CHAPTER 5

Essential Plant Nutrients, Their Deficiency Symptoms and Toxicities in Horticultural Crops

OBJECTIVES

After studying this chapter, the students should be able to learn about:

- Essentiality of plant nutrition
- Classification of essential nutrients on the basis of their requirement to plant
- Identify and diagnose common plant nutrient deficiency andtoxicity symptoms

INTRODUCTION

Plants, like all other living things, need food for their growth and development.The plant nutrients are essential for optimum plant growth. Nutrients are naturally present in the soil. Now, certain questions may arise in your mind. Why does plant need nutrients? How many nutrients 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 and diagnose the deficiency symptoms of a particular nutrient in the soil? You can face several questions of this category. Each nutrient assists with different plant functions that allow the plant to grow and reproduce. Each plant nutrient is needed in different amounts by the plant, and varies in how mobile it is within the plant. It is useful to know the relative amounts of each nutrient that is needed by a crop in making fertilizer recommendations. In addition, understanding plant functions and mobility within the plant should prove useful in diagnosing nutrient deficiencies. 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 for a complete life cycle. However, man can artificially modify soil through the addition of manures and fertilizer to promote vigorous growth and increase 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 element are absorbed by roots principally as inorganic ions in soils and these are derived mostly from mineral constituent of soil. The term **Mineral Nutrition** generally refers to an inorganic ion obtained from soil and required 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 need for basic chemical elements 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 which it cannot manufacture 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) . Ni is recently added as an essential nutrient. There is a dispute among plant physiologists concerning the role of nickel in plant nutrition. Since many physiologists exclude it as essential, in some textbooks, lists consist of only 16 essential inorganic nutrients.

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 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-** Of the 95% of total dry matter of plants, carbon and oxygen constitute 45% each. 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 whereas **Ca, Mg,** and **S** are known as secondary nutrients. They are known as secondary nutrients due to their secondary importance to the manufacturer of primary nutrient fertilizers.

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.

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

1. Catalysts for enzymatic reactions (either as part of the enzyme structure or as regulators or activators),
2. Regulators of the movement of water in or out of the cell and maintenance of turgor pressure
3. Regulators of membrane permeability,
4. Structural components of the cell or of electron receptors in the electron transport system, or as buffers (which maintain the pH within cells).

NON-MINERAL NUTRIENTS

Three elements, carbon (C), hydrogen (H), and oxygen (O), are considered to be non-mineral nutrients because they are derived from air and water, rather than from soil minerals. Although they represent approximately 95% of plant biomass, they are generally given little attention in plant nutrition because they are always in sufficint supply.

Based on the functions, the nutrients are classified into four groups:

1. Elements that provide basic structure to the plant- C, H, O.
2. Elements useful in energy storage, transfer and bonding- N, S, P. These are accessory structural elements which are more active and vital for living tissues.
3. Elements necessary for charge balance- K, Ca, Mg. These elements act as regulator and carriers.
4. Elements involved in enzymes activation and electron transport- Fe, Mn, Zn, Cu, B, Mn, 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 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. The major functions and deficiency symptoms of essential plant nutrients are as under:

Mobile nutrients are nutrients that are able to move out of older leaves to younger plant parts when supplies are inadequate. Mobile nutrients include N, P, K, Cl, Mg, and molybdenum (Mo). Because these nutrients are mobile, visual deficiencies will first occur in the older or lower leaves and effects can be either localized or generalized.

Immobile nutrients(B, Ca,Cu, Fe, Mn, Ni, S, and Zn) are not able tomove from one plant part to another and deficiency symptoms will initially occurin the younger or upper leaves and be localized. Zn is a partial exception to this as it is only somewhat immobile in the plant, causing Zn deficiency symptoms to initially appear on middle leaves and the naffect both older and younger leaves as the deficiency develops.

Functions, deficiency symptoms and toxicities of essential plant nutrients:

Carbon, hydrogen and oxygen: These are the major constituents of organic compounds like carbohydrates and fats found in the plants and provide energy required for growth and development. They are rarely limiting as a nutrient and there are no specific symptoms

Nitrogen

It is a constituent of proteins, enzymes, vitamins and plant hormones. It imparts vigorous vegetative growth and dark green colour to plants, produces early growth, delays maturity of plants, and governs the utilization of potassium, phosphorus and other elements. Its deficiency results in drastic reduction in vegetative growth, stunted shoots and roots with thin, upright and spindly appearance. Chlorosis is first observed on older leaves. Leaves are thin, fragile, small, pale- yellowish in colour and defoliate prematurely. Flowering, fruit-bud formation and fruit setting are reduced. Woody fruits without any flavour are formed. Excess levels result in abundant foliage with dark green colour, making plants more susceptible to pest and disease attack. Yields are low. Fruits are poorly coloured with poor eating quality and storage properties. It delays fruit maturity. P uptake is low.

Severe nitrogen deficiency in citrus

Phosphorus

It is found in younger parts-flowers, maturing fruits and seeds. It enhances maturity of crop, root growth and development, activity of rhizobia and formation of root nodules. Its deficiency leads to stunted roots and shoots with abnormally small leaves with dull dark green colour, which later turns into bronze colour. Older leaves prematurely defoliate. Flowering is delayed, fruit-bud formation is reduced, and yields are with poor quality. Excess of P results in interveinal chlorosis in younger leaves and marginal scorch of older leaves followed by necrosis, tip die back, heavy leaf shedding and death of shoots. It results in Zn, Cu, Mn and Fe deficiency.

Phosphorus deficiency in pear

Potassium

Young leaves, root tips and meristematic tissues are very rich in K. It is involved in cell division, synthesis and translocation of carbohydrates and synthesis of proteins in meristematic tissues. K plays a unique role in osmotic regulation, opening and closing of stomata. It has a beneficial effect on symbiotic N_2 fixation by leguminous plants and increases resistance of plants to various abiotic and biotic stresses. It improves the colour, flavour and size of fruits. Deficiency symptoms first appear on recently matured leaves. Marginal burning of leaves starts from tip which turns reddish-brown in colour and eventually die giving a scorched, ragged appearance. Shoots are thin with poor growth. Excess of K leads to Mg, Mn, Zn and Fe deficiency by affecting their uptake.

Potassium deficiency in banana

Calcium

Calcium occurs mainly in the leaves as calcium pectate. It plays an important role in cell division, elongation, maintenance of membrane integrity, development and functioning of roots and root apices, respiration, uptake of N, Fe, B, Zn, Cu and Mn. Since Ca is not freely mobile, its deficiency first appears on the shoot tips. Terminal buds fail to grow and eventually die. Leaves are distorted with margins curled downwards or upwards, Fruits crack, roots are abnormally short, thick and crooked. Excess Ca produces alkalinity and reduces the availability of nutrients such as P, K, Mn, Fe and Zn.

Magnesium

It is a constituent of chlorophyll, protoplasm, chromosomes, etc. It is a catalyst in several enzymes and is essential for formation of carbohydrates, oils, fats and vitamins. Deficiency symptoms first appear in older leaves. The most prominent symptom is yellowing of leaf margins that progresses through the interveinal tissue towards the rib. The veins and adjacent tissues remain green. Excessive Mg levels may result in either K or Ca deficiency in plants.

Magnesium deficiency in peach leaves

Sulphur

Sulphur is present abundantly in leaves. It is a constituent of cystine, methionine, proteins and fatty acids. It increases root growth, nodule formation and stimulates seed formation. Chlorosis is first observed on the young leaves in sulphur deficient plants. Shoot growth is restricted. Leaf area and fruiting is reduced. Leaves fall early. Excess of Sulphur results in reduced leaf size, leaf burning or mottling with a yellow or bronzed colouration, accompanied by leaf abscission.

Sulphur deficiency in banana

Iron

Iron acts as a catalyst in formation of chlorophyll and in several enzymes. It is a key element in various reactions of respiration, photosynthesis and reduction of nitrates and sulphates. In its deficient plant interveinal chlorosis is first seen in young terminal leaves. In severe cases, the new leaves unfold completely, devoid of green colour but veins usually turn green later. The fine network of veins is distinctively green against a

Iron deficiency symptoms- yellowing of youngest leaves yellow back ground. Plants seldom show Fe toxicity symptoms as solubility of Fe in the soil solution is rather low.

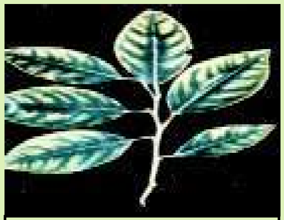
Zinc

It is required for synthesis of tryptophan, a precursor of auxin, Indole acetic acid. It is essential for carbon dioxide evolution and utilization, carbohydrate and phosphorus metabolism, and synthesis of proteins. Its deficiency leads to short internodes, small narrow leaves, interveinal chlorosis and shoot and branch dieback. In advanced stage, small, narrow, terminal leaves are arranged in whorls giving rise to a typical 'rosette' or little leaf symptoms. Root growth is restricted. The symptoms disappear as the season advances. Soils derived from parent material rich in zinc or impregnated with seepage water from Zn ore, excessive fertilization with Zn in acid soils causes toxicity in plants. Toxicity of Zn can be reduced by liming or by adding superphosphate to the soil, thus reducing the solubility and absorption of Zn.

Zinc deficient mango shoots have shortened internodes, resulting in leaf rosetting.

Manganese

Manganese accumulates in leaves more than seeds and stalk tissue. It plays an essential role in respiration, nitrogen metabolism, chlorophyll synthesis and breakdown. Deficiency symptoms appear soon after the leaf is fully expanded and persists throughout its life. It is characterised by a pattern of leaf chlorosissome what between that caused by magnesium and iron deficiency. High acidity leading to greater solubility of Mn; addition of acid forming fertilizers and regular application of $MnS0_4$ over many years or poor soil aeration cause Mn excess in soils.



Manganese deficient orange; leaves develop a mottled pattern of light and dark green.

Copper

It is required in oxidation-reduction reactions, photosynthesis, respiration, carbohydrate/ nitrogen balance, chlorophyll and vitamin A formation, biosynthesis and activity of ethylene in fruit ripening. Dieback, gum pockets at nodes of twigs and brownish excrescence on fruits, twigs and leaves are common in copper deficient plants. Chlorotic and small leaves sometimes also show brown or bronze areas. Fruits have thick peel, lack juice and are insipid with a tendency of cracking or splitting of rind. Excess of copper results in reduced plant and root growth with less branching, more thickening and abnormally dark root-lets.

Boron

It plays a part in flowering, fruiting, photosynthesis, hormone movement and action, cell division, differentiation and development, sugar translocation, pollen germination, pollen tube growth, rooting and active salt absorption. In its deficiency, terminal buds fail to open or abort and twigs die-back. Leaves are darker green, boat like, brittle and abscise early, starting from the shoot tips. Fruits are malformed, hard, misshapen with rough skin. Corky areas develop in cortex and browning in core region. In some cultivars, fruits crack. Available B content of 0.5 ppm in soil may cause a deficiency in some plants but leaves (>5 ppm) become toxic for normal plant growth.

Boron deficient papaya fruits develop bumps.

Molybdenum

The Mo plays an important role in nitrogen metabolism. It is constituent of two major plant enzymes namely, nitrogenous and nitrate reductase. It helps in fixation of atmospheric nitrogen in legume crops. Deficiency symptoms develop on leaves as yellow spots. In late summer, large yellow spots are apparent with gum and corky cells forming on the lower leaf. Fruit yield is adversely affected. Mo toxicity is not reported in plants

Molybdenum deficient grapefruit leaves have interveinalchlorosis.

Chlorine

It is involved in the oxygen evolution in primary reactions of photosynthesis, cell multiplication and turgor production in guard cells. Chlorosis, necrosis, unusual bronze discolouration of foliage and wilting of plants is seen in Cl deficient plants. High levels of Cl result in depressed growth, chlorosis, burning of tips and margins of leaves, bronzing, premature yellowing and abscission of leaves.

Nickel

It is an essential part of enzyme in nitrogen metabolism. Leaf tips with dead spots.

These deficiency symptoms can be overcome by supplying nutrients artificially. Nutrients can be supplied to vegetables by organic manures and chemical fertilizersin 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 (for boron).

Activity

Visit nearby fruit and vegetable farms and collect samples of plants showing some abnormalities. Try to diagnose the symptoms associated with nutrient deficiency and prepare herbarium.

CHECK YOUR PROGRESS

1. Write the criteria of essentiality of an element. Classify all essential nutrients on the basis of their requirement.
2. Write five nitrogenous andphosphatic fertilizers along with their percent N and P2O5 contents.
3. Classify all essential nutrients on the basis of their mobility in plant system.
4. Write the functions and deficiency symptoms of nitrogen, calcium, zinc and boron in plants.
5. Define the following terms

   a) Mobile nutrients b) essential nutrient c) Macro nutrient

   d) Secondary nutrient e) Fertilization f) Mineral nutrition

FILL IN THE BLANKS

1. Deficiency symptoms of nitrogen first appear on..............leaves.
2. Ca, Mg, and Sare known as ______________________ nutrients.
3. A nutrient which plays a unique role in osmotic regulation, opening and closing of stomata is ....
4. Elements that provide basic structure to the plant are.............., ...and..................
5. Nutrient required for synthesis of tryptophan, a precursor of auxin, Indole acetic acid is......................
6. Deficiency of............... causes 'little leaf" in citrus.

SUGGESTED FURTHER READINGS

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