from water molecules and picked up by carrier molecules.
- ADP being converted to energy rich ATP molecules, which can then be available for other reactions.

Carbon dioxide fixation

The light reaction is only the first stage of photosynthesis. When it has produced hydrogen, the second phase can take place. This is called carbon dioxide fixation and it does not need light. It takes place in the watery material surrounding the grana. In simple terms it involves the combining of hydrogen from the light phase with carbon dioxide. It is a very complex series of reactions involving energy from ATP and a number of enzymes and other chemicals. They build up a complex food molecule (glucose) in a step-by-step series of reactions.

The importance of this process to all living things cannot be over-emphasised. This is the only way in which large food molecules containing rich supplies of energy can be built up using an outside source of energy. We still do not know enough about the details of the process to be able to copy it in the laboratory. All green plants seem to carry out photosynthesis in a similar way, although some plants such as maize and sugarcane have a rather more efficient variation of the carbon dioxide fixation process.

The end product

The simple sugar, glucose, is the end product of these reactions. The glucose is very soluble and is quickly converted to other substances.

Any surplus glucose loses water molecules and is converted to large, relatively insoluble starch molecules. In this form it is stored until needed. Often the chloroplasts may contain grains of starch. In some plants the starch is stored in special areas, such as the roots of potatoes or carrots.

Most glucose is transported to other cells. It may be directly fed into the respiratory cycle where it may be broken down to release its energy. It may also undergo chemical changes and be converted into lipids, or changed into amino acids to become part of proteins.

Remember, all food chains start with photosynthesising plants — therefore green plants really supply food for all living things.

Activity 1 The Carbon Cycle

Materials needed:
Newsprint or hard boards;
Markers;
Coloured pens.

Aim To investigate the role of plants in the carbon cycle.

1. In pairs study the incomplete carbon cycle below:
2. Discuss and fill in the missing words in the ovals and rectangles.
3. Discuss and write a paragraph on the importance of plants in the carbon cycle.
4. List one plant and one animal process that is essential for the carbon cycle.
5. Redraw the flow chart of the carbon cycle on a piece of paper. Colour in the diagrams.
6. Pin or stick your carbon cycle charts on the class walls.

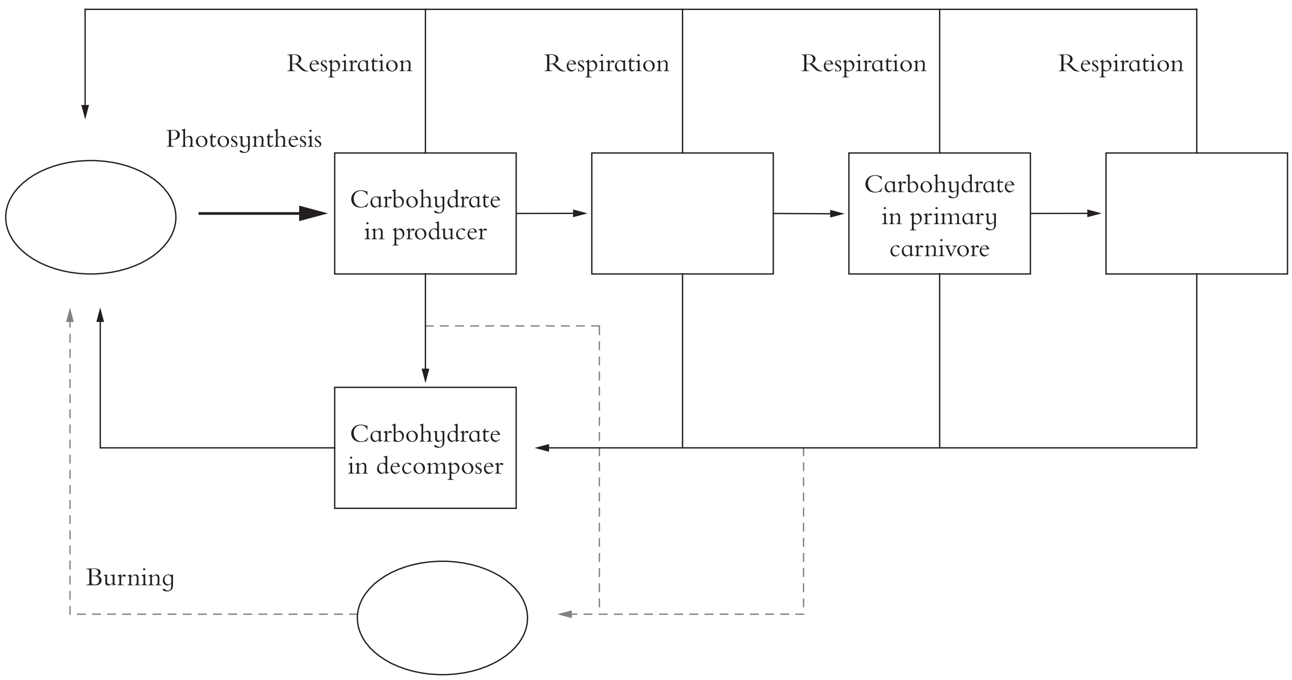


Figure 7.5A
Incomplete Carbon Cycle.

Activity 2 The Nitrogen Cycle

Materials needed
Newsprint or hard boards;
Markers;
Coloured pens.

Aim To investigate the role of plants in the nitrogen cycle.

1. In pairs study the incomplete nitrogen cycle on the next page.
2. Discuss and fill in the missing words in the ovals and rectangles.
3. Discuss and write a paragraph each on the importance of plants in the nitrogen cycle.
4. List two plant processes that are essential in the nitrogen cycle.
5. Redraw the flow chart of the nitrogen cycle using diagrams. Colour in the diagrams.
6. Pin or stick your nitrogen cycle charts on the class walls.

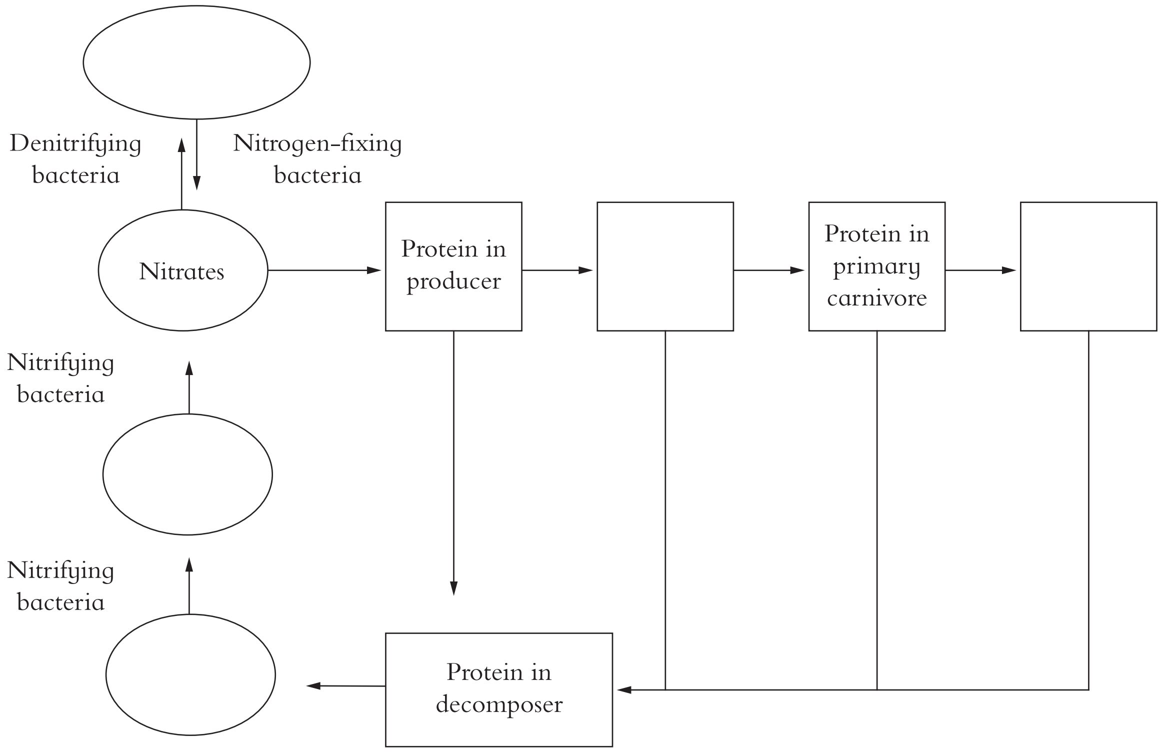


Figure 7.5B
Incomplete Nitrogen Cycle.

Activity 3 Photosynthesis

Materials needed:
Cup of sand;
Mortar and pestle;
Leaves;
Ethanol or acetone;
Sodium hydroxide;
Clear plastic bag;
Foil;
Test tube;
Beaker;
Hot plate.

Aim To study the different aspects of photosynthesis.

Part A: Photosynthesis
With your partner, read the background information, then discuss and fill in the empty boxes using the words in the box at the bottom.

Photosynthesis

H_2O	+		Light →		+	O_2

Raw materials — Products

CO_2	$C_6H_{12}O_6$	ATP	N_2	ADP

Part B: Extraction of chlorophyll

1. Chop some green leaves into small pieces.
2. Put them into a mortar with a pinch of sand.
3. Add a little ethanol or acetone and crush the leaves with a pestle. The chlorophyll will dissolve in the ethanol.
4. Filter the fluid to remove sand and remains of leaves.
5. How does the colour differ from the original leaves? (You will use this extract in Part C.)

Part C: The effect of chlorophyll on light

1. Dilute part of your solution of chlorophyll and pour it into a narrow transparent container.
2. Set up a projector or other light source, a prism and a screen. Focus so that you can see the screen.
3. Place the chlorophyll solution in the beam of light.
4. Note the effect on the spectrum of colours. Do any of the colours disappear? Which? What does this suggest about the wavelengths of light that are used in photosynthesis?

Part D: Raw materials needed for photosynthesis

1. Choose a plant that has soft leaves. Place the plant in the dark for at least 12 hours to de-starch the leaves. Your teacher will help you set up the experiments shown in Figure 7.7.

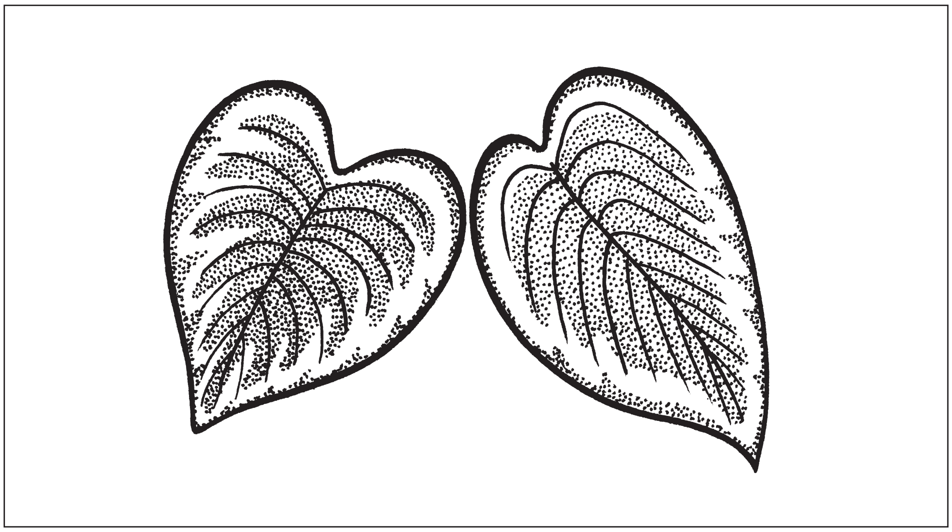


Figure 7.6
Variegated leaves.

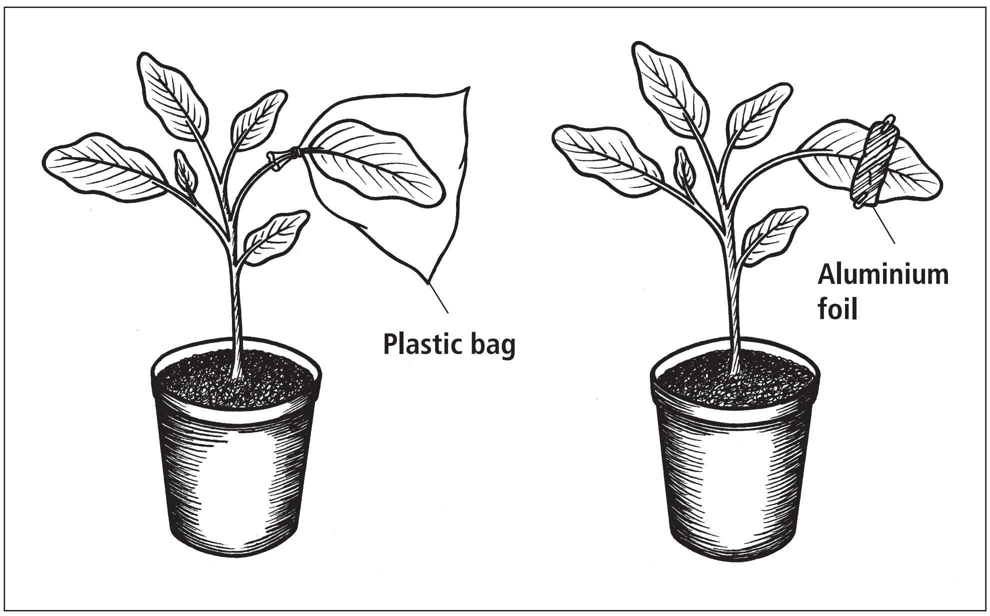


Figure 7.7
Experiment set-ups.

2. Leave the plants in the light for at least 24 hours.
3. Do a starch test on each of the experimental leaves. For the carbon dioxide experiment you also will need to do a starch test on another leaf. This will act as a control.

Starch test

- Boil the leaf in methylated spirits in a water bath for about 10 minutes in order to remove the chlorophyll.
- Rinse the leaf in hot water to remove the methylated spirits and soften it.
- Cover the leaf with iodine. You may need to press the leaf to help the iodine penetrate deep enough.

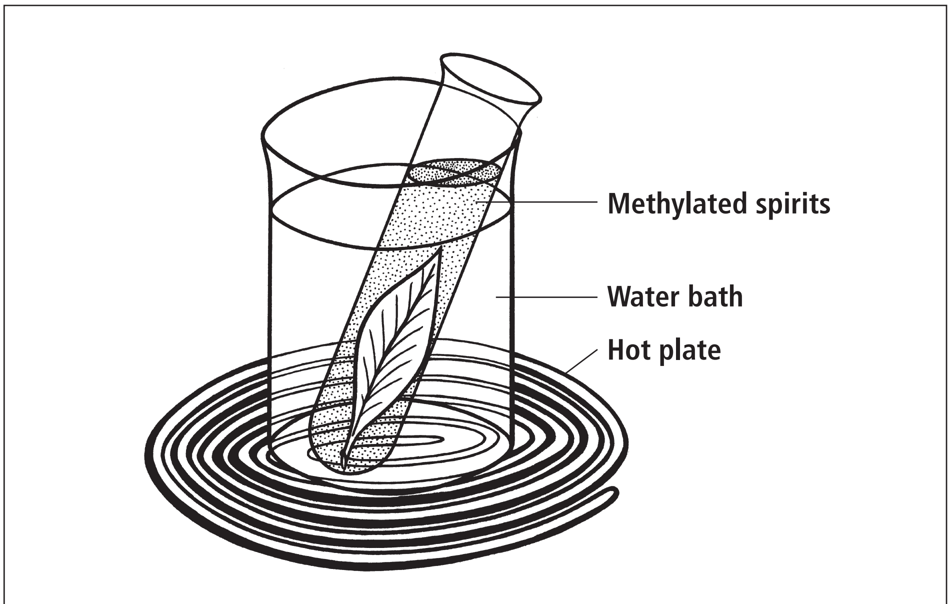


Figure 7.8
Doing a starch test.

- Note which leaves and which parts of leaves showed the presence of starch by turning black.

1. For each experiment, explain which leaf or part of each leaf is acting as a control. Why are these controls important?
2. Explain why it is important to de-starch the leaves first.
3. Explain why it is important to choose soft leaves.

Activity 4 Respiration

Materials needed:
Test tubes;
Bromothymol blue;
Soda limes;
Cotton wool;
Small insect;
Potato;
Test tube stopper;
Volumeter.

Aim To measure respiration.

Part A: Do living things give off carbon dioxide?

1. In groups of three set up a series of test tubes as shown in Figure 7.9. The bromothymol blue will lose its colour if carbon dioxide is given off.
2. Put a variety of living things in the test tubes — small animals or insects, a small piece of potato, even a green leaf. If you use a green leaf the tube should be put in the dark.
3. Make sure that you have a control — a test tube with no living things in it. Why is this needed?
4. Leave the test tubes for 24 hours then examine them. Do all the living things give off carbon dioxide?
5. Why was it necessary to keep the green leaf in the dark?

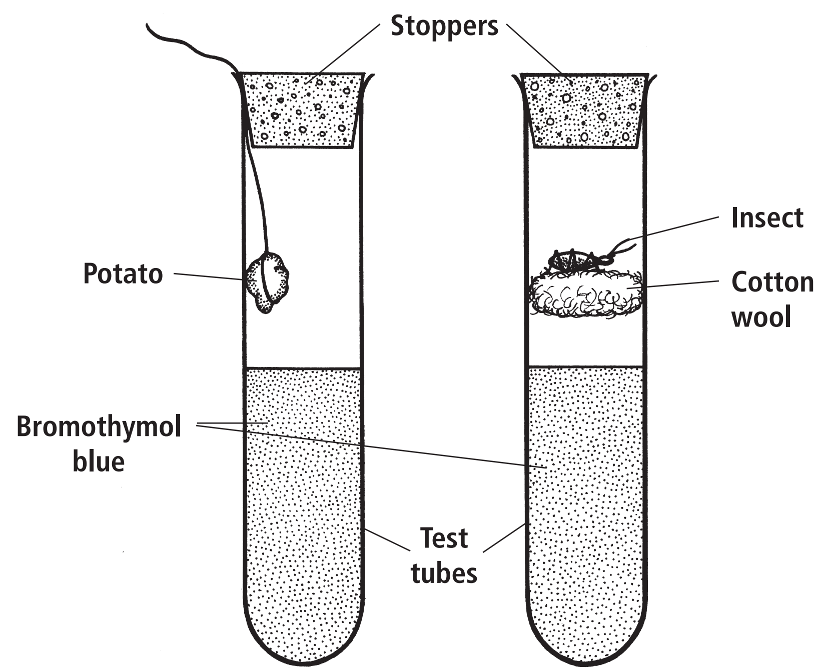


Figure 7.9
Testing for carbon dioxide.

Part B: Do living things take in oxygen?

1. Set up a volumeter — your teacher will show you how. The soda lime is to absorb carbon dioxide. Why is this necessary? The syringe is useful for altering the air pressure and moving the bubble back.
2. Again, use various living things and set up a control.
3. Take recordings of the movement of the bubble every five minutes for 20 minutes. Explain why it moves.

Review

1. Explain the role of plants in the carbon cycle.
2. Explain the role of plants in the nitrogen cycle.
3. Name two crop plants that can convert nitrogen from the air into the soil.
4. What name is given to the kind of plants you mentioned in question three?
5. The term respiration is often used when we are taking about breathing. What is the difference between the terms breathing and cellular respiration?
6. Two market gardeners had an argument about how they could increase plant growth in a glasshouse by painting the glass. One painted her glasshouse green and the other painted his glasshouse red. In which glasshouse do you think the plants would grow better? Explain why.
7. The two market gardeners had another argument. One felt that if he sealed up the glasshouse and pumped carbon dioxide into it, he would get higher yields from the crops. Do you think he was right? Give reasons for your answer.
8. If a green plant is kept in the dark for a week or more the leaves turn yellow. Suggest why this happens. Explain how you could find out if this had any effect on photosynthesis.

Key Vocabulary

Ways of defining things
Niche crops are high value produce that are only produced for special markets and fetch high returns.

Ways of saying things in different ways
This type of classification is often termed phenetic or artificial classification.

Ways of describing the structure of a thing
DNA is shaped like a twisted rope ladder; the rungs of the ladder are made up of four chemical bases. They are called A-adenine, T-thymine, G-guanine and C-cytosine.

Ways of expressing characteristics
Some of the essential characteristics of organic systems include: . . .

Ways of expressing reasons for a procedure
The hardening process helps plants recover rapidly from the stress of transplanting.
Tillage allows organic material to decompose faster.
The advantage of crop rotation is that it helps to maintain soil fertility and controls pests and diseases.

Ways of expressing how a procedure should be carried out
Watering should be done in the morning.
Watering should be done carefully until the seedlings emerge.
The growth medium should be free from soil-borne plant pathogens. Therefore, it is very important to sterilise the medium.
Over-watering should be avoided as this encourages 'damping off' disease.
Seedlings must never be allowed to dry out.
Do not wet leaves in the evening, as this encourages diseases.

Ways of expressing causes or conditions
These differences are mainly due to the type of clay and organic matter content.
This results from a lower content of organic matter, . . .

Ways of expressing effect
This causes restricted root penetration.

Ways of expressing causes/conditions and their effect
The available water capacity of soil is related to soil texture.
The texture determines the amount of surface on which the reactions occur.
The beneficial effects are attributed to the added nitrogen and to the improvement of structures.
Many important physical and chemical reactions in soil are governed by texture.
Texture is determined by the relative proportions of sand, silt and clay.
Soil organic matter contributes to good soil structure and water-holding capacity.
If the soil is too dry, big hard clods will be turned over by plough action.

Key vocabulary for Year 11 Book 1 Agricultural Science

Vocabulary	Useful words that go with the key word	Other words
adjacent	adjacent plants; plants adjacent to	
aggregate	soil aggregates, poorly formed aggregates, the formation aggregates the resistance of aggregates to . . ., the stability of aggregates, aggregate stability	
available	the best available piece of land for, the best land available, must be available for . . ., availability of land	availability
capacity	water-holding capacity, storage capacity	
characterisitcs	essential characteristics, favourable characteristics, undesirable characteristics, characteristic of	characteristic
consistency	soil consistency, wet, moist and dry consistency	
contribute to		
control(s)	pest control, mechanical control; erosion control; varietal control, cultural control; biological control, chemical control; regulatory control, legislative controls; a weed control method; to keep under control; the control of; control measures; to control pests; it is difficult to control . . .; the most effective method of controlling . . .	to control, controlling
conventional	conventional farms; conventional food; conventional food production; conventionally grown food	conventionally
converted	to be converted to; to become converted into	
decomposer	soil decomposers; many stages of decomposition; decomposes slowly; is decomposed; decomposing organic matter; fully decomposed organic matter	decomposition, decomposes, is decomposed, decomposing, decomposed
deficiency	nutrient deficiency, deficiency symptoms	
degree	the degree of cohesion, the degree of adhesion	
density	soil density, particle density, bulk density	dense
depletes	depletes the soil's structure, depletion of	depletion
determine	you can determine if; has been determined; ways of determining the	determined, determining
factors	environmental factors, additional factors, factors affecting . . .	
fertility	soil fertility, a high fertility requirement, a fertility restoring crop	
genetic	genetic engineering (GE), genetic diseases, genetic matter, defective genes, genetically engineered foods	phylogenetic, genes, genetically
germination	seed germination, a low germination percentage	germinated
management	management methods, management practices, soil management, a soil management programme, organic farming management, nursery management, Integrated Pest Management (IPM)	
medium	soil medium, growth medium	
nutrients	micronutrients, available nutrients, nutrient supply, plant nutrient deficiencies, nutrient deficiency symptoms	nutrient
optimize	optimise production, optimising organic farming practices, the optimum germination temperature	optimizing, optimum
organic	organic soils; organic matter, organic residue; organic farmers; certified organic; organic food, organic produce; organically grown; produced organically	inorganic, organically
peds	soil peds, distinctive peds, the arrangement of peds, the distinctiveness and strength of the peds, ped size and grade	ped
pests	plant pests, pest problems, chemical pesticides	pest, pesticides
proximity	proximity to	

Key vocabulary for Year 11 Book 1 Agricultural Science

Vocabulary	Useful words that go with the key word	Other words
requirements	the climatic requirements, the soil requirements, the fertiliser requirements, the nutrient requirements of crops	
residue(s)	crop residue, plant residue, pest residues	
resistant	resistant to pest and diseases, plant resistance to, to resist disease	resistance, to resist
rotation(s)	crop rotation(s), bed rotation, field rotations, suitable for rotating with, rotational grazing	rotating, rotational
saturated	water saturated soils, water saturation	saturation
seed	seed propagation, a seed bed, the emerging seedling, seedling emergence, seedling establishment, the seedbed method	seedling, seedbed
significant	significant effects on, significant increases in	
soil	soil tilth, soil conservation, soil erosion, soil compactness, soil evaluation, soil tests	
superior	superior than, superior to	
sustainable	sustainable production, to sustain crop production	to sustain
systems	cropping systems, organic systems	
texture	the texture of surface soils, coarse textured soil, fine textured soil, the textural class of the soil, the textural triangle, texturally coarse	textured, textural, texturally
viable	viable seed, remain viable for	
water	water retention and movement, water permeability, water infiltration	
yield(s)	crop yields, yields of crops, organic yields, reasonable yields, the maximum yield, higher - yielding varieties	yielded, yielding

Related to processes in plants
plant processes, the nutrient cycle, the nitrogen cycle, the carbon cycle, denitrifying bacteria, nitrogen-fixing bacteria, nitrifying bacteria, nitrates, nitrites, fossil fuels, cellular respiration, carbon dioxide fixation, the chloroplast

Related to classification of plants
taxonomy, species, genus, genera, phenetic, phenetically, crop plants, vascular plants, Spermatophyta, Pteridophyta, Sphenophyta, Lycophyta, Psilophyta, Angiospermae, Gymnospermae dicotyledonous plants, monocotyledonous plants

Related to genetics
cell membrane, cytoplasm, the nucleus, chromosomes, hybrid, offspring, dominant, recessive, heredity, alleles, genotype, phenotype, homozygous, heterozygous, a Punnett square, mutation, artificial selection

Related to organic farming
regulations, soil biota, crop rotation, certification, to certify, verification, to verify, synthetic agrochemicals, synthetic pesticides, synthetic fertilisers

Related to agriculture in Samoa
hydroponics, niche crops

Related to soil properties
chemical properties, soil acidity, the neutralising effects, mineralisation, precipitation, porosity, coarseness, sandy or gravel nature, tillage, the pipette method, a field method, plate-like, prism-like, block-like, spheroidal, granular, arid, humid, to fallow, clods, the rhizosphere, microbial activity, cohesion, adhesion, friable soils, plasticity, porosity, macropores, plant analysis, biological testing, field test

Related to growing and managing crops
recommended varieties, site selection, climatic conditions, shifting cultivation, fallowed land, tilling, tillage, ploughing, harrowing, mounding, ridging, terracing, the rate of maturation, temperate vegetables, vegetative propagation, life expectancy, the broadcast method, the drill method, soil crusting, crust formation, mulch, mulching, indirect sowing, broadcast method, drill sowing, aeration, slow releasing, fertiliser, rogueing, pruning, cotyledons, mixed cropping, trap crops, repellents, pheromones, antifeedants, exclusion, eradication, the zygote, the plumule, the radicle, the ovule, the testa, the ovary, micro-organisms