Chapter-4

ESSENTIAL PLANT NUTRIENTS AND THEIR DEFICIENCY SYMPTOMS

OBJECTIVES

After studying this unit, you will be able to understand:

- Essentiality of plant nutrition
- Classification of essential nutrients on the basis of their requirement to plant
- Functions of plant nutrients on growth and development of crop plants and their deficiency symptoms

INTRODUCTION

The plant nutrients are essential for optimum plant growth. Nutrients are naturally present in the soil. There may be certain questions arising in your mind. Why does plant need nutrients? How many nutrients are there which are required for the growth and development of the crop? What are their functions and effects on plant growth and development? What will happen if there is deficiency of these nutrients? How will we identify the deficiency symptoms of a particular nutrient in the soil and plant? The knowledge of the specific role of the essential elements in normal growth and development of the plant, their deficiency symptoms and amount required for the optimum crop production is considered necessary to understand soil fertility better and to adopt scientific use of fertilizers. Plant nutrients taken up by crops during the growing season may come from many sources including soil, synthetic fertilizers or manure, and also crop residues. Most soil conditions across the world can provide plants with adequate nutrition and do not require fertilizer(s) for a complete life cycle. However, man can artificially modify soil through the addition of fertilizer to promote vigorous growth and higher yield. It is essential to apply balanced quantity of nutrients through man-made fertilizers. An element present at a low level may cause deficiency symptoms, while the same element at a higher level may cause toxicity.

What is Plant nutrition?

Plant Nutrition is the study of the chemical elements and compounds that are necessary for plant growth, and also of their external supply and internal metabolism. During the first half of the 19th century, it was found that elements are absorbed by roots principally as inorganic ions in soils and these are derived mostly from mineral constituents of soil. The term **Mineral Nutrition** generally refers to an inorganic ion obtained from the soil for plant growth.

The process of absorption, translocation and assimilation of nutrients by the plants is known as **mineral nutrition**. Nutrients are chemical elements, which are absorbed by the plants in more and less large quantities to transform light energy into chemical energy and to keep up plant metabolism for the synthesis of organic materials.

Difference between plant nutrition and fertilization
Plant nutrition means basic chemical elements required for plant growth whereas fertilization refers to the external application of synthetic plant nutrients to supplement the nutrients naturally present in the soil.

Criteria of Essentiality: Arnon & Stout proposed criteria of essentiality, which was refined by Arnon (1954). According to this criterion, an element is considered as essential when-

1. A deficiency of the element makes it impossible for the plant to complete its life cycle.
2. Its deficiency can be corrected or prevented only by supplying this element.
3. The element is directly involved in the metabolism of the plant.

ESSENTIAL NUTRIENTS: An **essential nutrient** is one required by an organism for normal growth and development, but it cannot be manufactured by the plant on its own. There are 17 elements which are essential for plants namely, carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl), boron (B) and nickel (Ni). Nickel has been recently included to be an essential nutrient. There is a controversy among plant physiologists concerning the role of nickel in plant nutrition.

CLASSIFICATION OF ESSENTIAL ELEMENTS: Over 95 percent of the dry weight of a flowering plant is made up of three elements namely, carbon, hydrogen, and oxygen which are taken by the plant from the air and water. The remaining 5 percent of the dry weight comes from chemicals absorbed from the soil. Roots absorb the chemicals present in their surroundings, but only 14 of the elements absorbed are essential for plant growth. These 14 elements, along with carbon, hydrogen, and oxygen, are called as the **17 essential inorganic nutrients**, or **elements**. All elements are needed in specific amounts.

Therefore, depending upon the quantity of nutrients present in plants, these elements can be grouped into three categories:

1. ***Basic Nutrients***- Out of the 95% of the total dry matter content of the plants, carbon and oxygen constitute 45% each. For example:- total dry matter produced by rice crop in one season is about 12 t/ha in which 5.4 t is oxygen, 5.4 t is carbon and 0.7 t is hydrogen.

2. **Macronutrients** The nutrients which are required in larger quantities for better growth and development of the plant are known as macronutrients. They include N, P, K, Ca, Mg, and S. Among these, **N, P and K** are called primary nutrients as they are usually deficit in the soil and plants require them in large amounts for growth and development, whereas **Ca, Mg**, and **S** are known as secondary nutrients. They are known as secondary nutrients due to their secondary importance to the plants. Usually, soils are not deficit in secondary nutrients so there application is not done in general.

3. ***Micronutrients-*** The nutrients which are required in small quantities are known as micronutrients or trace elements. They are Fe, Zn, Cu, B, Mo, Mn and Cl. These are also known as trace/minor/rare elements which are very efficient. Their deficiency and excess can be harmful to the plants.

Criteria of essentiality: An element is said to be essential if

1. It is required for normal growth and reproduction
2. It can not be replaced by another element
3. It can be part of a molecule clearly essential to the plant structure or metabolism.

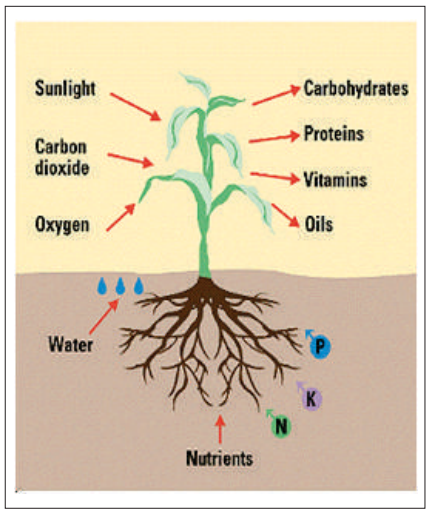
Plants use elements in different amounts and forms *e.g.* some as cations and others as anions. Almost all elements are used in a variety of ways-

i) Catalysts for enzymatic reactions (either as a part of the enzyme structure or as a regulator or an activator),
ii) Regulators of the movement of water in or out of the cell and maintenance of turgor pressure
iii) Regulators of membrane permeability,
iv) Structural components of the cell or of electron receptors in the electron transport system, or as buffers (which maintain the pH within cells).

Functions in the plants-Based on the functions, the nutrients are classified into four groups:

1. Elements that provide basic structure to the plant- C, H, and O.
2. Elements useful in energy storage, transfer and bonding- N, S, and P. These are necessary structural elements which are more active and vital for living tissues.
3. Elements necessary for charge balance- K, Ca, and Mg. They act as a regulator and as a carrier.
4. Elements involved in enzyme activation and electron transport- Fe, Mn, Zn, Cu, B, Mn, and Cl. These elements are catalyzers and activators.

The importance of all the 17 essential elements lies in their specific function or roles in various biochemical or biological system essential for growth and development of the plant. As each nutrient perform specific function, its adequate and deficient supply lead to development of visual deficiency symptoms in plants. The deficiency symptoms generally appear on specific plant parts *i.e*. leaves, stem or roots. Deficiency symptoms are the first indication of non availability of nutrients in soil and hence the specific and general functions and visual deficiency symptoms of the essential plant nutrients will help in better understanding of fertilizer or nutrient need of plants.



Source: BMP Home page

Functions of essential plant nutrients

1. CARBON-

- It is obtained from the air in the form of carbon dioxide.
- Carbon is a building block of all organic compounds.

Deficiency symptoms:

- It is rarely limiting as a nutrient and there are no specific symptoms

2. HYDROGEN-

- It is obtained from the soil in the form of water.
- Hydrogen is the component of water and all organic compounds.

Deficiency symptoms:

- It is rarely limiting as a nutrient and there are no specific symptoms

3. OXYGEN-

- It is also obtained from the soil in the form of water.
- Oxygen works as a final electron acceptor in aerobic respiration and act as a constituent in carbohydrates, nucleic acid and many organic compounds.

Deficiency symptoms:

- It is rarely limiting as a nutrient and there are no specific symptoms.

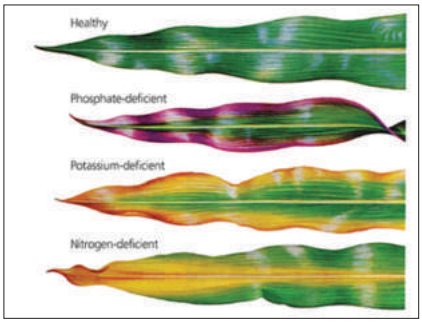
4. NITROGEN-

- It is considered as a basic constituent of life since it is an essential component of many important compounds like proteins, chlorophyll, nucleotides, phosphatides, alkaloids, enzymes, hormones, vitamins, *etc.*
- It imparts dark green color to plants.
- It promotes vegetative growth and results in delayed maturity.
- Nitrogen is most likely to be deficient in soil.

Deficiency symptoms

- Growth is seriously restricted and leaves become small.
- Uniform yellowing of the leaves including veins.
- The leaves become stiff and erect and crops show characteristics 'V' shaped yellowing at the tip of lower/older leaves and die prematurely.

5. PHOSPHORUS-



- It is a constituent of nucleic acid, phytin, phospholipids, and many enzymes.
- It has a great role in energy transfer and storage. Thus, it is essential for photosynthesis and other physiological processes taking place in the plant.
- It is closely related to cell division and development.
- It stimulates flowering and seed development and counteracts the effects of excessive nitrogen.
- Phosphate compound act as “energy currency” within plants *i.e.* in the form of adenosine di and tri-phosphate (ADP and ATP).
- It is particularly useful for leguminous crops as it increases the activity of nitrogen fixing bacteria living inside the nodules located on roots of legume plants.
- It is the second most likely nutrient to be deficient in soil.

Deficiency symptoms

- Growth is restricted and in contrast to nitrogen, the foliage remains dark green.
- Growth of the plant is stunted.
- Leaves become small, erect, unusually dark green with a greenish red, greenish brown or purplish tinge; the rear side shows bronzy appearance.
- Margin of leaves tend to curl upward and inward and die prematurely.

6. POTASSIUM-

- It is essential in the formation and transformation of starches and sugars.

- It improves the quality of final products such as quality of leaves, taste, size and keeping quality of fruits.
- It counteracts the injurious effect of N in plants.
- It plays an important role in osmotic regulation in plant, stomatal opening and closing.
- It imparts vigour and resistance to plants against attack of pests.

Deficiency symptoms

- Stems and roots become weak and spindly.
- Symptoms appear especially on older leaves which look burnt along the margins of leaves (scorching) extending to the centre of leaf base which also become necrotic.
- Yellowing in leaves starts from tips or margins.
- Plants easily lodge and become sensitive to disease infestation especially the roots.
- Fruit and seed production is impaired and also their quality is affected.

7. CALCIUM-

- It is an important constituent of cell wall and increases stiffness of plants.
- It has an essential role in cell elongation and cell division.
- It is essential for root growth.
- It influences water economy of the plant, protein-carbohydrate ratio in fat metabolism as well as many other physiological processes.
- It corrects soil acidity and increases availability of other nutrients such as phosphorus, nitrogen and molybdenum in such soils.

Deficiency symptoms

- Young leaves and shoots are mostly affected.
- The bud leaves becomes chlorotic white with the base remaining green. About one-third chlorotic portion of the tip hook downwards and become brittle.
- In extreme cases, its deficiency results in death of terminal bud.
- Deficiency affects fruit quality and results in 'Blossom end rot' in tomato fruits

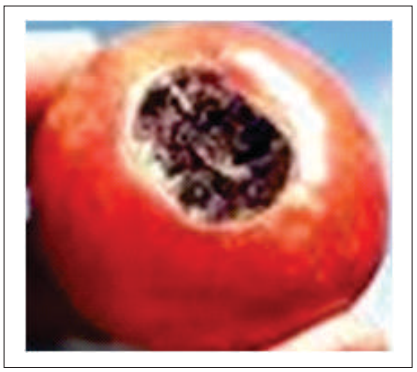
8. MAGNESIUM-

- It is the constituent of chlorophyll, thus helps in maintaining the dark green color of leaves.
- It acts as a carrier of P in plants particularly in connection with formation of seeds with high oil content. So, it promotes formation of oils and fats.
- It plays important role in the production of carbohydrates, proteins, fats and vitamins and in certain catalytic reactions in the enzyme systems.

Deficiency symptoms

- Leaf tips and margins turn upward mostly on older leaves; Chlorosis; mottling

- It causes yellowing, but differs from that of N. The yellowing takes in between the veins and the veins remains green.
- Some dead spots appear on leaves and leaves become reddish color.
- The necrosis (death of tissues) only on margin.



Deficiency of Ca and Mg results in 'Blossom end rot' in tomato

9. SULPHUR-

- It helps in chlorophyll formation and encourages vegetative growth in plants.
- It is an essential constituent of many enzymes, proteins, and certain volatile compounds like mustard oil.
- It promotes nodule formation on roots of legumes.

Deficiency symptoms

- The leaves become small and yellowish.
- The leaf veins are paler than inter-veinal portion.

10. IRON-

- It helps in formation of chlorophyll, though it is not a constituent of chlorophyll.
- It is a constituent of enzymes which play vital role in many processes like oxidation-reduction, respiration, photosynthesis, reduction of nitrates and sulphates.
- It helps in the synthesis of proteins of chloroplasts.

Deficiency symptoms

- Roots become short and slender.
- The youngest leaves become yellow and interveinal yellowing develops near the base of the older leaves.
- The principal veins remain green and other portions of leaf turn yellow and later on become white.

Fe deficiency symptoms- yellowing of young leaves

11. ZINC-

- It is a constituent of several enzyme systems which regulate various metabolic reactions in the plant like oxidation-reduction reactions in the formation of chlorophyll, *etc.*

- It influences the formation of some growth hormones in the plant. It helps in auxin synthesis.
- It is essential for the synthesis of proteins contained in the choroplast.
- It helps in maintenance of ribosome structure

Zinc deficiency symptoms in tomato- stunting growth with white spotting between veins

Deficiency symptoms

- Size of leaves and internodal length get reduced.
- Leaf lamina become chlorotic and the veins remain green especially in older leaves.

12. BORON-

- The primary role of B is associated with Ca metabolism.
- It increases solubility and mobility of Ca in plants.
- It acts as a regulator of K/Ca ratio in plants and helps in absorption of nitrogen.
- It plays role in many other functions pollen germination and growth of pollen tubes, carbohydrate metabolism as well as nitrogen metabolism *etc.*

Boron deficiency causes cracking of fruits in tomato

Deficiency symptoms

- Young tissues are most affected.
- Yellowing on the tip of the mature leaves gradually spread around the margins and the main vein become reddish-brown.
- Abnormal development of the growing points with the apical meristems eventually becoming stunted and later on the apical meristem wither.
- Root tips become swollen and discolored.
- Flowers and fruits abort.

13. COPPER-

- It acts as an “electron carrier” in enzymes which brings about oxidation and reduction in the plants.
- It helps in utilization of Fe during chlorophyll synthesis. Lack of Cu causes Fe to accumulate in nodes of the plants.

Deficiency symptoms

- Wilting and twisting of dark green young leaves with numerous dead spots on leaf blades.
- Chlorosis of veins occurs and leaves lose their luster.
- Copper is rarely deficient

Mn deficiency symptoms

14. MANGANESE-

- It is an activator of enzymes
- It is required for O_2 release in photosynthesis *i.e.* it helps in chlorophyll formation.
- It acts as a catalyst in oxidation-reduction reaction within plant tissues.
- It counteracts the bad effect of bad aeration.

Deficiency symptoms

- The young leaves become bright yellow green and develop dark brown interveinal areas usually initiating from the leaf tip. Severely affected leaves wither and drop off.
- Small diffused yellow areas develop on the older leaves which may become brown later.

Whip tail in cauliflower is due to Mo deficiency
Source:
www1.agric.gov.ab.ca

15. MOLYBDENUM-

- It is an essential component of major enzyme nitrate reductase in plants.
- It is essential for atmospheric nitrogen fixation in plants both symbiotic and non-symbiotic.

Deficiency symptoms

- Chlorosis starts from older leaves and progress further to younger leaves.
- It causes death of interveinal areas and then of the whole leaf.
- Its deficiency causes 'Whip Tail' in cauliflower.

16. CHLORINE-

- It is involved in water balance (osmosis).
- It is implicated as a kind of co-factor in the photosynthetic liberation of oxygen.
- Chlorine is necessary for shoot apex and root growth.

Deficiency symptoms

- Wilting of leaves which in turn become reddish bronze in color.

- Stunted roots with abnormal thickening near tips

17. NICKEL-

- It is essential for activation of urease, an enzyme involved with nitrogen metabolism

Deficiency symptoms

- Necrosis initiating from the tip of leaf occurs.

How to overcome nutrient deficiency?

These deficiency symptoms can be overcome by supplying nutrients artificially. Nutrients can be supplied to the vegetables by organic manures and chemical fertilizers in appropriate quantities. Organic manures not only add the essential nutrients to the soil but they also improve the soil texture and structure. Nitrogen is applied in the form of farmyard manure and inorganic fertilizers such as urea, ammonium sulphate, calcium ammonium nitrate (CAN) *etc.* Phosphorus is applied in the form of phosphate such as single super phosphate, rock phosphate, di-ammonium phosphate *etc.* Potash is applied in the form of sulphate or chloride of potassium *etc.* For controlling of micronutrient deficiency, several water soluble fertilizers specific to micronutrients are available like borax and granubor (B), iron sulphate (Fe), zinc sulphate (Zn), manganese sulphate (Mn), and calcium chloride (Ca) *etc.*

References

1. Bennett WF. Nutrient Deficiencies and Toxicities in Crop Plants. St. Paul, MN. APS Press.
2. Mengel K and Kirkby EA. 2001. Principles of Plant Nutrition. Netherlands. Kluwer Academic Publishers. 849 p.
3. Fundamentals of Soil Science. Published by Indian Society of Soil Science, Bhopal.
4. Tucker MR. Essential Plant Nutrients: their presence in North Carolina soils and role in plant nutrition. http://www.ncagr.gov/agronomi/pdffiles/essnutr.pdf
5. Uchida R. Essential Nutrients for Plant Growth: Nutrient Functions and Deficiency Symptoms. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/pnm3.pdf
6. Plant nutrition. http://en.wikipedia.org/wiki/Plant_nutrition

Activity 1

Visit different fields of your area and collect samples of plants showing some abnormalities. Try to diagnose the symptoms associated with nutrient deficiency and make herbarium

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Check your progress

Fill in the blanks

1. Deficiency of _____shows characteristics 'V' shaped yellowing at the tip of lower/older leaves.
2. Ca, Mg, and S are known as _____nutrients.
3. _____ is the second most likely nutrient to be deficient in soil.
4. Deficiency of _____ leads to yellowing from tips or margins.
5. Deficiency of Ca and Mg results in _____ in tomato.
6. _____ imparts vigour and resistance to plants against attack of pests.
7. _____ corrects soil acidity.
8. Deficiency of _____ causes 'Whip Tail' in cauliflower.
9. The primary role of _____ is associated with Ca metabolism.

Tick the correct option

1. Lamina become chlorotic and veins remain green especially in older leaves, this typical symptom is due to the deficiency of

   a) Nitrogen b) Phosphorus c) Iron d) Zinc

2. Deficiency of which nutrients result in uniform yellowing of the leaves including veins?

   a) Nitrogen b) Phosphorus c) Potassium d) Calcium

3. Which nutrient imparts vigour and resistance to plants against attack of pests?

   a) Boron b) Phosphorus c) Potassium d) Calcium

4. Elements that provide basic structure to the plant

   a) C, H, O b) N, P, S c) K, Ca, Mg d) Fe, Zn, Mn

5. Which one of the following is primary nutrient?

   a) Zn b) Fe c) P d) Ni

6. 'V' shaped yellowing at the tip of lower leaf shows the deficiency of

   a) P b) K c) N d) S

7. The deficiency system of N first appear on

   a) Older leaves b) Newer leaves c) Flowers d) Stem portion

Define the following terms:

a) Plant nutrient b) Essential nutrient c) Macro nutrient

d) Secondary nutrient e) Fertilization f) Mineral nutrition

Long answers

1. Why are plant nutrients essential for a crop? Explain your answer by citing some examples.
2. Make a list of functions of primary nutrients and also explain their symptoms on plant.
3. Write deficiency symptoms of the following:
   a) Calcium b) Zinc c) Boron