Course- B.Sc. (SUBSIDIARY COURSE), Part -2

Subject- Botany, Paper-II (Group-B)

Topic- Mineral nutrition-Role of major and minor element.

PDF

Binod Kumar Pandey

Assistant Professor & HOD, Botany Department,

Ram Ratan Singh College, Mokama, Patna.

E.mail- binodkp14@gmail.com

Mineral nutrition-Role of major and minor element

Mineral Nutrition in Plants:

Under normal situation, all green plants are autotrophs. Hence, they require the supply of inorganic materials from outside for synthesis of their own organic material (viz., organic food).

A part from the elements carbon, hydrogen and oxygen that may be absorbed as water, carbon dioxide or oxygen, and which together makeup a large part of the weight of a plant, all the inorganic materials are absorbed by the plants directly or indirectly from the soil with the help of their roots.

As the source of these inorganic materials in the soil are minerals, they are called as mineral elements or mineral nutrients. The process involving the absorption, distribution and utilization of mineral substances by the plants for their growth and development is called mineral nutrition.

Since these mineral elements enter the biosphere mainly through the root system of plants, the plants, in a way, act as the "miners of earth crust". After absorption, inorganic mineral elements are transported to various parts of the plant either in the form of an anion or a cation, where they carry out specific biological functions.

In some cases, nitrogen fixing bacteria and mycorrhizal fungi in association with roots participate in the process of mineral nutrition. However, some epiphytes absorb the mineral ions from dust particles present in moisture.

Mineral Elements in Plants:

If a plant is burnt in a muffle furnace at 600° C, all organic components valorize leaving behind a white residue called plant ash that contains only the inorganic mineral elements in different concentrations. In fact, more than 60 elements of the 105 discovered so far are found in different plants. Now question arises, whether all the diverse mineral elements are really necessary for plants?

On the basis of their effects on plant, mineral elements are generally of two types:

i. Essential and

ii. Non-essential.

Only about 17-20 elements are found to be essential. The rest elements are called non-essential without which a plant can survive and reproduce. The non-essential elements may be beneficial or toxic. Beneficial elements improve growth or reduce disease susceptibility without which a plant can still complete its life cycle. For example, Silicon (Si) in grasses, Sodium (Na) in C_4 plants and halophytes. Toxic elements impair growth either in low or high concentrations.

Any mineral ion concentration in tissues that reduce the dry weight of tissues by about 10% is considered toxic. Toxic level for any element also varies for different plants. For

example, aluminum (Al) is always toxic in the acidic soil but acts as beneficial element for tea plant.

Na, Zn, B, Mo, Ma, Cu and Fe are toxic if present at high concentration is soil. It is very often seen that the uptake of one element inhibits the uptake of another element. For example, excess of magnesium uptake induce deficiency of iron, magnesium and calcium.

Essential Mineral Elements in Plants:

Let us make an in-depth study of the specific roles of essential mineral elements in plants with deficiency symptoms. After reading this article you will learn about (A) The Macronutrients (Major Elements) and (B) The Micronutrients (Minor or Trace Elements).

(A) The Macronutrients (Major Elements):

1. Nitrogen:

Specific Role (function):

i. It is important constituent of proteins, nucleic acids, porphyrins, alkaloids, some vitamins, coenzymes etc.

ii. Porphyrins are important part of chlorophylls and cytochromes.

Thus it plays very important role in metabolism, growth, reproduction and heredity.

Deficiency Symptoms:

i. Nitrogen deficiency causes yellowing i.e. chlorosis of leaves. Older leaves are affected first. (It is because nitrogen is very mobile in the plant and is readily transported from older to the rapidly developing younger leaves under conditions of nitrogen deficiency).

ii. In many plants e.g., tomato, the stem, petiole and the leaf veins become coloured due to the formation of anthocyanin pigments.

Plant growth is stunted (because protein content, cell division, and cell-enlargement are decreased).

2. Phosphorous:

Specific Role:

i. It is important constituent of nucleic acids, phospholipids, coenzyme NAD, NADP and ATP etc.

ii. Phospholipids along with proteins may be important constituents of cell membranes.

iii. Through nucleic acids and ATP it plays an important role in protein synthesis.

iv. Through coenzymes NAD, NADP, and ATP it plays an important role in oxidation-reduction and energy transfer reactions of cell metabolism e.g., photosynthesis, respiration, fat metabolism etc.

Deficiency Symptoms:

i. Phosphorous deficiency may cause premature leaf fall.

ii. Dead necrotic areas may be developed on leaves or fruits.

iii. Leaves may turn dark to blue-green in colour.

3. Sulphur:

Specific Role:

i. It is important constituent of some amino acids (cysteine and methionine) which with other amino acids form the proteins.

ii. Disulphide linkages help to stabilize the protein structure.

iii. It is also constituent of vitamins biotin, thiamine, and coenzyme-A.

iv. Sulfhydryl groups are necessary for the activity of many enzymes.

Deficiency symptoms:

i. Sulphur deficiency causes yellowing (i.e., chlorosis) of the leaves. The younger leaves are affected first.

ii. Tips and margins of the leaf roll inward.

iii. Stem becomes hard due to the development of sclerenchyma.

4. Calcium:

Specific Role:

i. It is important constituent of the middle lamella in cell wall.

ii. It is essential in the formation of cell membranes.

iii. It acts as second messenger in metabolic regulation.

iv. It helps to stabilize the structure of the chromosomes.

v. It may be an activator for many enzymes.

Deficiency Symptoms:

i. Calcium deficiency causes disintegration of growing meristematic regions of the root, stem and leaves.

ii. Chlorosis occurs along the margins of the younger leaves.

iii. Malformation of younger leaves also takes place.

5. Magnesium:

Specific Role:

i. It is very important constituent of chlorophylls.

ii. It acts as activator for many enzymes in phosphate transfer reactions particularly in carbohydrate metabolism and nucleic acids synthesis.

iii. It plays important role in binding ribosomal particles during protein synthesis.

Deficiency Symptoms:

i. Magnesium deficiency causes interveinal chlorosis of the leaves. The older leaves are affected first. (It is because magnesium is quite mobile in the plant and is readily transported from older to the rapidly growing younger leaves under conditions of magnesium deficiency).

ii. Dead necrotic patches appear on the leaves.

6. Potassium:

Specific Role:

i. Although potassium is not a constituent of important organic compound in the cells, it is essential for the process of respiration and photosynthesis.
ii. It probably acts as an activator of many enzymes involved in carbohydrate metabolism and protein synthesis.
iii. It is major contributor to osmotic potential of plant cells.
iv. It serves to balance the charge of both diffusible and non-diffusible ions.
v. Plays important role in stomatal movements.

Deficiency Symptoms:

i. Mottled chlorosis of leaves occurs.
ii. Necrotic areas develop at the tip and margins of the leaf which curve downward.
iii. Plant growth remains stunted with marked shortening of internodes.

(B) The Micronutrients (Minor or Trace Elements):

1. Iron:

Specific Role:

i. It is important constituent of iron porphyrin-proteins like cytochromes peroxidases, catalases etc.
ii. It is essential for the synthesis of chlorophyll.
iii. It is very important constituent of ferredoxin which plays important role in biological nitrogen fixation and primary photochemical reaction in photosynthesis.

Deficiency Symptoms:

i. Iron deficiency causes rapid chlorosis of the leaves which is usually interveinal. The younger leaves are affected first. (It is because iron is sparingly mobile in the plant and is not easily withdrawn from the older leaves to the rapidly growing younger leaves under conditions of iron deficiency).

(In soil solution, iron is less mobile due to its precipitation chiefly as insoluble hydrous oxides (Fe_2O_3, $3H_2O$) which interferes with its absorption by the plants. Because of this, the plants may show iron deficiency symptoms even though there is plenty of iron present in the soil especially in neutral or alkaline calcareous soil.

To avoid this problem in nutrient solution, suitable chelating agent (or chelator) such as citric acid or tartaric acid is added which forms soluble complex with the metal ion making the latter easily available to plant. These days, EDTA (ethylenediamine tetraacetic acid) is commonly used for this purpose).

2. Manganese:

Specific Role:

i. It is an activator of many respiratory enzymes.
ii. It is necessary for the evolution of oxygen during photosynthesis.

Deficiency Symptoms:

i. Manganese deficiency causes chlorotic and necrotic spots in the interveinal areas of the leaf.

3. Copper:

Specific Role:

i. It is constituent of several oxidizing enzymes.

ii. Its higher concentrations are toxic to plants.

Deficiency Symptoms:

i. Copper deficiency causes necrosis of the tip of the young leaves.

ii. It also causes die-back of citrus and other fruit trees and reclamation disease of cereals and leguminous plants.

4. Zinc:

Specific Role:

i. It is involved in the biosynthesis of the growth hormone auxin, Indole -3-Acetic acid (IAA).

ii. It acts as activator of many enzymes like carbonic anhydrase, alcohol-dehydrogenase etc.

Deficiency Symptoms:

i. Zinc deficiency causes chlorosis of the older leaves which starts from tips and the margins.

ii. It causes mottle leaf disease in apple, citrus, walnut and other fruit trees.

5. Boron:

Specific Role:

i. Specific role of boron in the metabolism of plants is not clear.

ii. It probably facilitates the translocation of sugars.

Deficiency Symptoms:

i. Boron deficiency causes death of the shoot tip.

ii. Flower formation is suppressed.

iii. Root growth is stunted.

iv. Leaves become coppery in texture.

6. Molybdenum:

Specific Role:

i. It is associated with the prosthetic group of the enzymes nitrate reductase and nitrogenase and thus plays important role in nitrogen metabolism.

Deficiency Symptoms:

i. Molybdenum deficiency causes chlorotic interveinal mottling of the older leaves.

ii. Flower formation is inhibited.

iii. Causes whip tail disease in cauliflower plants.

7. Chlorine:

Specific Role:

i. In the form of chloride ions it is involved in photolysis of water and oxygen evolution in photosynthesis.

ii. It is required for cell division in leaves and roots.

iii. It is an important osmotically active solute.

Deficiency symptoms:

i. Wilting of leaf tips occurs which is followed by general chlorosis and necrosis.

ii. Leaves show reduced growth and ultimately bronzing (bronze colour) occurs.

iii. Roots become stunted in length but thickened near the tips.

8. Nickel:

Specific Role:

i. It is cofactor of the enzyme urease in higher plants

Deficiency symptoms:

i. Due to accumulation of urea in leaves, necrosis of leaf tips occurs.

Sodium and silicon are beneficial to many plants and they are emerging as strong candidates for inclusion in list of essential elements in future.

A brief account of their role and deficiency symptoms in plants follows:

Sodium:

Specific Role:

i. It appears to be essential micronutrient for C_4 plants.

ii. It may be related to transport of pyruvate, an intermediate in C – pathway between bundle sheath cells and mesophyll cells.

iii. Stimulates growth through enhanced cell expansion

iv. May partly substitute K^+ as osmotically active solute.

Deficiency symptoms:

i. Plants show reduced growth.

ii. Chlorosis and necrosis of leaves occur.

iii. Plants may fail to form flowers.

Silicon:

It occurs in normal soils in abundance as SiO_2 and also as contaminant in glass containers, nutrient salts and atmospheric dust. In plants, it accumulates as hydrated silica (SiO_2, nH_2O) in the cell walls especially epidermal cells, ER and intercellular spaces.

Specific Role:

i. Equisetaceae (called scouring rushes) requires silicon to complete their life cycle where it may comprise up to 16% of the dry matter.

ii. It may be beneficial to variety of species of higher plants also especially grasses where it may comprise 1-2% of the dry matter and enhances their growth and fertility.

iii. It forms complexes with polyphenols and may serve as alternative to lignin in providing strength to cell walls.

iv. It may overcome toxicity of many heavy metals.

Deficiency symptoms:

Deficiency of silicon makes plants more susceptible to fungal infections and lodging (falling over due to heavy winds or rain).

Related Articles:

- Sources, Functions and Deficiency Symptoms of Essential Elements in Plants
- Essential Elements Required for Plants
- Essential and Non-Essential Elements in Plants
- Functions of Mineral Elements in Plants: 10 Important Functions