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Mineral Nutrition of Plants: Functions and Deficiency Symptoms of Nutrients

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SUMMARY

Mineral nutrients are elements acquired primarily in the form of inorganic ions from the soil. Although mineral nutrients continually cycle through all organisms, they enter the biosphere predominantly through the root systems of plants, so in a sense plants act as the "miners" of Earth's crust. The large surface area of roots and their ability to absorb inorganic ions at low concentrations from the soil solution make mineral absorption by plants a very effective process. After being absorbed by the roots, the mineral elements are trans located to the various parts of the plant, where they are utilized in numerous biological functions. Other organisms, such as my corrhizal fungi and nitrogen-fixing bacteria, often participate with mots in the acquisition of nutrients.

INTRODUCTION

The study of how plants obtain and use mineral nutrients is called mineral nutrition.The chemical compounds required by an organism are termed as nutrients. Nutrition may be defined as the supply and absorption of chemical compounds needed for plant growth and metabolism. For plant growth and metabolism, 17 elements are essential. They are C, H, O, N, P, K, Ca, S, Mg, Fe, Mn, Zn, B, Cu, Mo, Cl and Ni.

These essential elements are classified into two groups

- Major elements (macro nutrients)
- Minor elements (Micro nutrients) (Trace elements)

Major elements: The essential elements which are required by the plants in comparatively large amounts are called as major elements or macro nutrients. According to another definition minerals found in >1000 ppm concentration are macronutrients. They are C, H, O, N, P, K, Ca,S,Mg.

Minor elements: The essential elements which are required in very small amounts or traces by the Plants are called as minor elements or micronutrients or trace elements. According to another definition minerals found in <100 ppm concentration are micronutrients. They are Fe, Zn, Mn, B, Cu and Mo. Si is now transferred from list of beneficial elements to essential elements.

Beneficial elements: (Na, Si and Co)

Sodium has beneficial effect, and, in some case, it is essential. There are some plant species, particularly the Chenopodiaceae plants and species adapted to saline conditions that take up this element in relatively high amounts. Na is also required for turnips, sugar beets and celery. The same is true for Si, which is an essential nutrient for rice. Cobalt is an essential element for the growth of the Bluegreen algae, but it has not been shown to be essential for other algae or for higher plants. It is also required by certain legumes to fix atmospheric nitrogen. Here, however the cobalt ion is necessary for the symbiotic bacteria present in the nodules associated with the roots.

Criteria of Essentiality:

The term essential mineral element was proposed by Arnon and Stout (1939). According to them an element to be considered essential, three criteria must be met:

- A given plant must be unable to complete its life cycle in the absence of Mineral elements.
- The function of the element must not be replaceable by another mineral element
- The elements must be directly involved in plant metabolism. For eg. as a component of an essential plant constituents or it must be required for a distinct metabolic step such as an enzyme reaction.

Based on the mobility, elements are also classified into three types:

- Mobile elements : N, P, K, S and Mg
- Immobile elements : Ca, Fe and B
- Intermediate in mobility : Zn, Mn, Cu, Mo

Classification of plant nutrients based on their biochemical role and physiological function:

Essential elements are now classified according to their biochemical role and physiological function. Based on the biochemical behavior and physiological functions, plant nutrients may be divided into four groups.

Mineral deficiencies produce visible symptoms:

When minerals are deficient, the growth of the plant is stunted, or the plant shows other symptoms. The combination of symptoms observed for deficiency of a particular mineral can be traced to the roles that mineral plays in metabolism or physiology.

1. Stunted growth is a symptom for many deficiencies, especially stunted stems with nitrogen deficiency and stunted roots in phosphorus deficiency.

2. Chlorosis decreased chlorophyll synthesis or increased chlorophyll degradation,

Is observed with magnesium, nitrogen, and iron deficiencies. Magnesium is the central atom for the electron cloud of chlorophyll from which electrons flow through the light reactions.

3. Necrosis, dead spots or zones, is observed when magnesium, potassium or manganese deficiencies are present.

4. Colour changes such as excessive anthocyanin production is observed in stems with phosphorus deficiency. They generally pick up an intense purple colour sometimes extending onto the leaves.

Mineral availability shows an interesting dose effect:

The following graph demonstrates how deficiency reduces growth. As the mineral availability is increased, growth increases. As the mineral content continues to be increased there is no further increase in growth, but quality may be continuing to increase. This zone is called the luxury zone. However, continuing to increase the mineral concentration ultimately reaches toxic levels and growth is diminished. The goal of a plant grower is to keep the plant in the sufficient to luxury zone but never to get as low as deficiency or as high as toxicity for any one of the macronutrients or micronutrients. The trouble with that goal knows how wide the luxury zone is in terms of concentrations. For minerals like boron, the zone is very narrow, and it is easy to achieve toxic levels or to be in deficiency. For minerals like phosphorus, the luxury zone is quite broad and large amounts can be given and the plants will respond nicely in spite of that. As a result, it is difficult to overdose plants on phosphorus.

Specific roles of essential mineral elements:

A. The macronutrients:

1. Nitrogen specific role: Nitrogen is important constituent of proteins, nucleic acids, porphyries (chlorophylls & cytochromes) alkaloids, some vitamins, coenzymes etc. Thus N plays very important role in metabolism, growth, reproduction and heredity.

Deficiency symptoms: Plant growth is stunted because protein content cell division and cell enlargement are decreased. N deficiency causes chlorosis of the leave i.e yellowing older leaves are affected first. In many plants eg. tomato, the stem, petiole and the leaf veins become purple coloured due to the formation of anthocyanin pigments.

2. Phosphorus: It is important constituent of nucleic acids, phospholipids, coenzymes NADP, NADPH2 and ATP. Phospholipids along with proteins may be important constituents of cell membranes. P plays important role in protein synthesis through nucleic acids and ATP. Through coenzymes NAD, NADP and ATP, it plays important role in energy transfer reactions of cell metabolism eg. photosynthesis, respiration and fat metabolism etc.

Deficiency symptoms: P deficiency may cause premature leaf fall. Dead necrotic areas are developed on leave or fruits. And leaves may turn to dark green to blue green colour. Sometimes turn to purplish colour due to the synthesis and accumulation of anthocyanin pigments.

3. Potassium Specific role : Although potassium is not a constituent of important organic compound in the cell, it is essential for the process of respiration and photosynthesis. It acts as an activator of many enzymes involved in carbohydrate metabolism and protein synthesis. It regulates stomatal movement and water balance.

Deficiency symptoms: Mottled chlorosis of leaves occurs. Neurotic areas develop at the tip and margins of the leaf and plants growth remains stunted with shortening of internodes.

4. Calcium:
• It is important constituent of cell wall
• It is essential in the formation of cell membranes
• It helps to stabilize the structure of chromosome
• It may be an activation of may enzymes
Deficiency symptoms
• Calcium deficiency causes disintegration of growing meristematic regions of root, stem and leaves
• Chlorosis occurs along the margins of the younger leaves
• Malformation of young leaves takes place

5. Magnesium:
• It is very important constituent of chlorophylls
• It acts as activation of many enzymes in nucleic acid synthesis and carbohydrate metabolism
• It plays important role in binding ribosomal particles during protein synthesis.
Deficiency symptoms
• Mg deficiency causes mottled chlorosis with veins green and leaf tissues yellow or white appearing first on older leaves
• Dead neurotic patches appear on the leaves
• In cotton Mg deficiency leads o reddening of leaves and disorder is called as reddening in cotton.

6. Sulphur Specific Role:
• It is important constituent of some amino acids (cystine, cysteine and methionine) with which other amino acids form the protein
• S helps to stabilize the protein structure
• It is also important constituent of vitamin i.e biotin, thiamine and coenzyme A
• Sulphhydryl groups are necessary for the activity of many enzymes.
Deficiency Symptoms
• Deficiency causes chlorosis of the leaves
• Tips and margins of the leaf roll in ward
• Stem becomes hard due to the development of sclerenchyma.

B. Micronutrients:
1. Iron Specific Role:
• Important constituent of iron porphyrin proteins like cytochromes, peroxidanes, catalases, etc.
• It is essential for chlorophyll synthesis
• It is very important constituent of ferredoxin which plays important role in photochemical reaction in photosynthesis and in biological nitrogen fixation.
Deficiency Symptoms:
Iron deficiency causes chlorosis of young leaves which is usually interveinal.

2. Zinc Specific Role:
• It is involved in the biosynthesis of growth hormone auxin (indole 3 acetic acid)
• It acts activator of many enzymes like carbonic anhydrase and alcohol dehydrogenase, etc.

Deficiency Symptoms:
• Zinc deficiency causes chlorosis of the young leaves which starts from tips and the margins
• The size of the young leaves is very much reduced. This disorder is called as 'little leaf disease'
• Stalks will be very short.

3. Manganese:
• It is an activator of many respiratory enzymes
• It is also an activator of the enzyme nitrite reductase
• It is necessary for the evolution of oxygen (photolysis) during photosynthesis
Deficiency symptoms
• The young leaves are affected by mottled chlorosis
• Veins remain green
• Small necrotic spots developed on the leaves with yellow strips

4. Copper specific role:
• It is an important constituent of plastocyanin (copper containing protein)
• It is also a constituent of several oxidizing enzymes.
Deficiency symptoms
• Copper deficiency causes necrosis of the tip of the young leaves
• It also causes die-back of citrus and fruit trees
• Also causes reclamation disease or white tip disease of cereals and leguminous plants.

5. Boron specific role:
• Boron facilitates the translocation of sugars by forming sugar borate complex.
• It involves in cell differentiation and development since boron is essential for DNA synthesis
• Also involves in fertilization, hormone metabolism etc.
Deficiency symptoms
• Boron deficiency causes death of shoot tip
• Flower formation is suppressed
• Root growth is stunted
• The other diseases caused by B deficiency is Heart rot of beet, Stem crack of celery, Brown heart of cabbage, Water core of turnip, Internal cork formation in apple, Hen and chicken in grapes.

6. Molybdeneum:
• It is constituent of the enzyme nitrate reductase and thus plays an important role in nitrogen metabolism
• It is essential for flower formation and fruit set.
Deficiency symptoms
• Molybdenum deficiency causes interveinal chlorosis of older leaves
• Flower formation is inhibited
• Causes whiptail disease in cauliflower plants.

7. Chlorine Specific role:
• Chlorine has been shown to be involved in the oxygen evolution in photosystem II in photosynthesis (Cl and Mn are important for this reaction)
• It raises the cell osmotic pressure
• Chlorine accelerates the activation of amylase which converts starch into soluble sugars
Deficiency symptoms
• Chlorosis of younger leaves and an overall wilting of the plant
• In some plant species, like tomato, leaves show chlorotic mottling, bronzing and tissue Necrosis.

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