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NUTRITION IN PLANTS – MINERAL NUTRITION

Sometimes you may observe that a potted plant kept in sunlight and provided with sufficient water does not grow. Its leaves look pale and weak. Plant may not even flower properly. Such a situation is an indication, that the plant may not be getting all that is required for normal growth and development.

In most of such situations one or more minerals required may be lacking in the soil. You might have seen farmers adding some extra manure (khad) to the soil. In this lesson you will learn the importance of mineral nutrition in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define the terms mineral nutrition, macro and micro nutrients;*
- *explain the functions of minerals with reference to the techniques of hydroponics and aeroponics;*
- *list the role of macro and micro nutrients;*
- *mention the deficiency symptoms of macro and micro nutrients;*
- *differentiate between autotrophic and heterotrophic nutrition in plant;*
- *describe the saprophytic and parasitic modes of nutrition in plant.*

9.1 WHAT IS PLANT NUTRITION

As you know that all living organisms require food to survive, grow and reproduce so every organism takes in food and utilizes the food constituents for its requirements of growth. A series of processes are involved in the synthesis of food by plants, breaking down the food into simpler substances and utilization of these simpler substances for life processes. **Nutrition** in plants may thus be defined as a process of synthesis of food, its breakdown and utilisation for various functions in the body.

The chemical substances in food are called nutrients e.g. CO_2, water, minerals, carbohydrate, protein, fats etc. Green plants can make their own organic food from simple substances like water and carbon dioxide through the process of photosynthesis and are called autotrophs (auto : self; trophos : feeding). But the non-green plants and other organisms which cannot prepare their own food and obtain nutrition from green plants are called **heterotrophs** (heteros : different).

9.2 MINERAL NUTRITION

Now we will discuss how plants get the nutrients. You already know that carbohydrates are synthesised by the process of photosynthesis. What are the elements present in these carbohydrates?

Carbon, hydrogen and oxygen are the main elements in carbohydrates, fats and proteins. In addition to these three elements, plants need a variety of elements for their survival. These are generally referred to as mineral elements. They are absorbed by the root system of plants in the form of their salts.

The study of how plants get mineral elements and utilize them for their growth and development is called **mineral nutrition.**

If the minerals are not available to plants, specific symptoms appear due to the deficiency of a particular element. There are methods to determine the requirement of minerals by plants. Some such methods are given below.

9.3 METHODS TO DETERMINE THE REQUIREMENT OF MINERALS FOR PLANT

Minerals are absorbed by plants in **solution form.** So it is possible to grow plants in water containing the desired amount of mineral salts taking care that the aerial parts are exposed to air and light.

> This technique of growing plants in a nutrient solution in complete absence of soil is known as **Hydroponics/water culture.**
>
> It was demonstrated for the first time by a German Botanist Julius Von Sachs in the year 1980.

In water culture experiments, seedlings are made to grow in water containing the known nutrients in a particular proportion. Vigorous bubbling of the air is routinely done to provide sufficient oxygen to the root system. The culture solutions may contain all essential nutrients except the one whose importance is to be identified. Then the plant growing in it is compared to the one growing with all essential nutrients (**control experiment**).

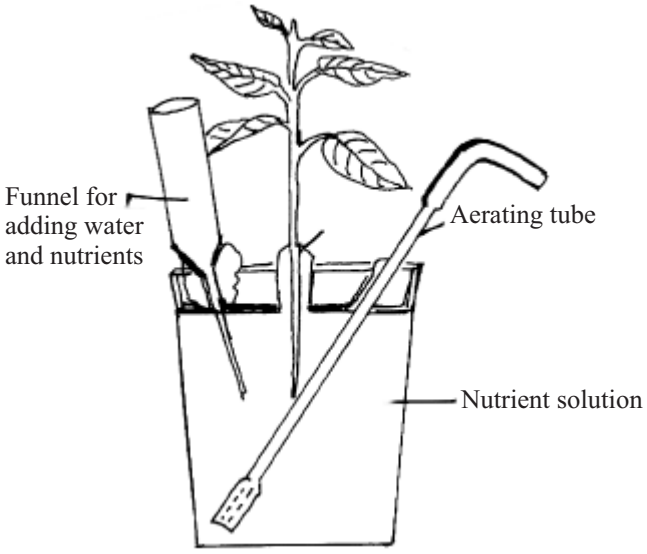

Fig. 9.1 Experimental set up for nutrient solution culture of plants.

Water culture experiments help us to understand :

(i) which element is essential for normal growth of the plant.

(ii) which element is not essential and is absorbed along with other nutrients.

(iii) how much quantity of each mineral is essential.

Hydroponics has been successfully employed for the commercial production of seedless cucumber, tomato and lettuce.

Aeroponics : Like hydroponics, aeroponics is another technique of growing plants in an air/mist environment without the use of soil.

Aeroponics is a technique of growing plants with their roots supplied with moisture present in the air. Rooted plants are placed in a special type of box. The shoots of the rooted plants are exposed to air and the roots are inside the box having computer controlled humid atmosphere. The roots are sprayed/misted for short durations with a hydro-atomized pure water/nutrient solution. This method has been developed recently. Since plants cultured by this technique get a very good growth of root hairs, it is very useful method for research purposes. Citrus plants and olives have been successfully grown through aeroponics.

INTEXT QUESTIONS 9.1

1. What are nutrients ?

   .....

2. Define aeroponics.

   .....

3. Why is it necessary to aerate nutrient solution in water culture?

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9.4 ESSENTIAL MINERAL ELEMENTS

You know that 112 elements have been discovered until now. So you might be wondering whether plants require all 112 elements for their mineral nutrition. Most of the mineral elements present in soil are absorbed by roots of the plant. But all are not essential. Only **17 elements** are considered as essential for the plants. Let us now discuss the criteria for the essentiality of an element for normal plant growth.

9.4.1 Criteria for Essentiality of Elements

The nutrients or elements which are essential for the healthy growth of the plant are called **essential nutrients or essential elements.** The roots absorb about 60 elements from the soil. To determine which one is an essential element, the following criteria are used :

(i) An essential element is absolutely **necessary for normal growth** and **reproduction** of the plant, and should be a part of essential metabolite for plant growth.

(ii) The requirement of the element is very specific and it **cannot be replaced** by another element.

(iii) The element is **directly** or indirectly **involved** in the metabolism of a plant.

(iv) In the deficiency of an essential element, the plant would exhibit specific symptoms of deficiency, and the plant would recover from its symptoms, if supplied with the deficient element.

Example : Magnesium is said to be an essential element because it is essential for the formation of chlorophyll molecule. Its deficiency causes yellowing of leaves.

9.4.2 Types of Essential Elements

Essential elements may be required in small amounts or large amounts. Accordingly they have been grouped into two categories

Essential Elements

Micro elements/Micronutrients	Macro elements/Macro nutrients
Required in minute quantities like 0.1 mg per gram of dry matter or less than that. Also called as **trace elements.**	Required in relatively large quantities like one to 10 milligram per gram of dry matter
Examples : Manganese, Boron, cobatt Copper, Molybdenum, Iron, Zinc and Chlorine are required in very small quantities	**Examples :** Carbon, Hydrogen, Oxygen Phosphorous, Potassium, Calcium and magnesium, Nitrogen, Sulphur

9.4.3 Sources of Essential Elements for Plants

After studying the types of essential elements we will now discuss about their sources. Most of the essential elements are taken from soil, and some from the atmosphere. The table given below focuses on the sources of different essential elements.

Table 9.1 Sources of Essential Elements

Elements	Sources of the elements
Carbon	Taken as CO_2 from the atmosphere (air)
Oxygen	Absorbed in the molecular form from air or from water. It is also generated within a green plant during photosynthesis.
Hydrogen	Released from water during photosynthesis in the green plant
Nitrogen	Absorbed by the plants as nitrate ion (NO_3^-) or as ammonium ion (NH_4^+) from the soil. Some organisms like bacteria and cynobacteria can fix nitrogen from air directly.
Potassium, calcium iron, phosphorus, sulphur magnesium	absorbed from the soil (are actually derived from the weathering of rocks. So they are called mineral elements). They are absorbed in the ionic forms e.g. K^+, Ca^{2+}, Fe^{3+}, $H_2PO_4^-$/ HPO_4^{2-} etc.

INTEXT QUESTIONS 9.2

1. In which form do plants get oxygen?

   .....

2. Molybdenum is a micronutrient. Give reason.

   .....

3. Why are carbon, oxygen, potassium and sulphur called macronutrients?

   .....

9.5 ROLE OF MACRO AND MICRO NUTRIENTS

Essential elements perform various functions. They carry out several metabolic processes in the plant cells like the maintenance of turgidity of cell, transportation of electrons, membrane permeability and enzyme activity. Essential elements also act as important constituents of the biomolecules and co-enzymes. Various functions of the macro and micro nutrients are given in the following table.

The forms in which the elements are taken in and their functions are described in the table given below -

Table 9.2 Essential Elements and their Functions

Element	Form in which the element is taken in	Region of the plant that requires the element	Function
Nitrogen, N	NO_2^-, NO_3^- or NH_4^+ ions	All tissues, particularly in meristematic tissues	Required for the synthesis of amino acids, proteins nucleic acids, vitamins, hormones, coenzymes, ATP and chlorophyll.
Phosphorus, P	$H_2PO_4^-$ or HPO_4^{2-}	Young tissues from the older metabolically less active cells	Required for the synthesis of nucleic acids phospho-lipids, ATP, NAD and NADP. Constituent of cell membrane and some proteins.
Potassium, K	K^+	Meristematic tissues buds, leaves and root tips.	Activates enzymes, associated with K^+/Na^+ pump in active transport, anion-cation balance in the cells. Brings about opening and closing of stomata. Common in cell sap in plant cell vacuole and helps in turgidity of cells.
Calcium, Ca	Ca^{2+}	Meristematic and differentiating tissues Accumulates in older leaves	Present as calcium pectate in the middle lamella of cell walls that joins the adjacent cells together. Activates enzymes needed for the growth of root and shoot tip. Needed for normal cell wall development. Required for cell division, cell enlargement.
Magnesium, Mg	Mg^{2+}	Leaves of the plant	Forms part of the chlorophyll molecule. Activates enzymes of phosphate metabolism. Important for synthesis of DNA and RNA. Essential for binding of ribosome subunits.
Sulphur, S	SO_4^{2-}	Stem and root tips young leaves of the plant	As a constituent of amino acids cysteine and methionine and of some proteins. Present in co-enzyme A, vitamin thiamine, biotin and ferredoxin. Increases root development. Increases the nodule formation in legumes.

Iron, Fe	Fe^{3+}	Leaves and seeds	Needed for the synthesis of chlorophyll. As a constituent of ferredoxin and cytochromes. Activates the enzymes catalase.
Manganese Mn	Mn^{2+}	All tissues. Collects along the leaf veins.	Activates many enzymes of photosynthesis, respiration and N_2 metabolism. Acts as electron donor for chlorophyll b. Involved in decarboxylation reactions during respiration.
Molybdenum Mo	MoO_2^{2+}	All tissues particularly in roots	Required for nitrogen fixation. Activates the enzyme nitrate reductase.
Boron, B	BO_3^{3-} or $B_4O_7^{2-}$	Leaves and seeds	Increases the uptake of water and calcium. Essential for meristem activity and growth of pollen tube. Involved in translocation of carbohydrates
Copper, Cu	Cu^{2+}	All tissues	Component of oxidase enzymes and plastocyanin. Involved in electron transport in photosynthesis.
Zinc, Zn	Zn^{2+}	All tissues	Component of indoleacetic acid – a plant hormone. Activates dehydrogenases and carboxylases. Present in enzyme carbonic anhydrase
Chlorine, Cl	Cl^-	All tissues	Essential for oxygen evolution in photosynthesis. Anion-cation balance in cells.

INTEXT QUESTIONS 9.3

1. State any two metabolic processes for which mineral nutrition is required.

   .....

2. Which element is provided by NO_2 and NH_4 when taken up by plants?

   .....

3. State any two functions of Ca^{2+} in plants?

   .....

9.6 SYMPTOMS OF MINERAL DEFICIENCY IN PLANTS

The absence or deficiency (not present in the required amount) of any of the essential elements leads to **deficiency symptoms.** The symptoms can be studied by hydroponics. Under natural conditions, these symptoms can be taken as indicators of the mineral deficiencies in the soil.

Some common deficiency symptoms are :

- **Chlorosis** - It is the loss of chlorophyll leading to yellowing in leaves. It is caused by the deficiency of elements like K, Mg, N, S, Fe, Mn, Zn and Mo.
- **Necrosis** or death of tissues, particularly leaf tissue is caused by deficiency of K, Ca, Mg
- **Inhibition of cell division** is caused due to lack or deficiency of N, K, B, S and Mo.
- Stunted/Retarded plant growth caused by the deficiency of N, P, K, Zn, Ca
- Premature fall of leaves and buds is caused by deficiency of K, P.
- Delay in flowering is caused due to deficiency of N, S, Mo.

9.7 UPTAKE OF MINERAL ELEMENTS

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be **passive** or **active**.

(a) **Passive Absorption** : It is the initial and rapid phase wherein ions are absorbed into the "outer space" of the cells, through the apoplast (Recall from lesson No. 08) pathway. It does not require use of any metabolic energy.

(b) **Active Absorption :** It is the second phase of ion uptake. The ions are taken in slowly into the 'inner space' the symplast of cells (Lesson No. 08). It needs the expenditure of metabolic energy.

The movement of ions is called **flux.** When the ions move into the cells, it is called **influx** and the outward movement of ions is called **efflux**.

The mineral ions absorbed by the root system are translocated through the xylem vessels to other parts of the plant.

INTEXT QUESTIONS 9.4

1. What is meant by 'passive absorption' of minerals by plants.

   .....

2. Name the minerals whose deficiency affects normal cell division.

   .....

3. "Deficiency of K, Ca and Mg causes necrosis of leaves". What does this statement mean ?

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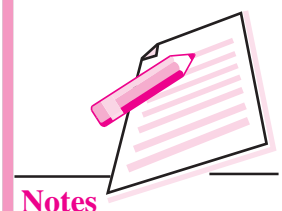
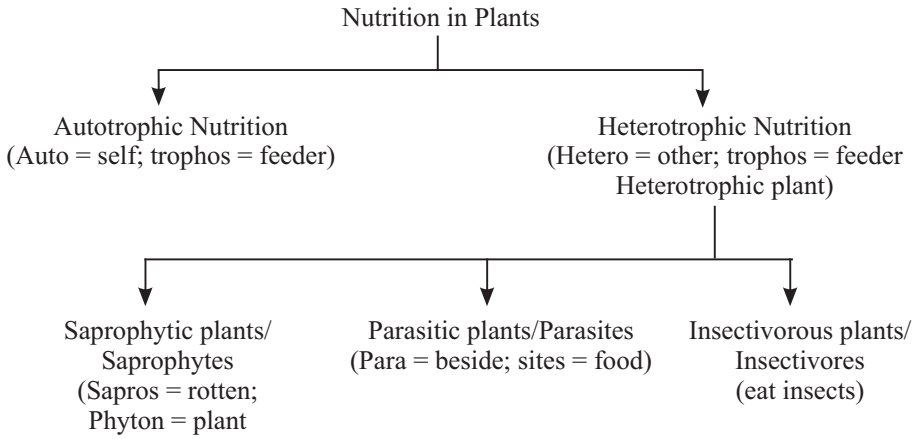


9.8 MODE OF NUTRITION IN PLANTS

Nutrition is plants is classified into two main categories : autotrophic and heterotrophic. Heterotrophic plants are further classified into saprophytes, parasite and insectivores.



1. Autotrophic Nutrition

It is a type of nutrition in which the living organisms manufacture their own organic food from simple inorganic raw materials. The green plants exhibit autotrophic mode of nutrition and hence called the autotrophs. The autotrophs require external energy source for the manufacture of organic substances. Green plants obtain energy from sunlight and therefore are called **photoautotrophs**. The process of synthesizing food in plant in the presence of sunlight is called **photosynthesis**. The insectivores are autotrophic but they develop specific structures to trap insects to overcome N_2 deficiency because they grow in soils having acute N_2-deficiency.

2. Heterotrophic nutrition

Certain non green organisms like fungi and many bacteria fail to synthesize their own organic nutrients from inorganic substances. These organisms are thus dependent on some other external sources for their organic nutrition. Such plants are called **heterotrophic plants** and the mode of nutrition is called **heterotrophic nutrition.**

The heterotrophic plants are broadly categorised into two main groups depending upon the source from which they get their nourishment. Saprophytes, and parasites.

(a) **Saprophytes** are those plants which grow and live on dead organic matter including animal and plant remains. Most of these plants secrete some extracellular enzymes (enzymes secreted and poured out on food) which break down the complex organic compounds into simple forms. The simple form are then absorbed by the plants. Saprophytes include mainly fungi and bacteria. Also among higher plants the Indian pipe plant *Monotropa* found in khasi hills of our country (Fig. 9.2) is a saprophyte.

Fig. 9.2 A Monotropa, a saprophyte.

(b) **Parasitic Plants** : *Dodder* (*Cuscuta*) known locally as Amarbel/Akashbel is a parasitic plant that lacks both chlorophyll and leaves. It is a yellow colour climber that attaches itself to the host. It gives out haustoria or the suckers that get attached to the phloem of the host and derive nutrition. *Cuscuta* does not have roots in the mature condition. It produces bunches of whitish or yellowish bell shaped flowers.

Insectivorous Plants : These are plants which are autotrophic but develop adaptations to trap insects in order to **supplement the deficiency of Nitrogen in the soil**. They feed on insects. They are generally found in nitrogen deficient habitats and hence to compensate the loss, they use insects as a source of nitrogen. Some examples are given below :

(i) Pitcher plant : *Nepenthes* (ii) Sundew : *Drosera*

(iii) Venus flytrap : *Dionaea* (iv) Bladderwort : *Utricularia*

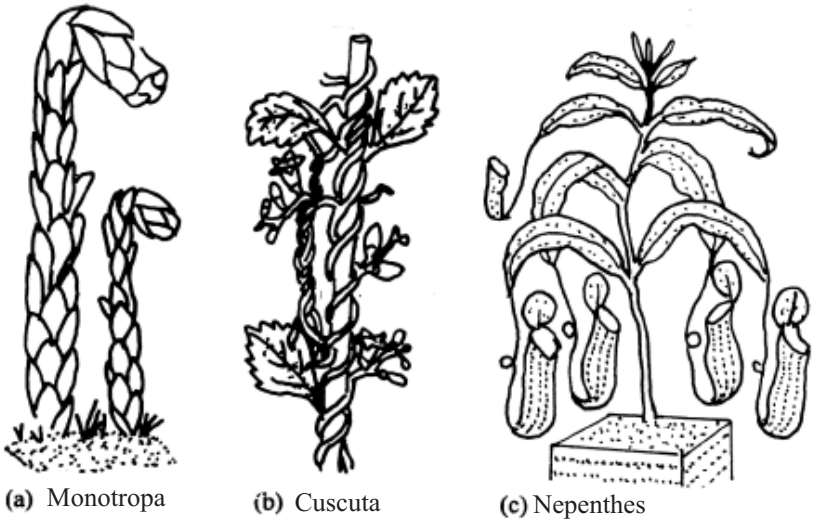
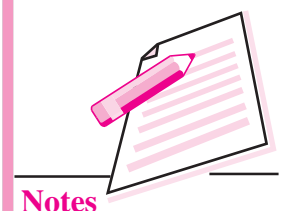


Fig. 9.3 Heterotrophic plants : (a) *Monotropa* (Indian pipe plant (b) *Cuscuta* (dodder) and (c) *Nepenthes* (pitcher plant)

Pitcher plant (Nepenthes) : It is found in north eastern India, Borneo and in many regions of North America.



These plants grow well in wet soils. The leaves are modified in the form of pitchers. The pitcher has nectar producing glands below its rim. Shiny surface of the pitcher and nectar secreted by nectar glands attract the insects. Insects once trapped can not escape due to the presence of numerous downward pointing hairs in the pitcher. The digestive glands present at the base of pitcher secrete enzymes. The insects are digested by the enzymes and the products which are mainly aminoacids are absorbed by the inner surface of leaves (pitcher).

INTEXT QUESTIONS 9.5

1. Give one point of difference between autotrophic and heterotrophic nutrition.

   .....

2. Name a plant which exhibits parasitic mode of nutrition.

   .....

3. Why does pitcher plant eat insects when it is capable of carrying out photosynthesis?

   .....

WHAT YOU HAVE LEARNT

- Plants have the nutritional requirement of various inorganic and organic raw materials for building their structure and maintaining body functions.
- Nutrition is the sum total of processes involving intake or synthesis of food and its utilisation.
- Plants generally derive their inorganic nutrients from soil, water and atmosphere.
- The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition.
- Plants require 17 essential elements. They are C, H, O, N, P, K, S, Mg, Ca, Fe, B, Mn, Cu, Zn, Mo, Cl and Co.
- The essentiality of minerals may be determined by employing the technique of hydroponics and aeroponics.
- Inorganic nutrients are broadly classified into two categories-micronutrients and macronutrients on the basis of the amount required by plant.
- Absence of any one element may cause deficiency symptoms in plants. These symptoms include reduction in growth, delaying of flowering, chlorosis, necrosis, early leaf fall, wilting etc.

- The minerals are taken by the roots through passive or active absorption.
- Basically, there are two modes of nutritioin autotrophic and heterotrophic.
- In autotrophic nutrition the organisms (plants) manufacture their own food from inorganic raw materials by photosynthesis or chemosynthesis.
- In heterotrophic nutrition the organism is dependent on other external sources for its organic nutrition.
- Heterotrophic plants are broadly categorised into two main groups: saprophytes, and parasites.
- Insectivorous plants are special type of autotrophic plants which grow in N_2-deficient soils and develop adaptations to trap insects to overcome N_2-deficiency.

TERMINAL EXERCISES

1. Which element can be obtained from both mineral and non-mineral sources.
2. Deficiency of which essential element causes yellowing of leaves in certain plants and why?
3. Why is magnesium included among essential elements?
4. What are the criteria of essentiality of elements?
5. Differentiate between micro and macro nutrients.
6. Why do biologists grow plants by hydroponics technique?
7. Explain the uptake of mineral nutrients by the plants.
8. Give the deficiency symptoms of nitrogen, phosphorus and potassium.
9. Differentiate between the different modes of heterotrophic nutrition in plants.
10. Write notes on :
    (i) Aeroponics
    (ii) Insectivorous plants
    (iii) Active absorption of minerals by plants

ANSWERS TO INTEXT QUESTIONS

9.1 1. Nutrients are the chemical substances in food

2. A technique of growing plants with roots supplied with moisture present in the atmosphere.

3. To supply oxygen in sufficient quantity

9.2 1. Molecular form from air or water

2. Required by plant in very small quantity. 0.1 mg per gram of dry matter or less.

3. They are required in large quantities 1-10 mg per gram of dry matter.

9.3 1 Membrane permeability, turgidity of cell, transport of electrons, enzyme activity (any two)

2. Nitrogen

3. See table 9.2

9.4 1. Without expenditure of energy

2. N, K, S, Mo (any two)

3. The deficiency causes death of leaf tissues

9.5 1. Autotrophs synthesize their own food, heterotrophs depend on others for food

2. *Cuscuta* (dodder)

3. Because it grows in a nitrogen deficient habitat.