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Indian Plant mineral nutrition

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Contents

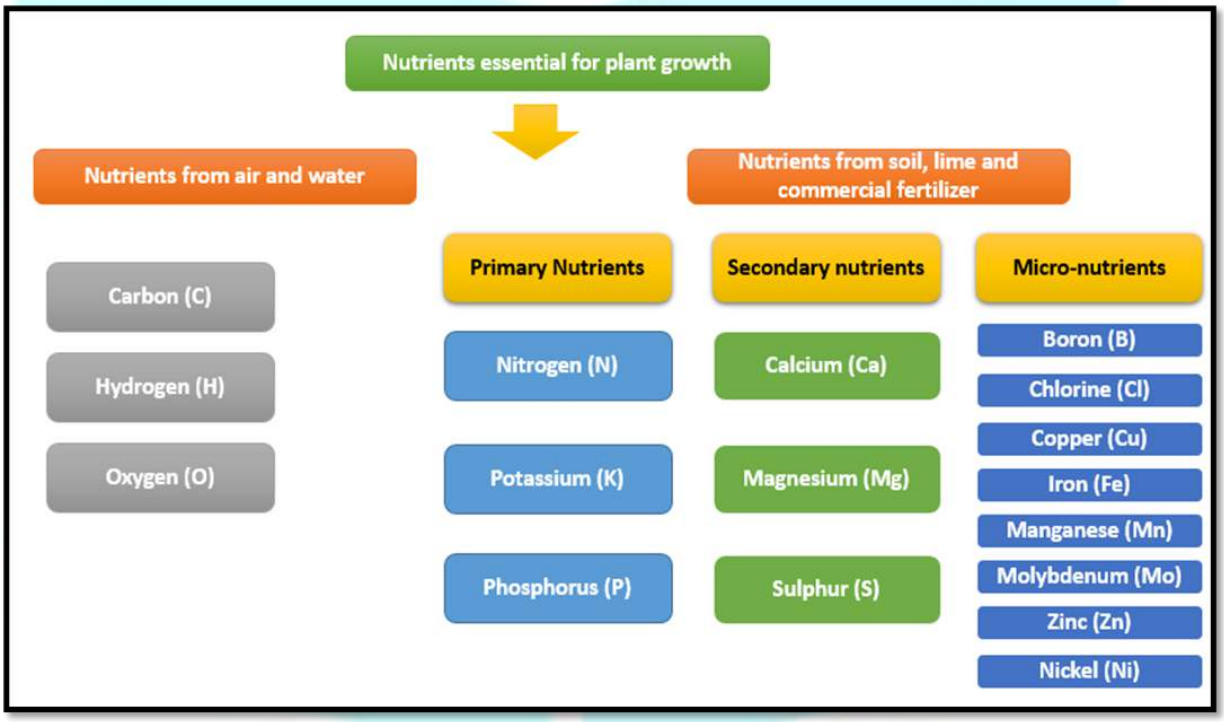
Plant Mineral Nutrition

- ✓ Plant contains **more than 90 elements**, out of which, **17 elements are known to be essential** which are **further classified** as **macro-nutrients** and **micro-nutrients** based on their relative abundance in plants.

- ✓ Now, when we say that the nutrients are essential. **How do we determine essentiality?** Let's understand.

1 Essentiality of plant nutrients

- ✓ **Arnon and Stout (1939)** and **Arnon (1952)** proposed the following **criteria of essentiality** of **mineral nutrients:**
  1. A **deficiency of the element** in question results in **failure to complete the life cycle**
  2. **Deficiency of element** in question can be **corrected only by supplying that particular element** and
  3. The **element must directly be involved in the nutrition** and **metabolism of the plant** and have a **direct influence on plant** apart from its **possible effects** in **correcting some micro-biological** or **chemical conditions** of the soil or other culture medium.
- ✓ Based on these criteria, we have a list of certain essential elements. There are 17 such elements.



Note: The **Primary and Secondary nutrients** are **together known as Macro-nutrients** or **Major nutrients.**

2 Mobility of nutrients in the soil and the plants

- ✓ There is **important aspects** that affects the availability of nutrients to plants. It is the **mobility of the nutrients in the soil and the plants**:

2.1.1 Mobility in the soils

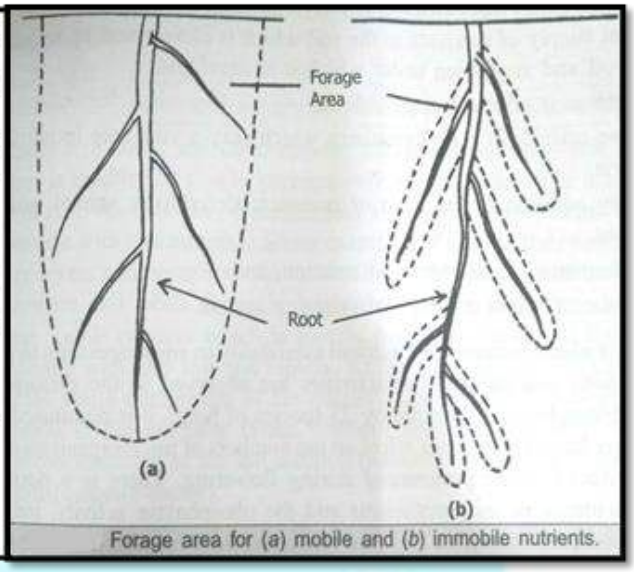
- ✓ Mobility of nutrients in the soils has **considerable influence on availability of nutrients** to plants and method of fertilizer application.
- ✓ **For plants to take up these nutrients**, two processes are important:
  (1) **Movement of nutrient ions** to the **absorbing root surface**
  (2) **Roots reaching the area** where **nutrients are available.**
- ✓ In the **case of immobile nutrients**, the **roots have to reach the area of nutrient availability** and **forage volume is limited to root surface area.**
- ✓ For **highly mobile nutrients**, the **entire volume of the root zone is forage area.**

Based on the mobility in the soil, the nutrient ions can be grouped as mobile, less mobile and immobile.

The mobile nutrients are highly soluble and are not absorbed on clay complex, e.g., NO3-, SO4 2-, BO32-, Cl-, Mn++.

Less mobile nutrients are also soluble, but they are absorbed on clay complex and so their mobility is reduced, e.g., NH4+, K+, Ca+, Mg++, Cu++.

Immobile nutrients ions are highly reactive and get fixed in the soil, e.g., H2PO4-, HPO4 2-, Zn++.



Forage area for (a) mobile and (b) immobile nutrients.

2.1.2 Mobility in plants

- ✓ Knowledge of the mobility of nutrients in the plant helps in finding what nutrient is deficient. A **mobile nutrient** in the plant, **moves to the growing points** in **case of deficiency**.
- ✓ **Deficiency symptoms**, therefore, **appear on the lower leaves**.
  - **N, P and K** are **highly mobile**
  - **Zn** is **moderately mobile**
  - **S, Fe, Mn, Cu and Cl,** are **less mobile**
  - **Ca and B** are **immobile**

2.1.3 How mobility of nutrients in plants has an effect on the appearance of deficiency symptoms?

- ✓ The **region of appearance of deficiency symptoms depends** on **mobility of nutrient in plants**.
- ✓ The nutrient deficiency **symptoms of N, P, K, Mg and Mo** appear in **lower leaves** (old) because of their mobility inside the plants.
- ✓ **Zinc** is **moderately mobile** in plants and deficiency symptoms, therefore, **appear in middle leaves.**
- ✓ The deficiency symptoms of **less mobile elements** (S, Fe, Mn and Cu) **appear on new leaves**.
- ✓ Since **Ca and B** are **immobile** in plants, **deficiency symptoms** appear **on terminal buds.**

2.1.4 Law of Minimum by Justus Von Liebig (1862)

- ✓ Justus von Liebig's **Law of the Minimum** states that **yield is proportional to the amount of the most limiting nutrient**, whichever nutrient it may be.
- ✓ From this, it may be inferred that **if the deficient nutrient is supplied**, **yields may be improved to the point that some other nutrient is needed in greater quantity** than the soil can provide, and **the Law of the Minimum would apply in turn to that nutrient.**

3 Functions of the Nutrients

Nutrient	Function
Carbon	✓ Basic molecular component of carbohydrates, proteins, lipids, and nucleic acids.
Oxygen	✓ Oxygen is somewhat like carbon in that it occurs in virtually all organic compounds of living organisms.
Hydrogen	✓ Hydrogen plays a central role in plant metabolism. ✓ Important in ionic balance and as main reducing agent and plays a key role in energy relations of cells.

Nitrogen	✓ Nitrogen is a component of many important organic compounds ranging from proteins to nucleic acids. Necessary for formation of amino acids, the building blocks of protein. ✓ Essential for plant cell division, vital for plant growth ✓ Imparts green colour to the plant ✓ Constituent of protoplasm of chlorophyll ✓ Play an important role in synthesis of auxin
Phosphorus	✓ Most essential functions are energy storage and transfer of energy (component of ATP) and acts as 'energy currency'. ✓ Essential component of nucleic acid ✓ Necessary for root development ✓ Increases the disease resistance ✓ Required for grain formation and maturity of grains. ✓ Central role in plants is in energy transfer and protein metabolism.
Potassium	✓ Most essential function is stomata regulation. Helps in osmotic and ionic regulation. ✓ Provides disease resistance in plants ✓ Potassium functions as a cofactor or activator for many enzymes of carbohydrate and protein metabolism. Helps in chlorophyll formation ✓ For sugar synthesis and its translocation to the storage tissue, potassium is highly important, especially in Sugarcane plants. ✓ Reduces the transpiration rate and increases the photosynthetic rate ✓ It is useful in stress condition as it secretes 60 enzymes
Calcium	✓ Calcium is involved in cell division and plays a major role in the maintenance of membrane integrity.
Magnesium	✓ Component of chlorophyll and a cofactor for many enzymatic reactions.
Sulfur	✓ Sulfur is somewhat like phosphorus in that it is involved in plant cell energetic. It is essential constituents in some amino acids i.e..cystine, cysteine etc.. ✓ It is essential for **oil seeds and pulses** because it improves **oil content** and **protein content** in oil seeds and pulses respectively.
Iron	✓ An essential component of many heme and nonheme Fe enzymes and carries, including the cytochromes (respiratory electron carriers) and the ferredoxins. ✓ The latter are involved in key metabolic function such as N fixation, photosynthesis, and electron transfer. An essential component of many enzymes ✓ Essential for formation of chlorophyll ✓ Acts as an **oxygen carrier**
Zinc	✓ Essential component of servral dehydrogenases, and peptidases, including carbonic anhydrase, alcohol dehydrogenase, glutamic dehydrogenase, and malic dehdrogenase, among others. It is required for biosynthesis of hormones ✓ Aids in seed formation. ✓ Necessary for starch formation

Manganese	✓ Involved in the O2 – evolving system of photosynthesis and is a component of the enzymes arginase and phospho transferases. Involved in the oxygen evolving system of photosynthesis ✓ It is a cofactor of enzyme (thus functions as a part of certain enzyme systems)
Copper	✓ Constituent of a number of important enzymes, including cytochrome oxidize, ascorbic acid oxidase, and laccase. ✓ Important for reproductive growth. ✓ Aids in root metabolism and helps in the utilization of proteins. ✓ Essential for photosynthesis and respiration
Boron	✓ Necessary for pollen germination ✓ Concerned with water reactions in the cells and regulates the intake of water into the cell ✓ Necessary for sugar translocation ✓ May act as regulator of potassium ratio and keeps calcium in soluble form within the plants ✓ The taste in cauliflower is due to the presence of Boron
Molybdenum	✓ Required for the normal assimilation of N in plants. An essential component of nitrate reductase as well as nitrogenase (N2 fixation enzyme) which reduces nitrates to ammonium in plant (Playing a role in Nitrogen Cycle). ✓ Helps in the Nitrogen fixation in Pulses. ✓ It converts inorganic phosphates to organic forms in the plant.
Chlorine	✓ Essential for photosynthesis and as an activator of enzymes involved in splitting water. It is absorbed in the Cl- form. ✓ Essential for photosynthesis and as an activator of enzymes involved in splitting water. ✓ It also functions in **osmoregulation of plants** growing on **saline soils**.
Nickel	✓ It is a component of some plant enzymes, most important urease, which metabolizes urea nitrogen into useable ammonia within the plant. ✓ It is also used as a catalyst in enzymes used to help legumes fix nitrogen.

✓ Overall, based on the functions, nutrients are grouped into four: Basic structure, energy use, charge balance and enzyme activity:

- **Elements that provide basic structure to the plant:** Carbon, Hydrogen and Oxygen
- **Elements useful in energy storage, transfer and bonding:** Nitrogen, Sulphur and Phosphorus. These are **accessory structural elements** which are more active and vital for living tissues.
- **Elements necessary for charge balance:** Potassium, Calcium and Magnesium. These elements act as regulators and carriers.
- **Elements involved in enzyme activation and electron transport:** Fe, Mn, Zn, Cu, B, Mo and Cl. These elements are **catalysers and activators**.

4 Deficiency symptoms

✓ When **nutrient is not present in sufficient quantity**, plant growth is affected. **Plants** may not **show visual symptoms upto a certain level** of nutrient content, but **growth is affected**, and **this situation is known as hidden hunger.**

✓ When a **nutrient level still falls**, **plants show characteristic symptoms** of deficiency.

✓ These symptoms though vary with crop, **have a general pattern**. These are generally **marked by diseases and other stresses** and need careful and patient observation on more number of plants for typical symptoms. The **deficiency symptoms appear clearly** in crops **with larger leaves.**

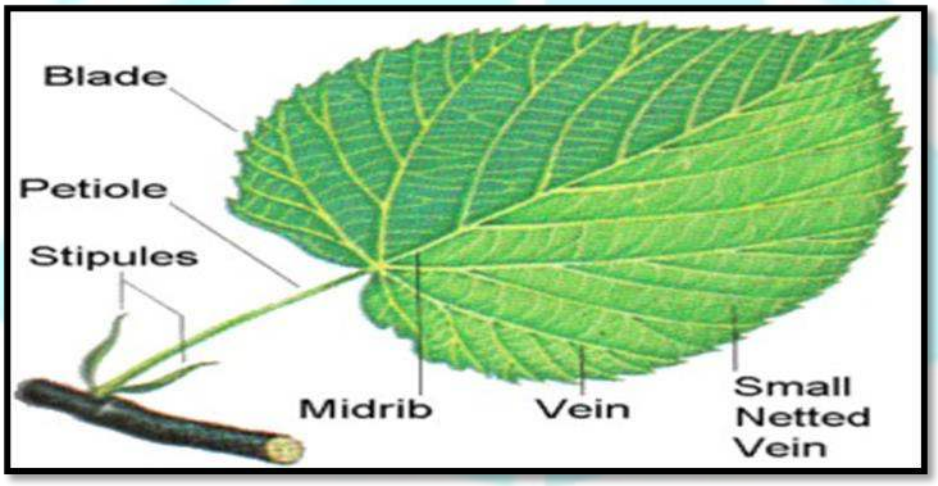
- ✓ **Nutrient deficiency symptoms** may be classified as follows:
    1. **Complete crop failure** at the seedling stage.
    2. **Severe stunting** of plants
    3. **Specific leaf symptoms** appearing at varying times during the season.
    4. **Internal abnormalities** such as clogged conductive tissues.
    5. **Delayed or abnormal maturity**.
    6. **Obvious yield differences**, with or without leaf symptoms.
    7. **Poor quality of crops**, including differences in protein, oil, or starch content, and storage quality.
    8. **Yield differences** deleted only by careful experimental work

- ✓ Before going into further detail, we shall have a look at **certain important terms** and the **parts of the leaf**:

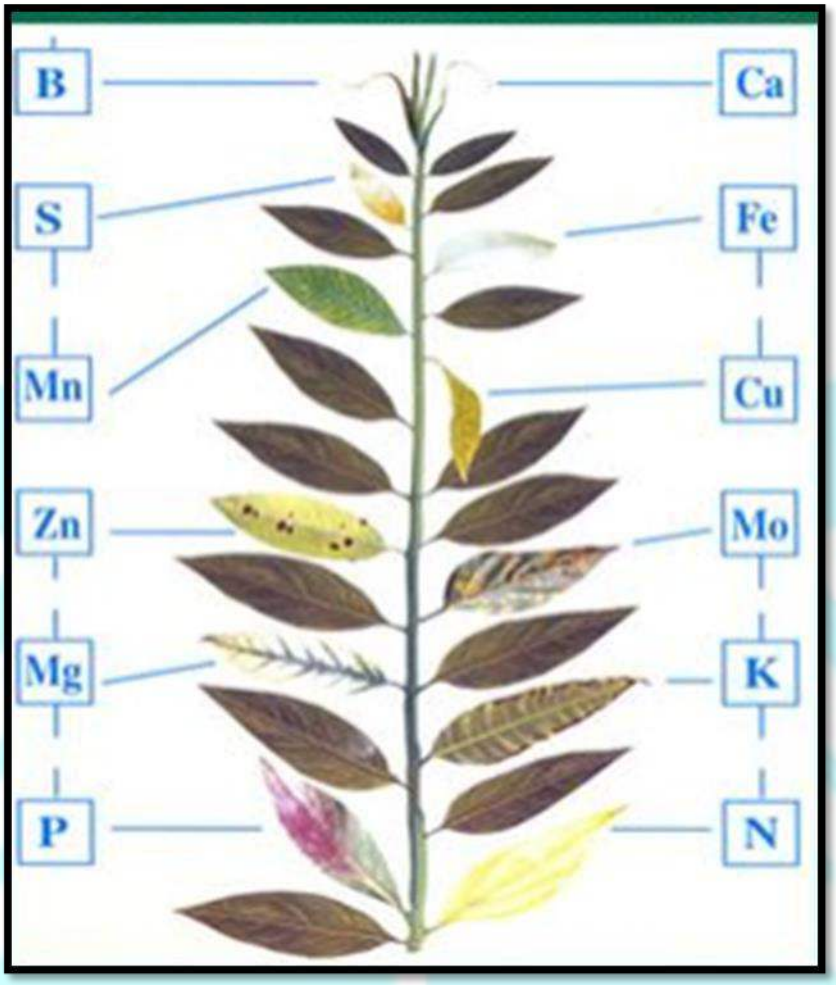
Important Terms:

- ✓ **Chlorosis:** It is a physiological disorder that occurs due to deficiency of mineral elements (eg; Mn, K, Zn, Fe, Mg, S and N).
- ✓ Leaves or plants parts become abnormally yellow.
- ✓ **Mottled surface:** Surface marked with coloured spots (anthocyanin develops) eg. Due to deficiency of N, Mg, P, S.
- ✓ **Necrosis** refers to patch of dead tissues, due to the deficiency of Mg, K, Zn, Ca and Mo.

Parts of the leaf:



5 Detailed discussion of each nutrient



5.1 Nitrogen (N)

Deficiency:

- ✓ Uniform yellowing of older leaves including veins, leaves that will eventually turn brown and die.
- ✓ Plant growth is slow; plants will be stunted, and will mature early, cereal crops show 'V' shaped pale yellowing at lower leaf tips.
- ✓ Deficiency causes 'Buttoning in cauliflower'.

Excess:

- ✓ Plants will be dark green in colour and new growth will be succulent; susceptible if subjected to disease and insect infestation; and subjected to drought stress, plants will easily lodge. Blossom abortion and lack of fruit set will occur.

5.2 Phosphorous (P)

Deficiency:

- ✓ Plant growth will be slow and stunted
- ✓ the older leaves will have a purple coloration, particularly on the underside, rear sides develop bronzy appearance, premature leaf falling is most common.
- ✓ Deficiency causes 'Sickle leaf disease' of pepper.

Excess:

- ✓ Phosphorus excess will not have a direct effect on the plant but may show visual deficiencies of Zn, Fe and Mn.
- ✓ High P may also interfere with the normal Ca nutrition, with typical Ca deficiency symptoms occurring.

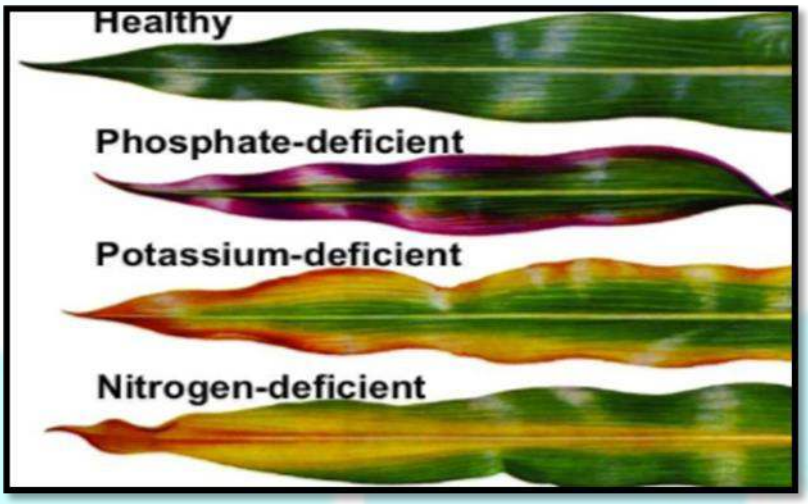
5.3 Potassium (K)

Deficiency:

- ✓ Yellowing starts from tip/margin of lower leaves and extend to centre of leaf base.
- ✓ Yellowing parts became dead spots (necrotic). The edges of older leaves will look burned, a symptom known as scorch.
- ✓ Scorching and burning on margins of bottom leaves are most common.

- ✓ **Excess:** Plants will exhibit typical Mg, and possibly Ca deficiency symptoms due to a cation imbalance.

The diagram below compares the deficiency symptoms of Nitrogen, Phosphorus and Potassium:



5.4 Calcium (Ca)

Deficiency:

- ✓ Terminal bud leaf becomes chlorotic white with base remains green.
- ✓ 1/3 chlorotic portion of tip hooks downward and brittle.
- ✓ Death of terminal buds. Deficiency causes 'Blossom end rot' in Tomato and Ber and 'Tip hooking in Cauliflower.

Excess:

- ✓ Plants may exhibit typical Mg Deficiency symptoms, and when in high excess, K deficiency may also occur.

5.5 Magnesium (Mg)

Deficiency:

- ✓ Older leaves will be yellow between veins and veins remain green (Interveinal chlorosis).
- ✓ Leaves become mottled.
- ✓ Also affects chlorophyll formation.
- ✓ Deficiency causes 'sand drawn disease' in tobacco.

Excess:

- ✓ Results in cation imbalance showing signs of either a Ca or K deficiency.

5.6 Sulphur (S)

Deficiency:

- ✓ Yellowing of leave, leaves are paler than interveinal portion.
- ✓ Occurrence of 'Downward cupping of leaves in tobacco and tea'.
- ✓ Also, In cabbage, there is a reddening and purpling of both upper and lower leaf surfaces;
- ✓ the cupped leaves turn back on themselves, presenting flattened-to-concave surfaces on the upper side. In rapeseed the leaves are cupped inward.

Excess:

- ✓ A premature senescence of leaves may occur.

5.7 Boron (B)

Deficiency:

- ✓ Yellowing/chlorosis starts from base of terminal bud leaf and extends to tip results in appearance of 'Whip like structure' and become brownish/blackish brown.
- ✓ Deficiency causes 'Internal necrosis in Amla and mango', 'Hen and chicken disorder in grape' and heart rot in sugar beet'.

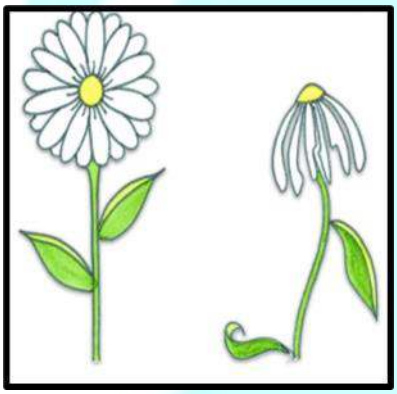
Excess:

- ✓ Leaf tips and margin will turn brown and die.
- ✓ **Other disorders:**
  - Browning of hollow stem of cauliflower
  - Top sickness of tobacco
  - Die back of apples
  - Fruit cracking of tomato
  - Hard fruit of citrus

5.8 Chlorine (Cl)

Deficiency:

- ✓ Younger leaves will be chlorotic, and plants will easily wilt.
- ✓ For wheat, a plant disease will infest the plant when Cl is deficient.



Excess:

- ✓ Premature yellowing of the lower leaves with burning of the leaf margins and tips.
- ✓ Abscission will occur, and plants will easily wilt.

5.9 Copper (Cu)

Deficiency:

- ✓ Leaves including veins become yellow and tending towards whiteness.
- ✓ Occurrence of 'Marginal leaf burning'. Deficiency causes Limb die back in shoots of young plants of citrus

Excess: Fe deficiency may be induced with very slow growth.

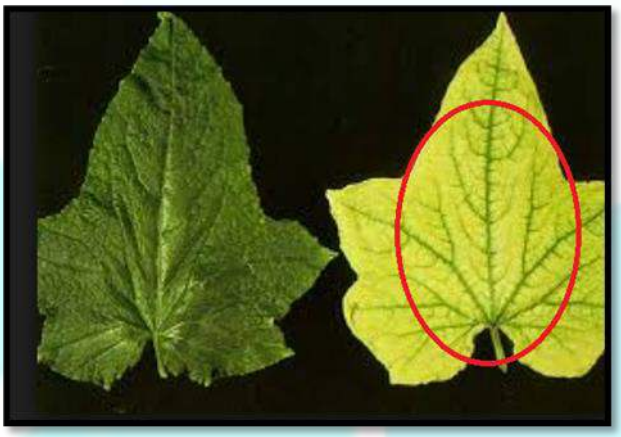
- ✓ Roots may be stunted.

Other disorder: Gummosis and Xanthomenia disease of citrus.

5.10 Iron (Fe)

Deficiency:

- ✓ Veins remain conspicuously green and other leaf portion turn yellow and tending towards whiteness.
- ✓ Interveinal chlorosis will occur.
- ✓ Deficiency causes 'Leaf bleaching in sugarcane' and 'Ivory white of paddy'.



Excess:

- ✓ A bronzing of leaves with tiny brown spots on the leaves, a typical symptom frequently occurring with rice.

5.11 Manganese (Mn)

Deficiency:

- ✓ Interveinal yellowing of young leaves but not tending towards whiteness.
- ✓ Veins remain green.
- ✓ Deficiency causes 'Marsh disease in pea'

Excess:

- ✓ Older leaves will show brown spots surrounded by a chlorotic zone and circle.

5.12 Molybdenum (Mo)

Deficiency:

- ✓ Older and middle leaves become chlorotic first.
- ✓ Translucent spots of irregular shape between veins; spots become impregnated with resinous gum.
- ✓ Occurrence of 'typical interveinal chlorosis'.
- ✓ Deficiency causes 'Whiptail disease and browning in cauliflower'.

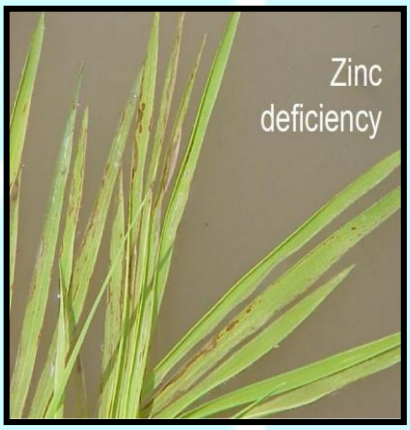
Excess:

- ✓ Not of common occurrence.

5.13 Zinc (Zn)

Deficiency:

- ✓ Upper leaves will show chlorosis on midrib.
- ✓ Veins green and dead spots occur in all parts of leaf (veins, tips and margins).
- ✓ Plants appear bushy due to reduced intermodal elongation.
- ✓ 'White bud of maize' is caused by the deficiency.



Excess:

- ✓ Fe deficiency will develop.
- ✓ **Other disorders:**
  - Khaira disease of rice;
  - Little leaf of cotton and apple
  - Mottled leaf of citrus; Leaf Die back and Little leaf of citrus.
  - Rosette formation in apple (The little leaf in apple and pears trees lead to distortion of shoot tips resembling rosette formation).

5.14 Nickel (Ni):

- ✓ Minor Nickel Deficiency displays no visual symptoms but can reduce growth and yield of plants.

- ✓ Significant nickel deficiency will display visual symptoms typically in the old leaves of the plants.
- ✓ Mostly whole leaf chlorosis accompanied by necrotic leaf tips is observed.