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Topic-	**Essential Plant Nutrients**
Sub-Topic-	**Plant Nutrient Elements**
	Classification of Plant Nutrients
	Forms in which Nutrient Elements are taken in by Plants
	Criteria of Essentiality of Plant Nutrients
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	Functions and Deficiency Symptoms of Plant Nutrients
	Critical Levels of Deficiency and Toxicity

Faculty-	**Mr. Rajeev Kumar**
E-mail-	**r.k.sharma198510@gmail.com**

Plant Nutrient Elements:

Like animals and human beings, the plants also need food for their proper growth and development. The food of plants is constituted by several chemical elements that are called **plant nutrients** or **plant food elements.** There are 18 plant nutrient elements. These are:

1. Carbon
2. Hydrogen
3. Oxygen
4. Nitrogen
5. Phosphorus
6. Potassium
7. Calcium
8. Magnesium
9. Sulphur
10. Iron
11. Manganese
12. Zinc
13. Copper
14. Molybdenum
15. Boron
16. Chlorine
17. Cobalt
18. Nickel

Classification of Plant Nutrients:

Based on the requirement of the nutrients by the plants, the plant nutrient elements are classified as below:

1**. Major or Macro Nutrients**: The elements which are required by the plants in large quantities are called major or macro nutrients. These are: C, H, O, N, P, K, Ca, Mg and S. These are also classified into two groups:

(i) Primary Nutrients: N, P and K are required by the plants comparatively in very large amounts. Hence, these elements are called primary or main nutrient elements. The fertilizers of N, P and K are used by the farmers in large quantities. So, N, P, K are called **fertilizer elements**.

(ii) Secondary Nutrients: Plants require Ca, Mg and S also in large amounts but they have less function to do as compared to the main nutrients. Hence, these elements are called **secondary nutrients**. The importance of Ca, Mg and S is secondary to the manufactures of NPK fertilizers.

2. Minor, Micro or Trace Nutrients: Seven nutrient elements namely iron, manganese, zinc, copper, molybdenum, boron and chlorine are utilized by field crops in very small

quantities. Hence, these elements are called **minor** or **macro nutrients**. The micro nutrients are also as essential as macro nutrients for the plant growth.

Forms in which Nutrient Elements are taken in by Plants:

Field crops obtain carbon and oxygen from air and photosynthesis. Hydrogen is obtained by the plants from soil water. The other 13 elements are obtained by the plants from soil solution or in ionic form from the surface of soil colloids.

Plants absorb the nutrients in the following forms:

The eighteen essential elements for plant growth

Element	Symbol	Form Absorbed by Plants
Carbon	C	CO_2
Hydrogen	H	H^+, OH^-, H_2O
Oxygen	O	O_2
Nitrogen	N	NH_4^+, NO_3^-
Phosphorus	P	HPO_4^{2-}, $H_2PO_4^-$
Potassium	K	K^+
Calcium	Ca	Ca^{2+}
Magnesium	Mg	Mg^{2+}
Sulfur	S	SO_4^{2-}
Iron	Fe	Fe^{2+}, Fe^{3+}
Manganese	Mn	Mn^{2+}, Mn^{4+}
Boron	B	H_3BO_3, BO_3^-, $B_4O_7^{2-}$
Zinc	Zn	Zn^{2+}
Copper	Cu	Cu^{2+}
Molybdenum	Mo	MoO_4^{2-}
Chlorine	Cl	Cl^-
Cobalt	Co	Co^{2+}
Nickel	Ni	Ni^{2+}

Criteria of Essentiality of Plant Nutrients: The criterion of essentiality of elements for plant nutrition was given by Arnon. There are 18 elements essential for the plant growth and development. The plant nutrient elements must fulfill the following three requirements for their essentiality in plant nutrition.

(i) In the absence or deficiency of an element, the plant cannot complete the vegetative or ripening stage of its life cycle.

(ii) The deficiency symptom is specific to the nutrient element and it can be removed or cured only by referring that particular element to the plant.

(iii) The nutrient element must have a direct effect on the plant and its nutrition.

Sources of Plant Nutrients:

The sources of plant nutrients are:

- Organic manures.
- Commercial fertilizers.
- Green manure crops.
- Soil amendments.
- Some weedicides and fungicides.

Organic manures: The bulky as well as concentrated organic manures like FYM, compost, night soil, sludge, oil - cakes and blood meal etc. Supply organic matter to the soil in large quantities. They also supply plant nutrients in small quantities.

Commercial fertilizers: Inorganic commercial fertilizers such as ammonium sulphate, superphosphate, muriate of potash and calcium ammonium sulphate etc, and organic commercial fertilizers such as urea and calcium cyanamide (nitrolim) supply essential nutrients to the plants through soil.

Green manure crops: Green manure crops add organic matter as well as plant nutrients to the soil. If legumes are sown as green manure crops, they add 60 to 80 kg of nitrogen per hectare of the soil.

Soil amendments: Soil amendments are mainly added to the soil to improve the soil conditions of acidic or alkaline soils. Soil acidity is rectified by adding ground lime stone which also supplies calcium nutrient. The soil alkalinity is corrected by adding gypsum or other sulphur compounds which also supply available calcium and sulphur to the soil.

Some weedicides and fungicides: These chemical substances also add some amounts of nutrients to the soil. For example, when copper fungicides and Bordeaux mixture are used as fungicides, they supply available copper and calcium to the soil.

Nitrogen is about 79% in air. It comes to the soil due to its fixation by symbiotic bacteria. Some nitrogen also comes to the soil by rain water. Organic matter is a rich source of nitrogen. Phosphorus occurs in the soil as phosphates of Fe, Al and Ca. It is about 90% as apatite mineral in the soil.

Potassium occurs in the soil mainly as silicates. Its main minerals are mica, biotite, orthoclase and microcline. 90 to 98% of total potassium in the soil is found in the form of these minerals.

Functions and Deficiency Symptoms of Plant Nutrients:

In general, about 95% or more of plant weight is constituted by carbon and moisture i.e., oxygen and hydrogen. Carbon, oxygen and hydrogen constitute about 45%, 43% and 6% of the total tissues respectively. Hence, C, and H are the main structural elements of plant tissues. Actually, C, O and H are not limited to plant growth. But out of the 18 essential plant nutrients, the remaining 13 elements are limited to plant development as a whole.

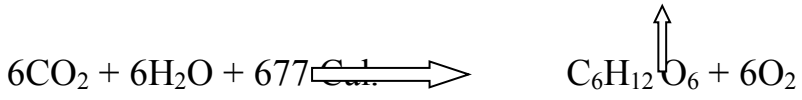
C, O, H, N, P and S are the plant nutrients which take part in the synthesis of protein and then protoplasm. Hence, these elements help in the structure of proteins of plant tissues.

The functions of carbon, oxygen and hydrogen may be described as follows:

Functions of carbon:

1. Carbon constitutes about 45% of the total tissues of plants.

2. Green plants make their food from CO_2 and water in presence of sunlight by photosynthesis in which carbohydrates such as glucose, fructose and starch are synthesized. These carbohydrates contain carbon.



3. Fats and oils are also synthesized by the polymerisation of simple sugars like pentoses $C_5H_{10}O_5$ and hexoses, $C_6H_{12}O_6$ of which carbon is an essential constituent.

Functions of Oxygen:

1. Oxygen constitutes 43% of the total tissues of plants.
2. Oxygen plays an important role in respiration and photosynthesis processes.
3. The free oxygen liberated in photosynthesis is utilized by the plants in their respiration process. During the day, the plants absorb carbon dioxide and liberate oxygen. At night, the plants absorb O_2 in respiration and release CO_2 gas.

Functions of Hydrogen:

1. Hydrogen is essential for the growth of plants.
2. Hydrogen is a constituent of food materials for plants.
3. Hydrogen is combined with CO_2 to form sugars in plants.

The **functions** and **deficiency symptoms** of the remaining 13 essential plant elements are described as follows:

Functions of Nitrogen:

1. Nitrogen is an essential component of proteins and chlorophyll. Chlorophyll increases rate of photosynthesis.
2. It is also present in many compounds like enzymes, hormones, vitamins, alkaloids, nucleotides and phosphatides, etc. which are of great physiological importance in plant metabolism.

3. It imparts dark green color to the plants.

4. It causes rapid early growth.

5. It promotes leaf, stem and other vegetative growth. Thus, it increases straw and weight of fruits and sugarcane.

6. It improves quality and succulence of leafy vegetables. Due to increase in length of plants, they may easily fall by wind.

7. It increases protein content of cereals and fodder crops.

8. It increases water holding capacity of plants and decreases the rate of absorption of calcium by plants.

9. Due to increase in the surface area of leaves, transpiration increases. As a result, the plants require more water. This is why irrigation of soil is necessary when the nitrogenous fertilizers are added in the field crop.

10. It acts as a regulator in plants and governs the utilization of potassium, phosphorus and other elements.

Deficiency Symptoms of Nitrogen:

Typical deficiency symptoms developed by nitrogen are:

- The color of plant leaves becomes yellow or pale green.
- The growth of the plant does not take place properly and plant height remains short.
- The bottom leaves of the plants start drying up.
- White spots develop in the green leaves.
- In acute deficiency of nitrogen, the color of leaves becomes white and they stan firing.
- The size of fruits in fruit plants is short and starts falling before ripening.
- The yield of the crops is considerably reduced.

Toxic Effects of Nitrogen:

- Due to succulence or softness, the stems of the plants become weak. Consequently, the crop may fall due to wind easily.
- Due to increase in vegetation, the crop takes more time in ripening.
- Due to more vegetation, the yield of potato and other crops decreases.
- The straw content becomes more than cereals in wheat and other grain crops.
- The sugar content is lowered in sugarcane crop due to excess nitrogen.
- The quality of yield in cereal and fruit crops decreases.
- The keeping property of vegetables and fruits decreases and, hence, these cannot be kept safe for a long period.
- Due to thin walls of plants, they are easily damaged by drought and frost.
- The protein content in crops increases but carbohydrate and mineral contents are reduced.
- The insects and pests cause more harm to soft plants.

Functions of Phosphorus:

1. Phosphorus stimulates early root development and growth. It helps seedlings to establish quickly.
2. It gives rapid start to plants and strengthens straw.
3. It stimulates flowering and helps in seed formation.
4. It increases the ratio of grains to straw.
5. It improves the quality of crops and food grains.
6. It brings about early maturity of cereal crops in particular and counteracts the effects of excess nitrogen.
7. It is a constituent of phospholipids, nucleic acids and phytin.
8. It is an essential constituent of most of enzymes.
9. It enhances the activity of rhyzobia and increases the formation of root nodules in legumes. Hence, it helps in fixing more atmospheric nitrogen in nodules of roots.

10. It helps in the absorption of potassium and other nutrients by the plants.

Deficiency Symptoms of Phosphorus:

- Phosphorus deficiency causes slow growth and late maturity.
- The leaves start developing red and purple colors.
- Lower leaves become dry.
- Leaf petioles develop purple color. Purple color develops between veins.
- Legume plants suffer from nitrogen and potassium deficiency stimultaneously.
- The yield of fruits, grains and seeds decreases.

Toxic Effects of Phosphorus:

- Excess phosphorus may cause trace element deficiency particularly zinc and iron.
- The detrimental effects of overy lining may be alleviated.

Functions of Potassium:

1. Potassium regulates water conditions within the plant cell. It regulates water loss by carrying the balance between transpiration and respiration. Hence, it reduces the tendency of the plant to wilt.

2. It makes the plant strong and disease resistant.

3. It produces stiff straw in cereals like wheat and paddy.

4. It makes the grains and seeds flumpy or fatty.

5. It acts as an accelerator of enzyme action.

6. It is essential in the formation and transfer of sugars and starches in plants.

7. It helps in the formation of proteins and chlorophyll.

8. It improves the quality of tobacco leaf and fiber crop.

9. It improves the taste, size and keeping quality of fruits.

10. It counteracts the injurious effects of excess nitrogen in plants.

11. It acts as an iron carrier in various oxidation- reduction reactions in plants.

Deficiency Symptoms of Potassium:

- The leaves become thick and curl.
- Bottom leaves undergo scorching or burning on tips and margins.
- Potassium deficiency first develops in the wet portion of the field.
- The quality of vegetables and fruits is badly affected.
- The growth of plants is reduced and the plants are weak.

Toxic Effect of Potassium:

Excess of potassium has bad effect on quality of citrus fruits.

Functions of Calcium:

1. Calcium promotes early root development and growth of the plant.

2. It is a constituent of cell wall of plants.

3. It helps in the development of root hairs. As a result, the capacity of plants to absorb nutrients increases.

4. It occurs in legumes in sufficient quantities and helps in the synthesis of proteins.

5. It encourages seed production and increases stiffness of straw.

6. It provides a base for the neutralization of organic acids which are considered poisons formed in the plants. These are removed as insoluble calcium salts.

7. It improves intake of plant nutrients like nitrogen and trace elements including zinc, copper, manganese and boron by correcting soil pH.

8. It influences the water economy of the plant.

Deficiency Symptoms of Calcium:

- Young leaves are smaller than normal and they are distorted. They die - back at the tips and margins.
- Leaves show narcotic spots and stalk finally dies at the terminal bud.
- The roots do not develop properly and they start rotting.
- Potato plants become like herbs.
- Less and small nodules are formed in the roots of legume crops.

- The green color of leaves of citrus plants like lemons starts becoming light towards the margins.

Functions of Magnesium:

1. Magnesium helps in carrying the dark green color in leaves because it is constituent of chlorophyll which is essential for all green plants.
2. It helps in the production of carbohydrates, oils and fats, nucleoproteins and vitamins in the plants.
3. 3. It helps in translocation (movement from one part to the other) of starches.
4. It acts as a carrier of phosphorus in plants. In this way, it helps in the formation of seeds which contain high oil content. Hence, magnesium promotes the formation of oils and fats in plants.
5. It regulates the base economy of plants and the uptake of nutrients.

Deficiency Symptoms of Magnesium:

- General loss of green colour of leaves starts from bottom leaves which moves upward. Hence, chlorosis takes place in plants.
- The veins of the leaves remain green but, in cotton, leaves turn purplish red between green veins.
- Potato leaves become fragile and drop prematurely.
- The leaves of citrus plants like lemon develop yellow spots.
- Plant growth is retarded.
- A fruit starts falling from the trees and the yield decreases.

Toxicity Symptoms of Magnesium:

Due to excess magnesium, there is spiral deformation in the lower portion of the young leaves.

Functions of Sulphur:

1. Sulphur increases root growth and vegetative plant growth.
2. It promotes nodule formation on the roots of legumes.
3. It stimulates seed formation and yield of onions and garlic.
4. Sulphur is not a constituent of chlorophyll but it helps in the formation of chlorophyll in plants.
5. It is an important constituent of certain volatile compounds such as mustard oil and many proteins and enzymes.
6. It helps in the activation of ferments.
7. It helps in reduction - oxidation system in respiration.

Deficiency Symptoms of Sulfur:

- The growth of the plant is retarded due to decrease in protein formation.
- The plants are thin - stemmed and spindly. Young leaves are chlorotic (yellow). The veins and the tissue between them become light green in color.
- The disease like tea yellow develops in plants.

Toxicity Symptoms:

Due to excess of sulphur, leaves undergo interveinal yellowing and the leaf tissues bum.

Functions of Iron:

1. Iron helps in the absorption of other nutrients in the plants.
2. It is not a constituent of chlorophyll but it helps in its formation.
3. It is essential for protein synthesis found in chloroplasts.
4. It acts as oxygen carrier in respiration process.
5. It regulates respiration, photosynthesis and reduction of nitrates and sulphates in plants.
6. It is a constituent of enzyme system which takes part in oxidation - reduction reactions in plants.

Deficiency Symptoms of Iron:

- The growth of plants stops.

- Young leaves become chlorotic i.e. they develop a disease called chlorosis. Leaves in legumes become yellow but principal veins are green.
- Young growing tissues die - back.
- Stalks become short and slender (thin).
- Some trees may have a dead top.
- The development of fruits and seeds is poor.

Toxic Effects of Iron:

In an excess of iron, the plant growth is hindered. The lower leaves in paddy develop brown spots on upper corners and they spread towards the base.

Functions of Zinc:

1. Zinc acts as a catalyst in the formation of chlorophyll.
2. It is a constituent of several enzyme systems which regulate some metabolic reactions in plants.
3. It influences the formation of some growth hormones like auxins in plants.
4. It is helpful in the reproduction of some plants.
5. It is linked with water uptake in plants.

Deficiency Symptoms of Zinc:

- The plants become severely dwarfed due to poor crop growth.
- The internodes are short.
- The yellow stripping is formed between the veins of the leaves.
- The leaves become smaller than normal, thick, narrow and deformed.
- The older leaves drop prematurely after becoming yellow.
- Leaves are bushy due to low auxin formation.
- Seed formation is less and fruits are deformed. Hence, the yield decreases.

Toxic Effects of Zinc:

Due to excess of zinc, the new leaves become yellow. They become brownish - red and dry. The edges of zinc affected leaves become folded and their tissues become generally dead. Acute toxicity of zinc causes iron deficiency. Hence, iron chlorosis is seen.

Function of Manganese:

1. It supports the movement of iron in plants.
2. It influences auxin level in plants. It helps in breakdown of IAA (Indole acetic acid)
3. It helps in the formation of chlorophyll. So, it is essential for photosynthesis and formation of carbohydrates in plants.
4. It acts as a catalyst in oxidation - reduction reactions in the tissues of the plants.
5. As a coenzyme, manganese helps in respiration and in the synthesis of protein in the chlorplasts.
6. Sometimes, it also helps in counteracting the bad effect of poor aeration.

Deficiency Symptoms of Manganese:

Manganese is immobile in plants. Hence, its deficiency symptoms first appear in younger leaves.

- Plant growth is retarded because the synthesis of carbohydrates is reduced.
- Dead spots of dead tissues are scattered over the young leaves.
- Smallest veins remain green producing a reticulated (net - like) effect.
- The plants of tobacco, tomato, beans and oat remain dwarf. The spinach and soyabean become yellow.

Functions of Copper:

1. Copper helps in the utilization of iron in the synthesis of chlorophyll. Hence, it helps in the synthesis of chlorophyll indirectly.
2. It acts as an electron carrier in enzymes which carry out oxidation - reduction reactions in plants.
3. It affects respiration in plants.
4. It forms many compounds with amino acids and proteins in plants.

5. It can neutralize the harmful conditions by precipitating certain toxic substances present in peat soils such as in Kerala.

Deficiency Symptoms of Copper:

- Green leaves undergo chlorosis and become yellow.
- Leaves curl and terminal leaves become bushy.
- Young leaves are wilted permanently without spotting or marked chlorosis. Buds are affected more.
- In grains, white tip or yellow tip disease develops and heads are distorted or dwarfed.
- In plants of lemon family, the leaves become yellowish green and start falling prematurely. The branches become without leaves and start to die.
- Flowering fails, fruit quality is poor and, hence, yield reduces.

Toxic Effects of Copper:

- Plant growth is poor at initial stage of toxicity.
- Leaves show iron chlorosis at advanced stage of toxicity.

Functions of Molybdenum:

1. Molybdenum is essential for fixation of atmospheric nitrogen, both symbiotic as well as non-symbiotic.
2. It increases efficiency of legumes in fixation of atmospheric nitrogen.
3. It acts in enzyme systems which carry out oxidation - reduction reactions.
4. It helps in the reduction of nitrates to ammonia prior to amino acid and protein synthesis in plant cells.
5. It is essential for the synthesis of vitamin C (ascorbic acid) in plants.

Deficiency Symptoms of Molybdenum:

- The leaves undergo loss of chlorophyll and firing after wilting.
- Lower leaves of tomatoes and potatoes become brown and show curling of leaf edges.

- In oats, the leaves bend backward and later break at the affected areas with necrosis.

Functions of Boron:

1. Boron helps in absorption of nitrogen in plants.
2. It keeps calcium soluble and increases its mobility in plants.
3. It acts as a regulator of potassium / calcium ratio in plants.
4. It is needed for protein synthesis and formation of fruits and seeds.
5. It is necessary for translocation of sugars in plants.
6. It is a constituent of cell membrane and it is essential for cell division.
7. It is essential for the development of nodules in roots of legumes.
8. It affects various functions in plants like absorption of nutrients, flowering and fruiting processes and several metabolisms.

Deficiency Symptoms of Boron:

- Cell division ceases at the growing point but the individual cells continue growth.
- The bushy growth and major branches die.
- Young leaves of terminal bud become light green at the base and they finally break down.
- Leaves become twisted in later growth and stalks finally die at terminal bud.
- Length of internodes shortens and the stems are thick, corky and cracked.
- Flowering and the formation of fruits and seeds are restricted.
- Browning of curd and lesions in pitch in cauliflower takes place.

Toxic Effects of Boron:

Initially leaf tips show yellowing. In acute toxicity, the whole leaf shows chlorosis i.e. yellowing and scorching. The affected leaves drop prematurely.

Functions of Chlorine:

Chlorine was proved to be essential plant nutrient in 1954 in USA but its exact role in plant nutrition is not yet well defined. However, chlorine performs the following functions in plants:

1. Chlorine helps in making osmotic pressure in cells normal and controlled.
2. It maintains cation balance in cell sap.
3. It is a constituent of anthocyanins.
4. It is related to chlorophyll synthesis too.

Deficiency Symptoms of Chlorine:

- Leaves show symptoms of wilting of leaf - blade tips.
- Leaves become yellow indicating chlorosis.
- Leaves show bronzing and necrosis in areas near to wilting.

Critical Levels of Deficiency and Toxicity:

The plants normally contain a definite percentage range of nutrients in total tissues of the plants. In case the nutrient element present in plant tissues is less than the normal percentage range for it, there will be deficiency of this nutrient. In case the nutrient element present in plant tissues is more than the normal percentage range of it, then this nutrient will prove to be toxic.

The usual content of the nutrient elements present in the plant tissues as a whole is given in the following table.

Elements Present in Plant Tissues

S.No	Name of Nutrient	Percentage Range in total plant tissues
1	Carbon	45%
2	Oxygen	43%
3	Hydrogen	6%
4	Nitrogen	1-3%

5	Phosphorus	0.05 - 1.0%
6	Potassium	0.3-6.0%
7	Calcium	1.0-4.0%
8	Magnesium	0.05-1.0%
9	Sulfur	0.05 - 1.5%
10	Iron	10 - 1,000 ppm (Parts per million)
11	Manganese	5 - 50 ppm.
12	Zinc	5- 100 ppm.
13	Copper	2 - 50 ppm.
14	Molybdenum	0-01-10 ppm.
15	Boron	2-72 ppm.
16	Chlorine	100 - 250 ppm

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