Chapter 3

Nutrition in Plants

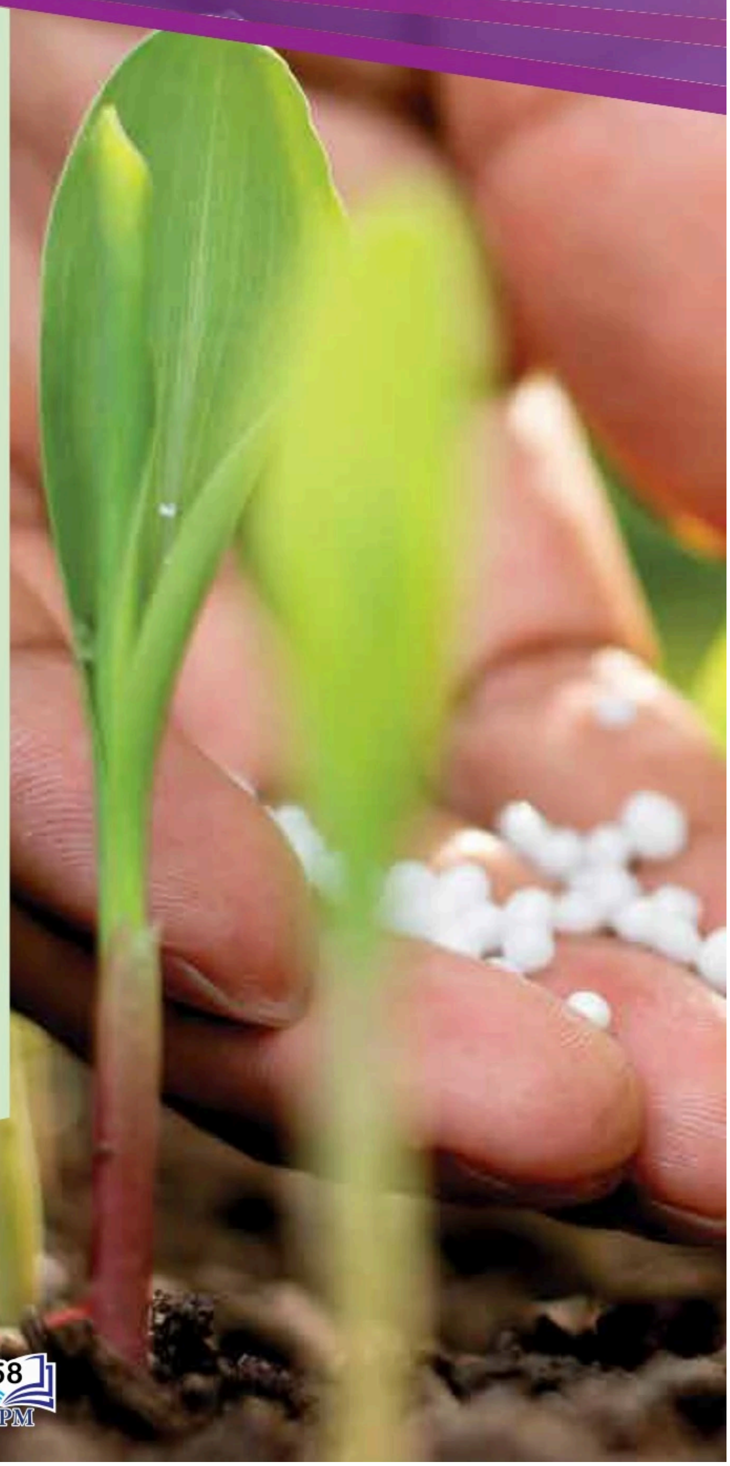
Chapter Exploration

- Main Inorganic Nutrients
- Organ for Water and Mineral Salts Uptake
- Diversity in Plant Nutrition

Learning Standards

Do You Know?

- What are the examples of macronutrients and micronutrients that are required by plants?
- Why do crops need to be fertilised?
- Can plants be infected with diseases?
- Why do the roots act as an organ for water and mineral absorption?
- How is the *Rafflesia* sp. able to live without leaves?



Organic Compost Fertilisers

Did you know that excess leftover food can be recycled to produce organic fertilisers? Compost is a type of fertiliser produced from the decomposition process of leftover substances such as crop leftovers, kitchen leftovers, plant excretory substances and animal faeces which are decomposed by microorganisms. How is the organic compost fertiliser made?

Leftover substances, together with bacteria, are placed in a container with aeration to speed up the decomposition process. Dry leftover substances are layered with wet leftover substances alternately. Water is sprinkled on every layer. The leftover substances are stirred every two days until compost is formed. The compost is usually done after being kept for a few months.

Figure 3.1
Leftover substances for composting

The practice of producing compost fertilisers at home can save many landfill sites. In addition, the cost of buying chemical fertilisers can also be reduced (Figure 3.1).

Keywords

- Chlorosis
- Culture solution
- Macronutrients
- Micronutrients
- Nutrition
- Nutrients
- Root hair
- Parasitic plants
- Epiphytic plants
- Carnivorous plants

3.1 Main Inorganic Nutrients

Like other living things, plants need nutrients to grow well and produce high quality yields. Plants need inorganic nutrients to produce organic compounds such as carbohydrates and proteins. What are the inorganic nutrients required by plants?

Macronutrients and Micronutrients Required by Plants

These nutrients can be divided according to quantities required by plants, which are **macronutrients** and **micronutrients** (Figure 3.2).

MAIN INORGANIC NUTRIENTS

Macronutrients
- Carbon (C)
- Calcium (Ca)
- Hydrogen (H)
- Magnesium (Mg)
- Oxygen (O)
- Phosphorus (P)
- Nitrogen (N)
- Sulphur (S)
- Potassium (K)

Micronutrients
- Chlorine (Cl)
- Zinc (Zn)
- Iron (Fe)
- Copper (Cu)
- Manganese (Mn)
- Nickel (Ni)
- Boron (B)
- Molybdenum (Mo)

Figure 3.2 Main inorganic nutrients

3.1.1

Three main macronutrients, which are **carbon**, **hydrogen** and **oxygen**, can be obtained easily from air and water from the soil. These nutrients make up most of the dry mass of plants. Therefore, the lack of these nutrients is rarely experienced by plants. The remaining nutrients are taken in the form of mineral salts which are dissolved in the soil through fertilisation.

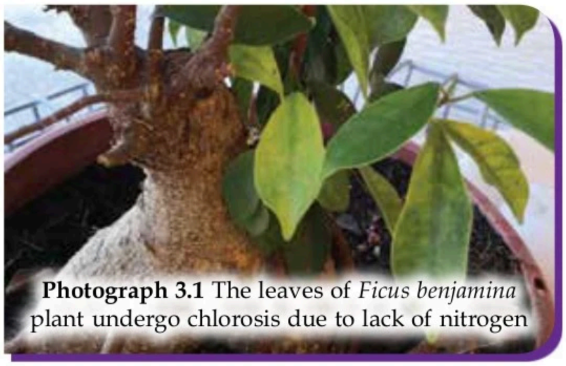
The Necessity of Macronutrients in Plants

Every nutrient has its own function in order to ensure that plants complete their life cycle and achieve optimum growth and development. The lack of one or more macronutrients can cause bad effects on the health and growth of plants. Table 3.1 shows the functions and effects of macronutrient deficiency.

Table 3.1 The functions and effects of macronutrient deficiency

Macronutrients	Functions	Effects of Deficiency
Carbon (C) Oxygen (O) Hydrogen (H)	• Important components in carbon cycle and oxygen cycle • Components in all organic compounds of plants and important components in synthesis of sugar	• Photosynthesis will not take place • Less oxygen released by plants • Stunted growth which can cause death because there is no glucose
Nitrogen (N)	• Gives the green colour to plants through the formation of chlorophyll • Main components of proteins, nucleic acids and enzymes in photosynthesis and respiration	• Leaves undergo chlorosis (yellowing of the leaves) (Photograph 3.1) mainly on matured leaves • Underlying leaves fall off • Protein synthesis disrupted • Stunted growth
Potassium (K)	• Important in protein synthesis and carbohydrate metabolism • As cofactors for some enzymes • Maintains plant turgidity	• Protein synthesis disrupted • Edges of leaves become yellowish (Photograph 3.2) • Premature death of plants
Calcium (Ca)	• Main component of middle lamella, cell wall and spindle fibres during cell division	• Stunted growth • Leaves become distorted and lobed • Parts between leaf veins become yellowish
Magnesium (Mg)	• Main component of the structure of chlorophyll molecule • Activates some plant enzymes • Involved in carbohydrate metabolism	• Parts between matured leaf veins become yellowish • Red spots on leaf surfaces • Lobed leaves
Phosphorus (P)	• Synthesises nucleic acids, adenosine triphosphate (ATP) and phospholipids in plasma membrane • Act as coenzymes in photosynthesis and respiration	• Unhealthy root growth • Formation of dark green and dull coloured leaves • Red or purple spots appear on older leaves
Sulphur (S)	• Components of a few amino acids • One of vitamin B constituents and a few types of coenzymes	• Leaves or the whole plant turns yellow

3.1.2



Photograph 3.1 The leaves of *Ficus benjamina* plant undergo chlorosis due to lack of nitrogen

Photograph 3.2 The leaves of *Cyrtostachys renda* (red pinang palm) caused by lack of potassium

The Necessity of Micronutrients in Plants

Table 3.2 shows the functions and effects of micronutrients deficiency.

Table 3.2 The functions and effects of micronutrients deficiency

Micronutrients	Functions	Effects of Deficiency
Chlorine (Cl)	• Important in the equilibrium of osmotic pressure in cells and photosynthesis reaction	• Plants wilt • Slower root growth • Leaves undergo chlorosis • Lesser fruit production
Iron (Fe)	• Acts as a cofactor in chlorophyll synthesis • Important in the growth of young plants	• Young leaves become yellowish
Manganese (Mn)	• Activates photosynthetic enzymes • Important for cell respiration and nitrogen metabolism	• Network of dark green leaf veins with a background of light green • Light brown or grey spots in between leaf veins
Boron (B)	• Helps the roots in calcium ion uptake and sucrose translocation • Involves in carbohydrate metabolism and helps in germination of pollen	• Death of terminal buds and abnormal growth • Leaves become thicker, rolled up and fragile
Zinc (Zn)	• Important in leaf formation • Synthesis of auxin (growth hormone) • As a cofactor in carbohydrate metabolism	• Leaf surfaces become spotted with chlorosis parts • Stunted growth
Copper (Cu)	• Involves in nitrogen metabolism and photosynthesis • Important for growth, reproduction and flower formation	• Death of young shoot apex • Brown spots on terminal leaves • Plants become stunted
Nickel (Ni)	• A component of plant enzymes involved in the breakdown of urea to become ammonia which can be used by plants	• Stunted growth • Reduces crop production • Burnt effect at the end of leaves due to urea accumulation
Molybdenum (Mo)	• Involves in nitrogen fixation and nitrate reduction during protein synthesis	• Chlorosis in between matured leaf veins • Leaf colour becomes pale green • Reduces crop production

3.1.2

A culture solution is used to study the importance of nutrients for plant growth. A culture solution known as **Knop's solution**, contains all nutrients including trace elements needed by healthy plants. A complete culture solution was prepared by a chemist named Wilhelm Knop in 1859. Table 3.3 shows the composition of a complete Knop's culture solution.

Table 3.3 The composition of a complete Knop's culture solution

Complete Knop's culture solution	
Calcium nitrate, $Ca(NO_3)_2$	0.8 g
Potassium nitrate, KNO_3	0.2 g
Potassium dihydrogen phosphate, KH_2PO_4	0.2 g
Magnesium sulphate, $MgSO_4$	0.2 g
Iron(III) phosphate, $FePO_4$	Trace
Distilled water	1000 cm^3

History Corner

Julius Sachs and Wilhelm Knop were the botanists who carried out experiments to determine the role of macronutrients in plant growth.

EXPERIMENT 3.1

The Effects of Nitrogen: Phosphorus: Potassium Ratios on Plant Growth

Problem Statement: What are the effects of nitrogen: phosphorus: potassium (N:P:K) ratio on the growth of corn seedlings?

Aim: To investigate the effects of identified nitrogen: phosphorus: potassium (N:P:K) ratio on the growth of corn seedlings

Hypothesis: Corn seedlings undergo healthy growth in Knop's solution with the ratio of nitrogen: phosphorus: potassium (N:P:K)

Variables

Manipulated variable: Nitrogen, phosphorus and potassium ratio

Responding variable: Growth of corn seedlings

Constant variable: Volume of solution

Materials: Corn seedlings (*Zea mays*), calcium nitrate, $Ca(NO_3)_2$, potassium nitrate, KNO_3, potassium dihydrogen phosphate, KH_2PO_4, magnesium sulphate, $MgSO_4$, iron(III) phosphate, $FePO_4$, distilled water, cotton, black paper, calcium chloride, potassium chloride, calcium phosphate, iron(III) oxide, sodium nitrate

Appparatus: Culture bottles, L-shaped delivery tubes, corks, air pumps

Procedure

1. Prepare five culture bottles with A, B, C, D and E labels.
2. Fill the culture bottles A, B, C, D and E with solution as shown in Table 3.4.
3. Select five corn seedlings of the same size and put each one of them into the culture bottles by inserting the stem through the hole on the cork. Make sure the roots of the seedlings are immersed in the solution.

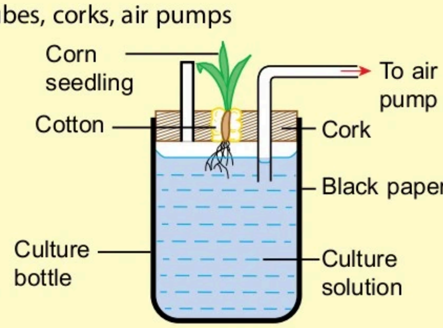


Figure 3.3 Set-up of apparatus

3.1.2

EXPERIMENT

4. Cover all the culture bottles with black paper to avoid the growth of green algae.
5. Connect the culture bottles to an air pump to ensure the roots receive oxygen supply.
6. Replace the culture solution in each bottle with a new solution every week.
7. Place the apparatus in a well-lit place.
8. Observe and record the growth of corn seedlings in terms of leaf colour, plant height, root length and stem strength after four weeks.

Table 3.4

Culture bottle	Components of culture solution					
	Calcium nitrate (0.8 g)	Potassium nitrate (0.2 g)	Potassium dihydrogen phosphate (0.2 g)	Magnesium sulphate (0.2 g)	Iron(III) phosphate (Trace)	Distilled water (1000 ml)
A (Complete culture solution)	✓	✓	✓	✓	✓	✓
B (control)	✗	✗	✗	✗	✗	✓
C (without nitrogen)	Replaced with calcium chloride	Replaced with potassium chloride	✓	✓	✓	✓
D (without phosphorus)	✓	✓	Replaced with potassium chloride	✓	Replaced with iron(III) oxide	✓
E (without potassium)	✓	Replaced with sodium nitrate	Replaced with calcium phosphate	✓	✓	✓

Observation

Culture bottle	Nutrient deficiency	Observation
A		
B		
C		
D		
E		

Discussion

1. State **two** precautionary steps to be taken during apparatus and material preparation. Justify.
2. Which culture bottle has grown a healthy corn seedling?
3. How does the ratio of nitrogen: phosphorus: potassium (N:P:K) affect the growth of corn seedlings?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

3.1.2