SOIL SCIENCE Section

Course No. : **SOIL-122**

Course Title : **Soil Fertility Management**

Credit : **3(2+1)**

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Assistant Professor
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Lecture no.- 3, 4 & 5

Essential Plant Nutrients

(8 %)

Sub-topics/ Key points

- Criteria of Essentiality of Nutrients
- Essential and Beneficial Nutrients and their Role
- Forms of nutrients in soil and critical levels of different nutrients in soil
- Deficiency and Toxicity symptoms of essential plant nutrients

Basic Parameter

- **Nutrient**

A nutrient element is one that is require to complete the lifecycle of an organism and its relative deficiency produce by specific deficiency symptom.

- **Sufficient**

Range of nutrient content in plants associated with optimum crop yield it is called as sufficient.

- **Toxicity**

When the concentration of nutrient element rise to high to cause significant growth reduction it is form as toxicity.

Basic Parameter

- **Available nutrient**

  It is the portion of nutrient in the soil that can be readily absorb and assimilated by the plants.

- **Total nutrient**

  It is the available and unavailable nutrient which is present in soil is called total nutrient.

- **Functional/ Metabolic nutrient**

  This term introduced by **Nicholas (1961).**

  Defined as an element that plays the role in plant metabolism whether or not that role is a specific or indispensable.

➢ Trace element

Trace element is element found in a low conc. **less than 1 ppm** and still less in soil, plant and water.

eg. Zinc, iron, copper, manganese, selenium, chromium, fluoride, and molybdenum etc.

➢ Tracer element

Radioisotope or stable isotope of element used for tracing its part in a system, to study the mechanism of interaction with the system is called tracer element.

eg. Uranium-238 (U-238), lead-206 (Pb-206).

Heavy metal

A metal having **specific gravity more than 5** or having **atomic no. higher than 20** is called as heavy metal.

- Any metal heavier than calcium is called heavy metal.

- eg. Arsenic, cadmium, chromium, lead, mercury and nickel.

Beneficial Nutrients/Elements

Beneficial elements are the mineral elements that stimulate the growth and exhibit beneficial effects at very low concentration or which are essential only for certain plant species or under specific conditions are called as “beneficial elements”.

- eg. **Na, Va, Co, Si. etc.**

➢ **Essential elements / nutrient :**

"A mineral element is considered to be essential for plant growth and development if the element is involved in plant metabolic functions and the plant cannot complete its life cycle without the element".

There are seventeen essential elements required for plant growth viz., **C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, Cl, Ni**

Criteria of essentiality

There are **17** elements that are essential for the growth and full development of higher green plants according to the criteria laid down by **Arnon and Stout** (1939) which was refined by **Arnon (1954).** These criteria are:

1. A plant cannot complete its life-cycle in the absence of the essential element.
2. The action of the element must be specific, with no other element being able to completely substitute for it.
3. The element is involved directly in the nutrition and metabolism of the plant.

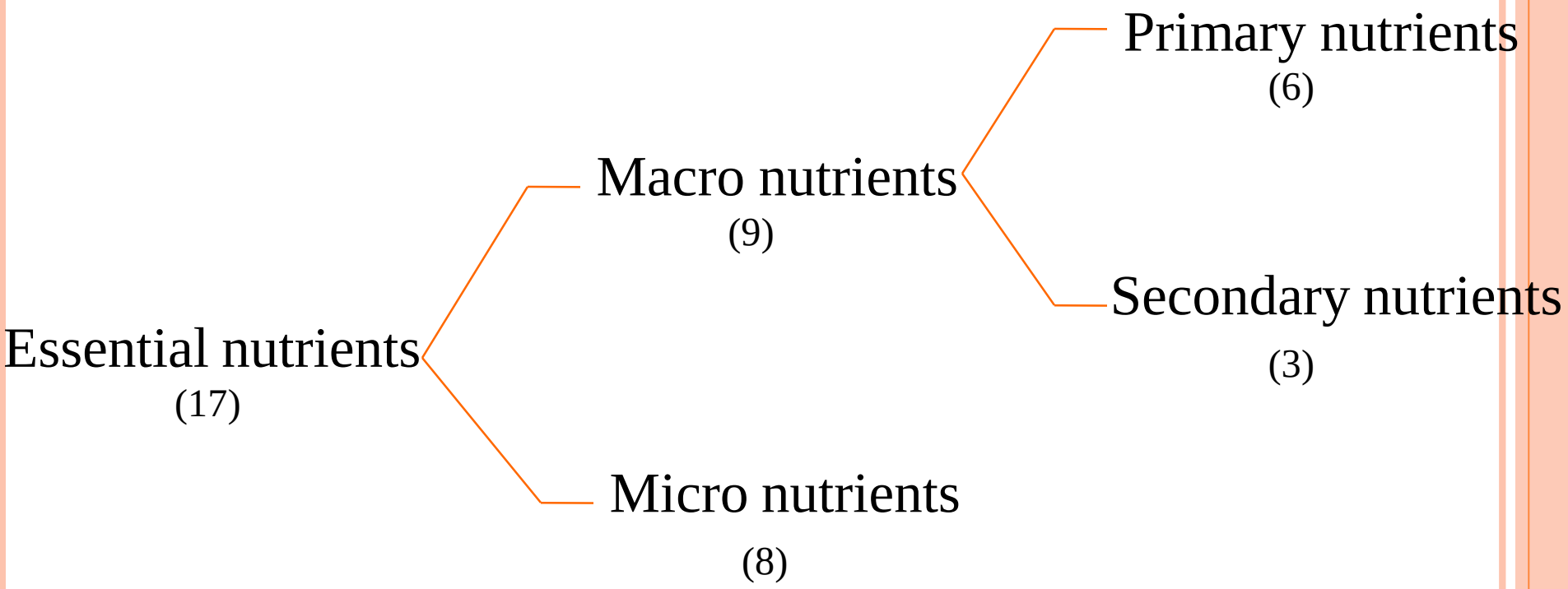
ESSENTIAL NUTRIENTS :

- According to Arnon & Stout there are 17 essential nutrients for plants.

1. **Essential nutrients are classified in 2 types:**

   (1) Macro/Major nutrients: They are the nutrients utilized by the plants in relatively large amounts (quantity) for their growth and development.

   (2) Micro nutrients/ trace/rare/nano element: The nutrients which are required by plants in relatively smaller quantities for their growth and development.


Essential nutrients
(17)
Macro nutrients
(9)
Micro nutrients
(8)
Primary nutrients
(6)
Secondary nutrients
(3)

Macro nutrients: There are 9 macro nutrients required for the growth and development of plants. These are further sub divided in 2 groups-

(A) Primary nutrients:
1) Carbon (C)
2) Hydrogen (H)
3) Oxygen (O)

Basic nutrients

4) Nitrogen (N)
5) Phosphorus (P)
6) Potassium (K)

(B) Secondary nutrients:
7) Calcium (Ca)
8) Magnesium (Mg)
9) Sulphur (S)

Micro nutrients: There are 8 micro nutrients required for the growth and development of plants. These are-

1) Boron (B)
2) Manganese (Mn)
3) Copper (Cu)
4) Zinc (Zn)
5) Molybdenum (Mo)
6) Chlorine (Cl)
7) Iron (Fe)
8) Nickel (Ni)

Nickel (Ni) is the 17th essential nutrient known in 1987 which found by **Brown et.al**

2) Classification based on the Role of element in plant system

(According to Truog, 1954)

i) Structural Elements : C, H, O

ii) Accessory structural elements : N, P, S

iii) Regulator & Carriers : K, Ca, Mg

iv) Catalyst & Activators : Fe, Mn, Zn, Cu, Mo, Cl, B

3) Classification based on Mobility of nutrient in plant

i) Highly mobile: N, P & K

ii) Moderately mobile: Zn

iii) less Mobile: S, Fe, Mn, Cl, Mo & Cu

iv) Immobile: Ca & B

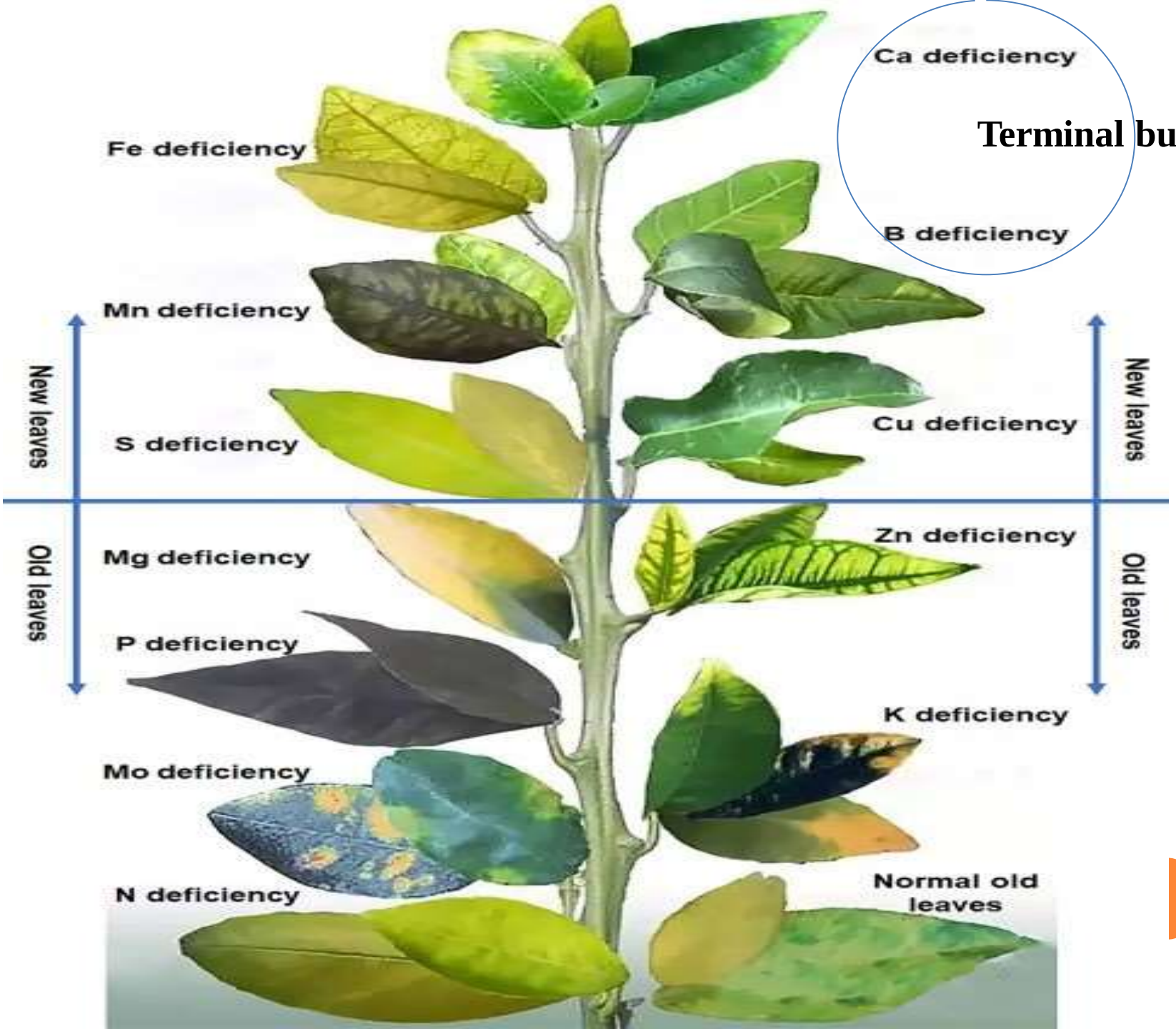
Nutrient essentiality discover and Plant usable form:

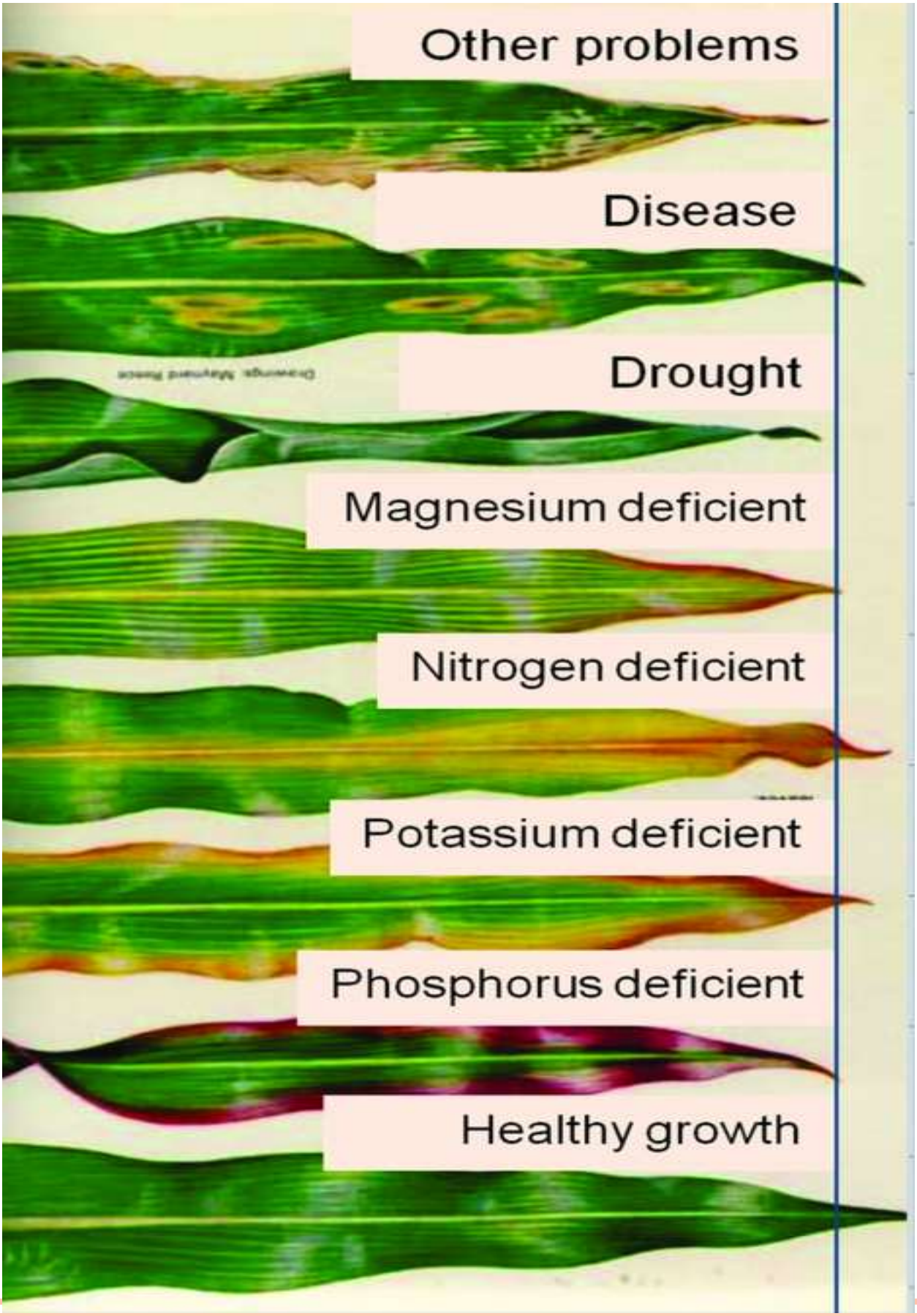
Sr. No.	Nutrient	Essentiality discover	Year	Plant usable form
1	H	-	-	H_2O
2	O	-	-	H_2O, O_2
3	C	Priestley *et.al*	1800	CO_2
4	N	Theodore de saussure	1804	NO_3^-, NH_4^+
5	K	C. Sprengel	1839	K^+
6	Ca	C. Sprengel	1839	Ca^{2+}
7	Mg	C. Sprengel	1839	Mg^{2+}
8	P	C. Sprengel	1839	$H_2PO_4^-$, HPO_4^{2-}
9	S	Sachs & Knop	1860	SO_4^{2-}
10	Cl	T. C. Broyer A. B. Carltol C. M. Jonshon P. R. Stout	1954	Cl^-
11	Fe	E. Greis	1843	Fe^{2+}

Nutrient essentiality discover and Plant usable form:

Sr. No.	Nutrient	Essentiality discover	Year	Plant usable form
12	B	K. Warrington	1923	H_3BO_3, $H_2BO_3^-$ & HBO_3^{2-},
13	Mn	J.S. Mc Hargue	1922	Mn^{2+}
14	Zn	A. L. Sommer C. P. Lipman	1926	Zn^{2+}
15	Cu	A. L. Sommer C. P. Lipman M. C. Kenny	1931	Cu^{2+}
16	Mo	D. I. Arnon B. R. Stout	1939	MoO_4^{2-}
17	Ni	Brown *et.al*	1987	Ni^{2+}

Functions and deficiency symptoms of nutrients


Ca deficiency
Terminal buds
Fe deficiency
B deficiency
Mn deficiency
New leaves
S deficiency
Cu deficiency
New leaves
Zn deficiency
Old leaves
Mg deficiency
Old leaves
P deficiency
K deficiency
Mo deficiency
N deficiency
Normal old leaves


Other problems
Disease
Drought
Magnesium deficient
Nitrogen deficient
Potassium deficient
Phosphorus deficient
Healthy growth

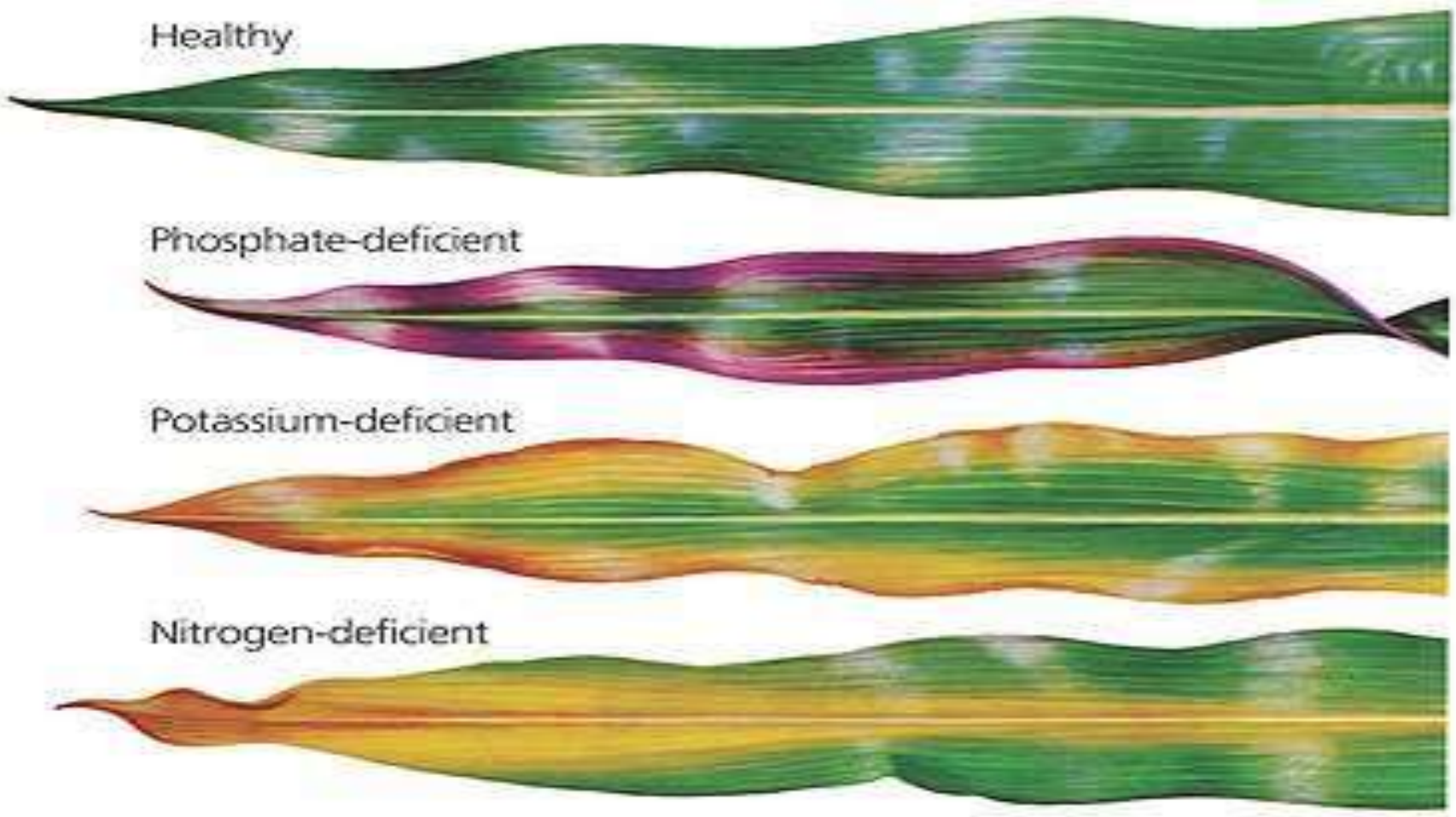
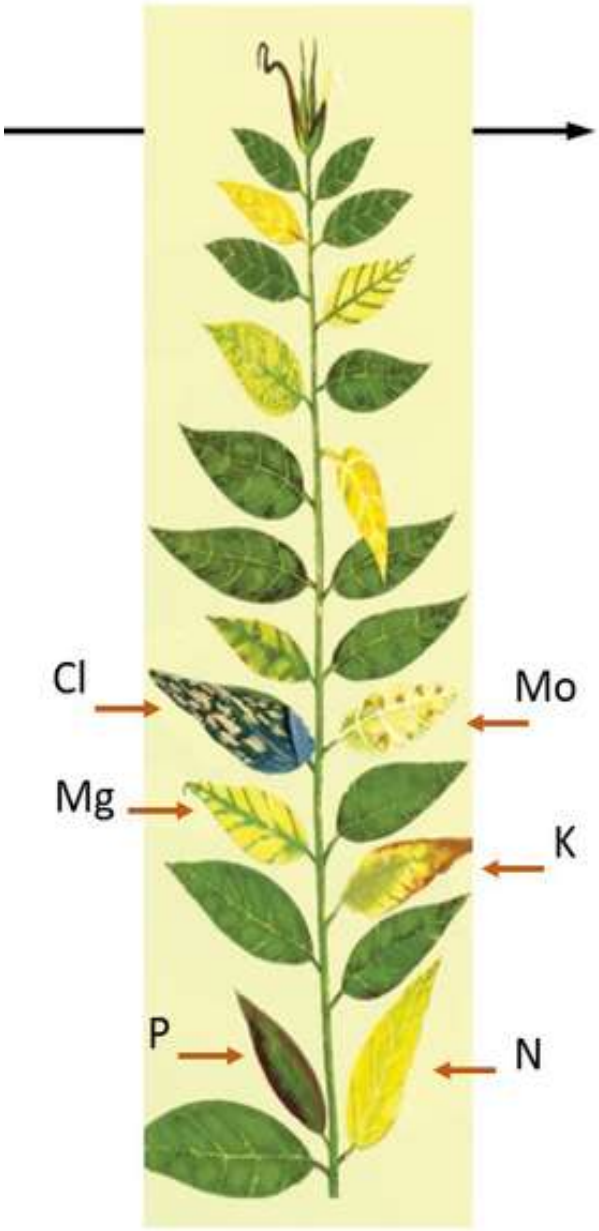
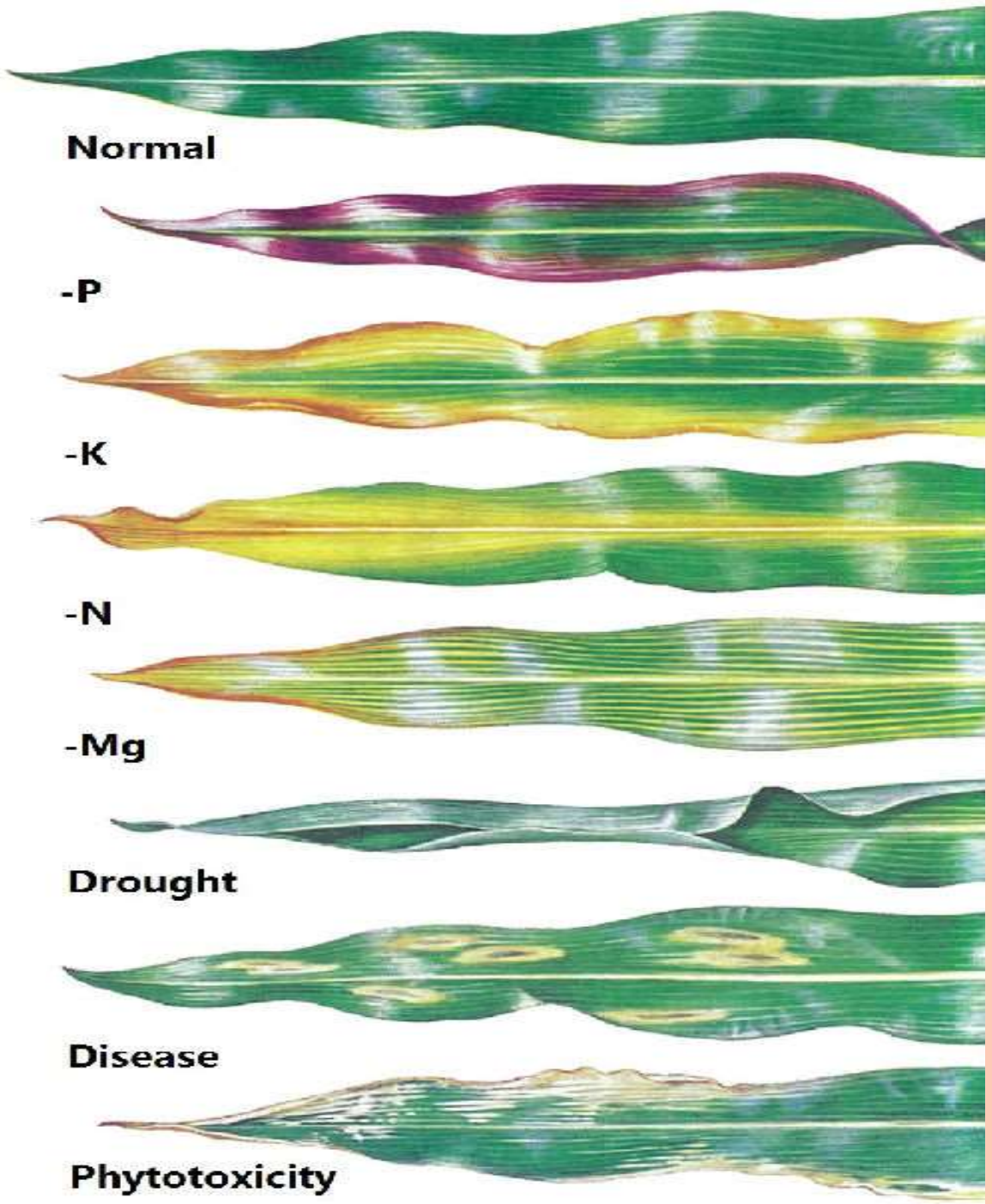


Fig: Deficiency symptoms of N, P and K

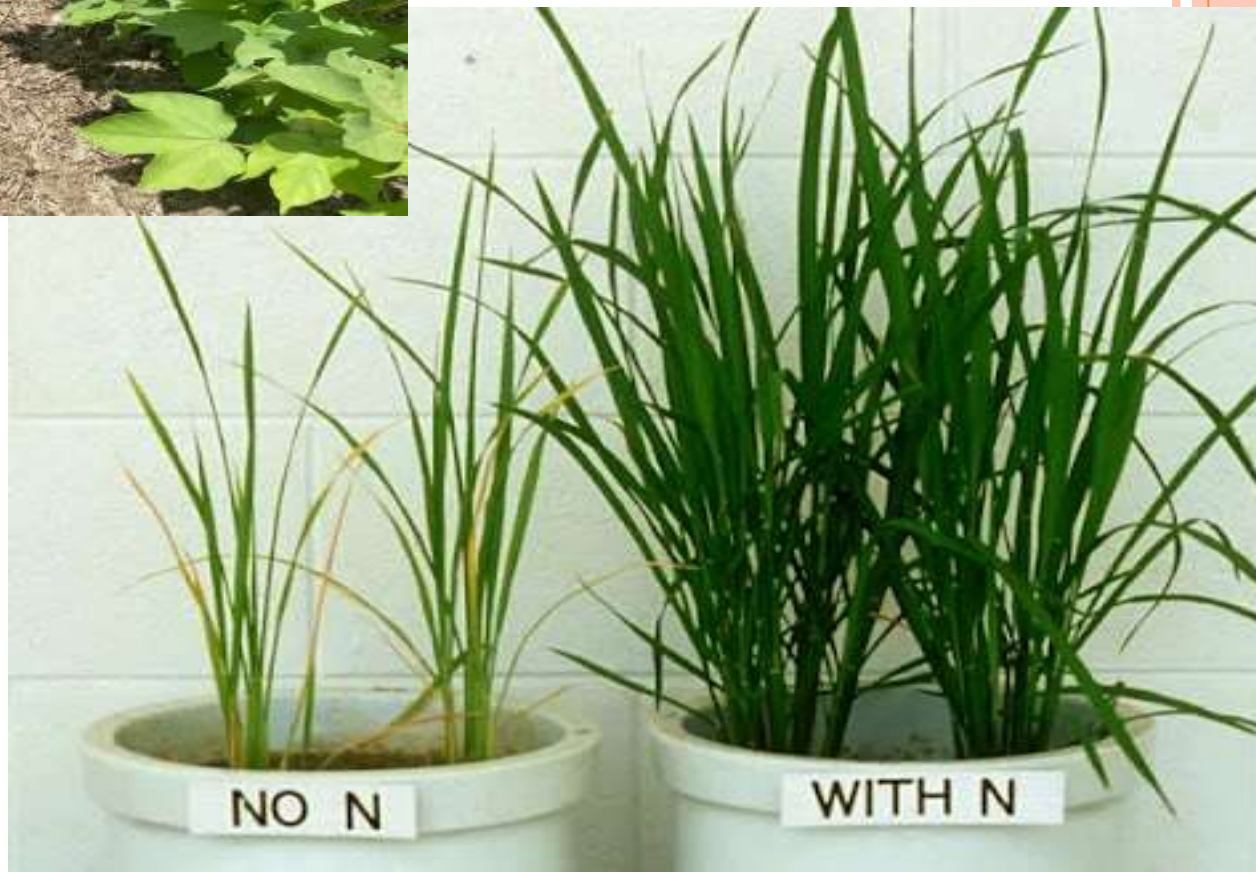


Leaf image source unknown



NITROGEN (N)

- Major **component of plant cells and cell wall**. Cell cytoplasm and organelles contain nitrogen in combination with C, H, O, P and S.
- Necessary for **formation of amino acids**, the building blocks of protein.
- Essential for plant cell division, vital for **plant vegetative growth.**
- **Integral part of chlorophyll**
- Necessary component of vitamins
- **Improves the quality of leafy vegetables**
- Affects energy reactions in the plant
- **Impart vegetative growth and green colour**.
- **Directly involve in photosynthesis**.


NO N
WITH N

Deficiency symptoms :

- Lower leaves become yellow firstly and dries
- Tillering is poor in cereals
- Stunted growth
- In case of cabbage, there is no formation of heads
- ‘V’ shaped chlorosis on older leaves
- Low yield

PHOSPHORUS (P)

- **Great role in energy storage and transfer** in the form of ATP and ADP. So it is also called as "**Energy currency**"
- Essential constituent of nucleic acid, phytin and phospho- lipids
- Involved in photosynthesis, respiration, cell division and enlargement
- Promotes early **root formation and growth.**
- **Improves quality of fruits, vegetables and grains**
- **Vital to seed formation**
- Excess of P can cause deficiency of certain micro-nutrient like Zn and Fe.

Deficiency symptoms :

- Deficiency symptoms are appears first on older leaves
- Deficiency imparts dark green colour in leaves
- Bronzing or **red purple coloration** on leaves due to synthesis of anthocyanin.
- Development of lateral buds is suppressed


HGIC, U of MD

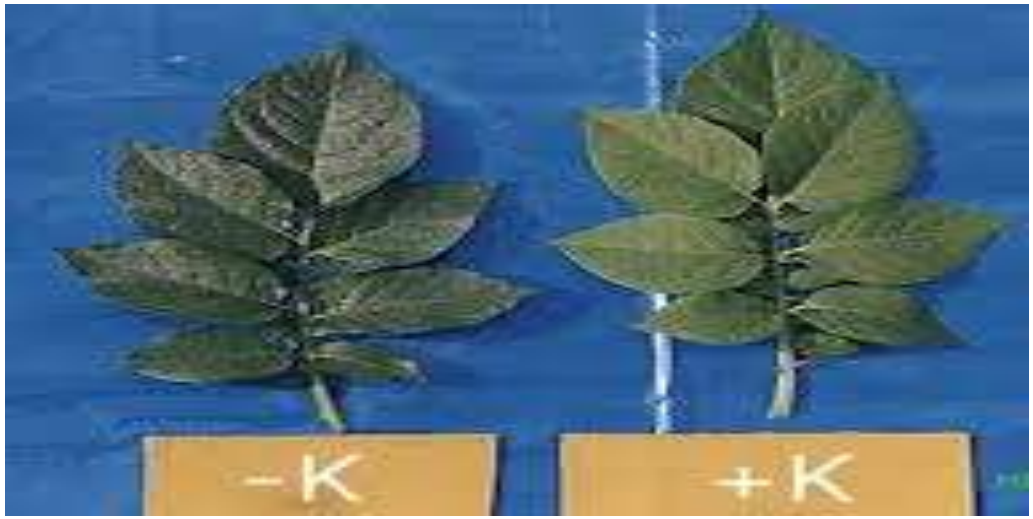
POTASSIUM (K)

- Most essential function of potassium is **stomata regulation.**
- Increases water **-** use efficiency
- Provides **disease resistance**
- Formation and **translocation of sugars**
- Increases photosynthesis
- Activates enzymes and controls their reaction rates
- **Improves quality of seeds and fruit**
- For quality product
- Improves winter hardiness
- In plants K^+ also reduced the transpiration rate and increase photosynthetic rate (production of O_2)

Deficiency symptoms :

- Scorching or burning of margins of older leaves
- Weakning of straw in grain crops
- Reduction in turgidity of cells
- Spots of dead tissues at tips
- Keeping quality of fruits and vegetables is reduced

Maize showing signs of potassium deficiency.


-K
+K

CALCIUM (Ca)

- **Constituent of cell wall.**
- Helps to maintain membrane permeability and stability
- Retards abscission and senescence of leaves
- **Important for growth of meristems and functioning of root tips.**
- Neutralizes the charge on acidic molecules of phosphoric acid and other organic acids i.e. citric acid, malic acid, oxalic acid which are injurious to plant growth
- Plays a important role in germination and growth of pollens
- **Increase nodulation in legumes**
- **Required for cell division and cell elongation**

Deficiency symptoms :

- Deficiency symptoms first appear on younger leaves.
- Its deficiency is manifested by **failure of terminal buds and apical roots to develop.** Thus the growth of plant ceases.
- **Deficiency of Ca leads to-**
  - Tip burn of cabbage, cauliflower
  - Black heart of celery
  - Blossom end rot of tomato and ber
  - Bitter pit of apple

MAGNESIUM (Mg)

- **Key element of chlorophyll production**
- Improves utilization and mobility of phosphorus
- Activator and component of many plant enzymes
- **Directly related to grass tetany**
- **Promote formation of oil and fat.**
- **Influences earliness and uniformity of maturity**
- Required for the reaction involving phosphate transfer from ATP.

Grass tetany, also known as **hypomagnesemia**, is a metabolic disease that occurs when the magnesium levels in an animal's blood fall too low.

It can affect cattle, sheep and other ruminant livestock.

Deficiency symptoms :

- May occur on acid soils, sandy soils or soils with high K levels.
- Deficiency symptoms first appear on older leaves.
- Deficiency symptoms manifests themselves in terms of **interveinal chlorosis.**
- **Grass tetany** is a nutritional disorder common in hypomagnesaemia, which is abnormally low level of blood Mg.
- Sand drawn disease in tobacco.

Maize showing signs of magnesium deficiency.


Interveinal beading
Interveinal chlorosis

SULPHUR (S)

- **Required for formation of S containing amino acids** i.e. Cysteine, Methionine etc.
- S is required for the synthesis of volatile compounds responsible for characteristic taste and smell in plants of mustard and onions.
- **Pungency in onion**: due to Allyl propyl disulphide

  Pungency in mustard oil: due to Allyl isocyanates
- **Improves the oil quality of oilseeds crops.**
- Improves the baking quality in cereals grains
- Necessary in chlorophyll formation (though it isn't one of the constituents)

Deficiency symptoms :

- First appears on younger growths as it is **immobile in plants.**
- Fading (to become or make something become lighter in colour or less strong or fresh) of normal green colour in young leaves, followed by chlorosis is the most common deficiency symptom.
- Older leaves become **puckered**

with inward raised areas between the veins.

- In brassicas, which are most susceptible to S- deficiency, the leaves are narrow, show **cupping** (curling of leaf margins) and arresting the growing points.


spring wheat
+ S
- S


Sulfur Deficiency
in Plants

MICRONUTRIENTS

The micronutrients are Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Chlorine (Cl), Molybdenum (Mo) and Nickel (Ni).

These plant food elements are used in very small amounts, but they are just as important to plant development and profitable crop production as the major nutrients.

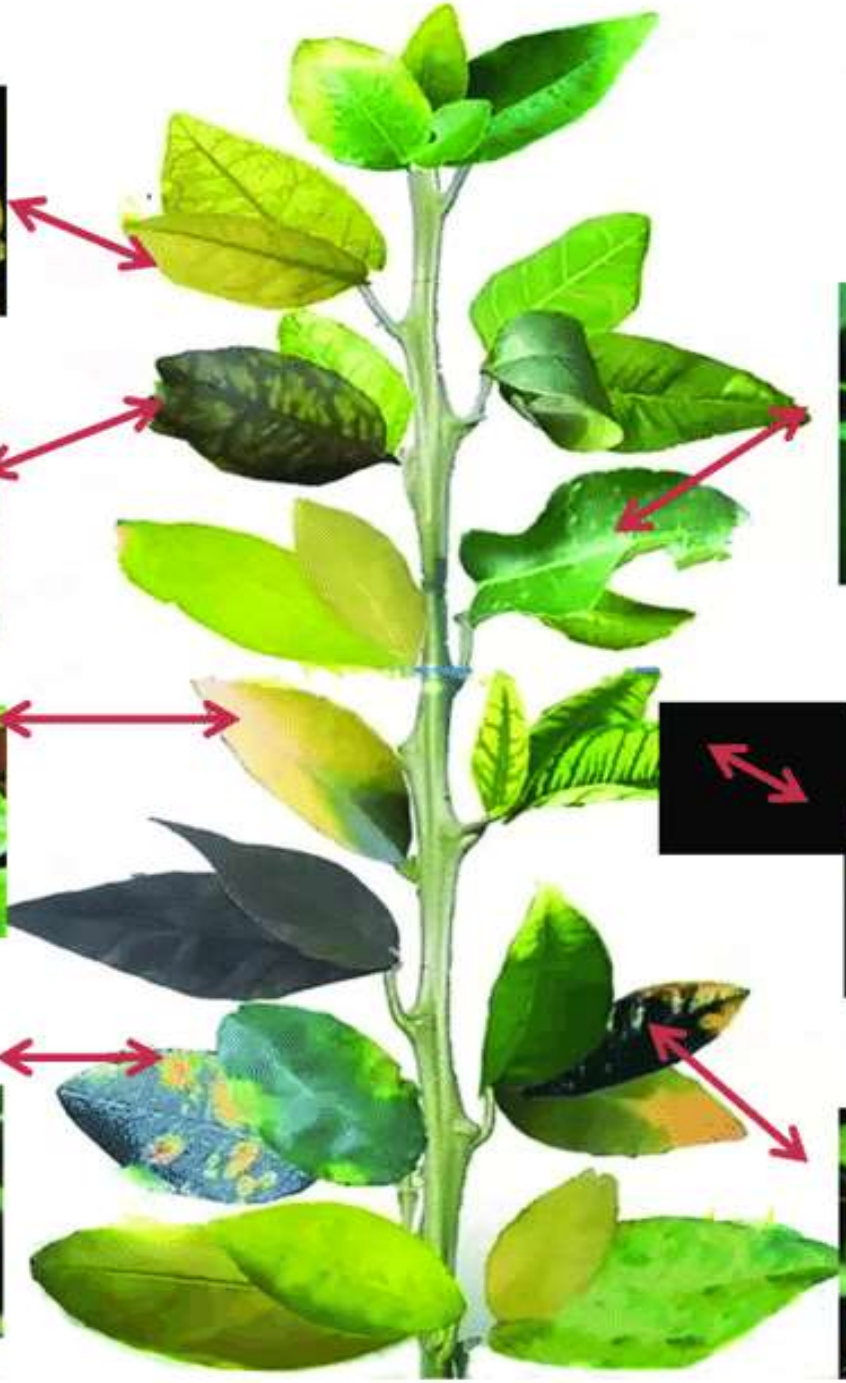
Especially, they work "behind the scene" as **activators of many plant functions.**

Iron deficiency

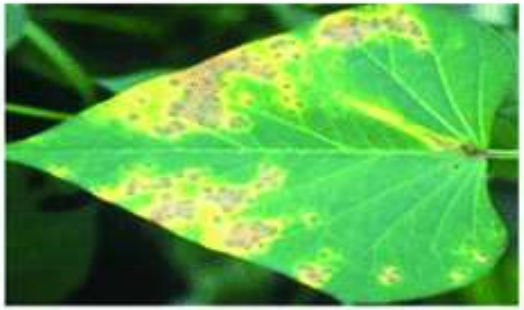
Boron deficiency

Chlorine deficiency

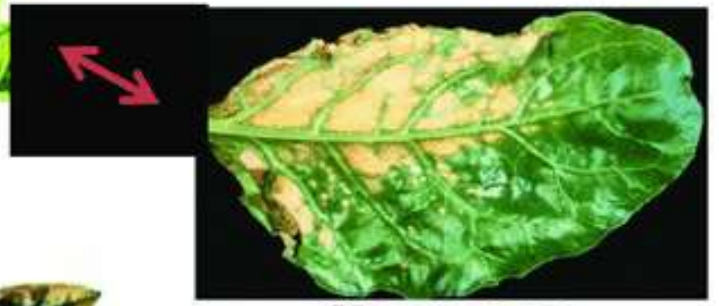
Molybdenum deficiency



Copper deficiency



Zinc deficiency



Manganese deficiency

IRON (Fe)

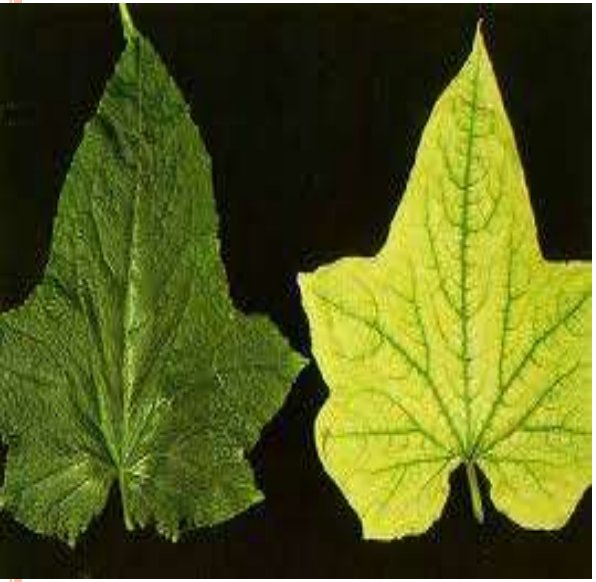
- Promotes synthesis of chlorophyll
- **Acts as an oxygen carrier** (**leghaemoglobin -** a protein that carries oxygen in the root nodules of leguminous plants).
- Reactions involving cell division and growth.
- **Acts as an enzyme activator**
- Iron helps transport oxygen throughout the plant.

IRON

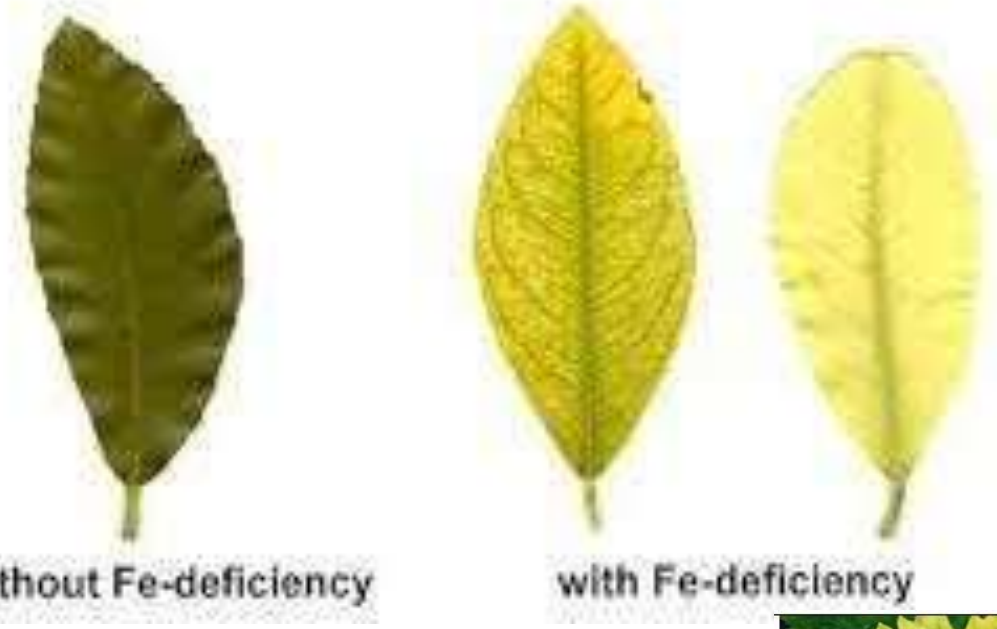
Deficiency symptoms :

- Causes **leaves to turn yellow** or **white between the veins**, and can eventually lead to leaf death.
- **Young leaves** turn pale or yellow, especially near the tips of branches.
- Veins remain green, while the surrounding areas turn yellow.
- In severe cases, leaves turn almost white and develop brown or black spots.
- Twigs may die back and **leaves may drop prematurely**

IRON

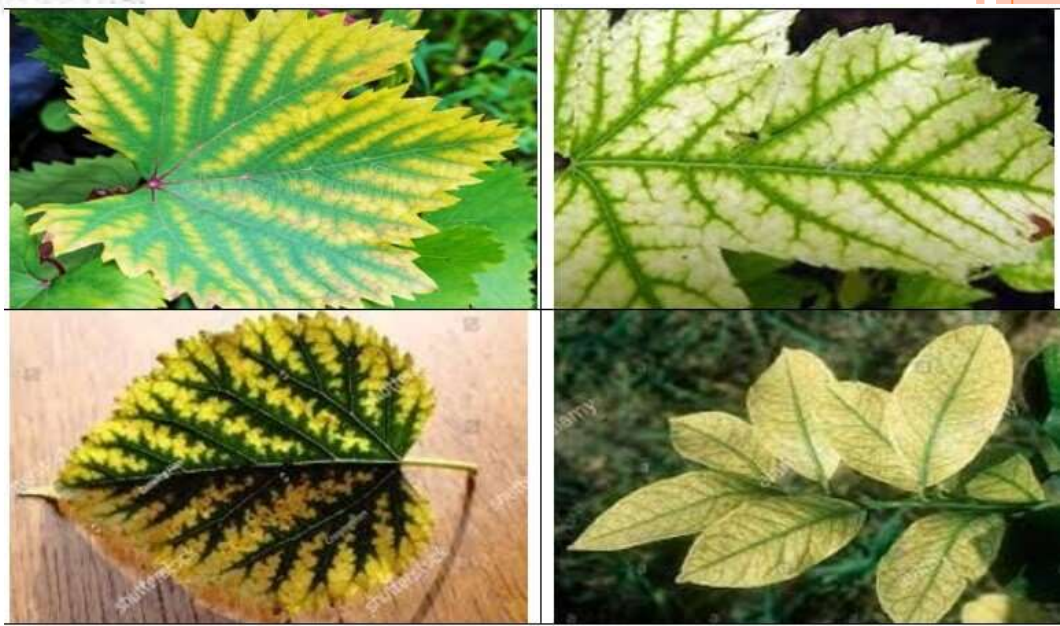


Fe-deficiency symptoms
(younger leaves of lemon)



without Fe-deficiency

with Fe-deficiency



MAGANESE (Mn)

- **Functions as a part of certain enzyme systems.**
- Aids in chlorophyll synthesis.
- **Increases the availability of P and Ca.**
- Required for maintenance of chloroplast structure.
- Mn helps plants germinate and mature.
- **Create pathogen defence.**

Deficiency symptoms

- **More severe on middle leaves** than on younger leaves.
- On dicot plants interveinal chlorosis and on monocot plants greenish grey spots and stripes on basal leaves.
- New leaves are yellow or whitish with green veins.
- Brown dead spots develop between veins.
- Leaf margins may become crinkled, curled or wavy.
- Shoot growth can be reduced.
- Leaves may turn pale green between the veins.
- The area between the veins becomes paler, enlarges and may brown and die.

- **Deficiency of Mn leads to-**
- Pahala blight of sugarcane
- Grey specks of oats
- Marsh spots of peas

- Speckled yellow of Sugarbeet
- **Toxicity of Mn leads to Crinkle leaf of cotton.**

ZINC (Zn)

- Crucial micronutrient for plant growth, playing **vital roles in metabolism, enzyme function, ion transport, and overall plant health, including root development and nutrient uptake.**
- Zn is **constituent** of **3 enzymes** i.e. carbonic anhydrase, alcoholic dehydrogenase and superoxide dismutase.
- Aids **plant growth hormones and enzyme system.**
- Influence translocation and transport of P.
- Important for **synthesis of tryptophan**, a component of some proteins.
- Necessary for chlorophyll production.
- Aids in **seed formation**

Deficiency symptoms :

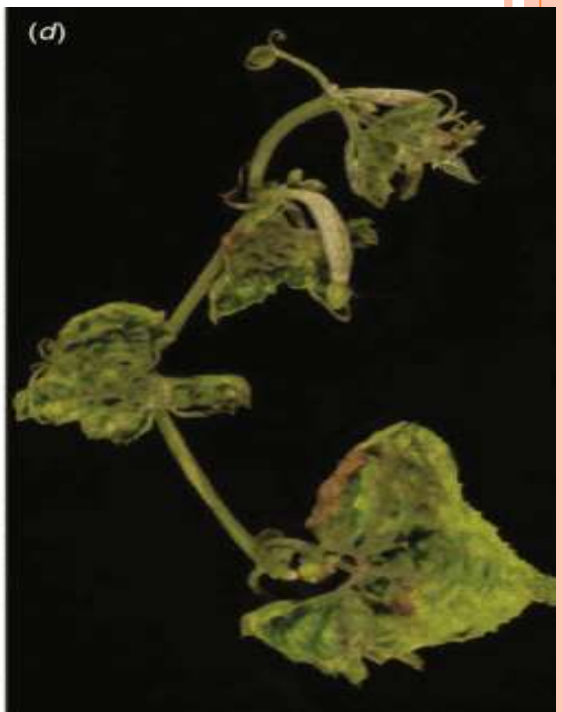
- First appears on **younger leaves.**
- In many plants its deficiency produces a symptom known as '**Rossette**' (a circular or spiral arrangement of leaves or leaf-like structures) in which the growth of main shoot is drastically reduced while the secondary shoots come up in large number.
- **Interveinal Chlorosis:** Yellowing or whitening of the tissue between the veins of the leaves.
- **Stunted Growth:** Shorter stems and smaller leaves.
- **Leaf Deformation:** Irregular margins and a puckered appearance.
- **Delayed Flowering and Fruit Development:** Reduced yield and quality.
- **Reduced Root Development:** Weaker and less extensive root systems.

- **Deficiency of Zn leads to-**
  - Khaira disease of rice
  - White bud of maize
  - Little leaf of cotton

Early stage of Zn deficiency.

Progression of Zn deficiency.

Later stage of Zn deficiency.



COPPER (Cu)

- **Component of plastocyanin** (a small, blue copper-containing protein that transfers electrons in photosynthesis)
- **Catalyzes several plant processes** (i.e. desaturation and hydrolysis of fatty acid)
- **Essential for photosynthesis.**
- Enhances the fertility of male flowers
- **Imparts disease resistant to plants.**
- **Improves flavour of fruits and vegetables.**

Deficiency symptoms :

- Copper deficiency in plants can cause **stunted growth, distorted leaves, and poor fruit production.**
- **Chlorosis**: Young leaves turn yellow, usually starting at the tips and margins.
- **Necrosis**: Dead areas develop on leaf edges or between veins.
- **Stunted growth**: Plants have shorter stems and smaller leaves .
- **Distorted growth**: Leaves may be cupped, deformed or twisted .
- **Poor fruit or seed development**: Plants may produce fewer or poorly developed fruits or seeds .

Deficiency symptoms :

- **Leaf margin and tip burn**: Leaf margins and tips may burn or die back .
- **Weak multiple buds**: Plants may have weak multiple buds .
- **Wilting**: Plants may wilt easily
- **Sterility of male flowers reduced.**
- Chlorosis of younger shoot tissues, necrosis and leaf distortion are the characteristic deficiency symptoms
- Reclamation disease of citrus **/ Die back of citrus** / twig dieback
- **Gummosis and xanthomenia (Canker) disease of citrus.**

BORON (B)

- Boron is the **only non-metal** element among the micro-nutrients
- Essential for **germination of pollen grains** and growth of pollen tubes.
- **Necessary for sugar translocation.**
- Essential for seed and cell wall formation
- **Promotes maturity**
- **Taste in cauliflower** is due to presence of boron

BORON

Deficiency symptoms :

- Browning of cauliflower

- Top sickness of tobacco

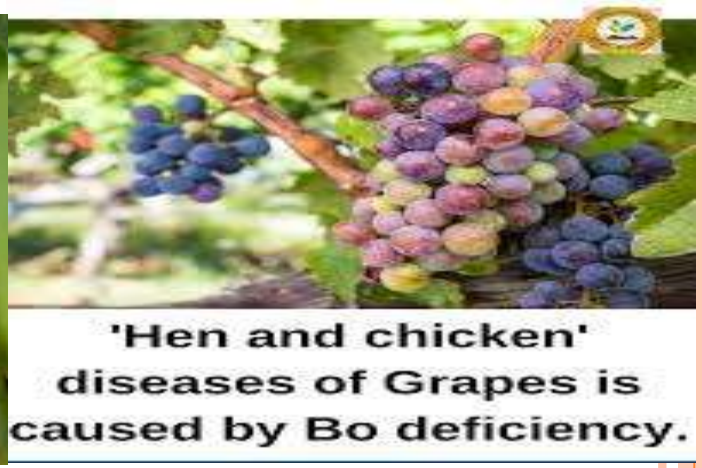
- Fruit crcking in tomato

BORON

Deficiency symptoms :

- Hard fruit of citrus

- Hen and chicken disease of grapes



- Hollow stem of cauliflower



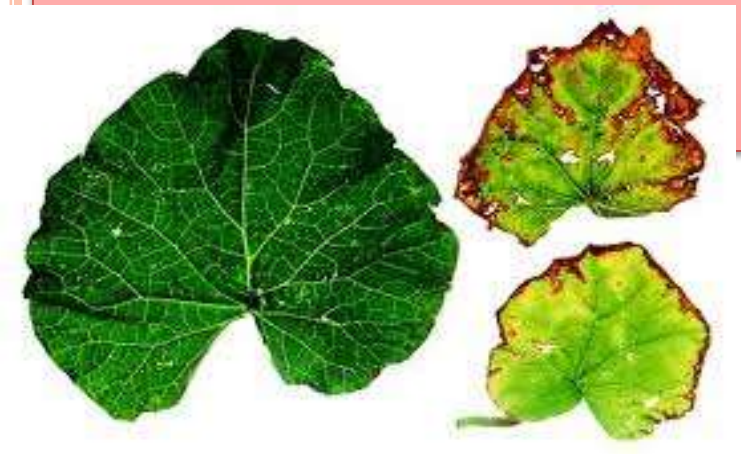



MOLYBDENUM (Mo)

- Molybdenum is a trace element that **helps plants use nitrogen, sulfur and carbon.**
- It also helps plants tolerate stresses like drought and salinity.
- Required to form the enzyme "**nitrate reductase**" which reduces nitrates to ammonium in plant.
- **Aids in the formation of legume nodules**.
- Needed to convert inorganic phosphates to organic forms in the plant.
- Mo is required for sweetness in carrot and raphanus.
- **Whiptail of cauliflower** is due to deficiency of Molybdenum.

Deficiency symptoms :

- Stunted growth
- Yellowing leaves
- Scorched leaf margins
- Cupped or rolled leaves
- Misshapen leaves
- Thinning leaf canopy

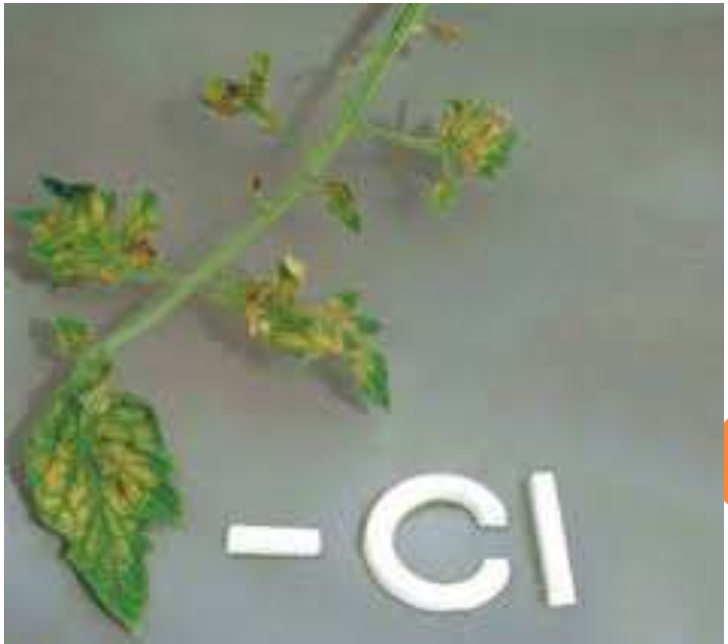


CHLORINE (Cl)

- **Involved in photosynthesis, stomatal regulation and osmotic balance, ultimately impacting water movement, nutrient transport and disease resistance.**
- Plays a important role in **osmo-regulation.**
- Chlorine in abundance supress the plant diseases
- Regulate the turgor potential of leaves
- **Co-factor in Mn containing water splitting enzymes photosystem – II.**

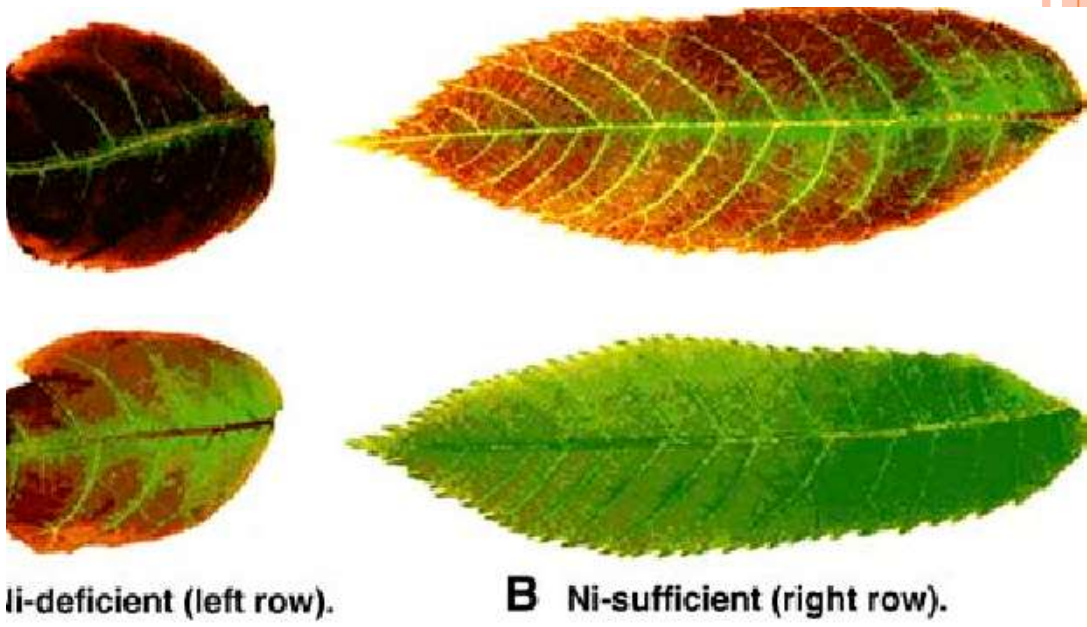
Deficiency symptoms :

- Can cause **leaf spotting, wilting and other symptoms**.
- **Leaf spotting**: Chlorotic and necrotic spotting with sharp boundaries between dead and alive tissue.
- **Leaf wilting**: Leaves wilt, especially along the margins.
- **Leaf curling**: Leaves curl as the deficiency worsens.
- **Leaf bronzing**: Leaves turn bronze as the deficiency worsens.
- **Leaf necrosis**: Parts of the plant may die.
- **Root system**: Roots may become highly branched.


-Cl

Nickel (Ni)

- Nickel is an essential micronutrient for plants, primarily functioning as a **cofactor for the enzyme urease**, which is crucial for converting urea into ammonia, a usable form of nitrogen for plants.



li-deficient (left row). B Ni-sufficient (right row).

Deficiency symptoms :

- Nickel deficiency in plants can cause stunted growth, distorted leaves, and necrotic lesions.
- **Mouse-ear**: Small, curled leaves with rounded tips.
- **Chlorosis**: Yellowing of leaves
- **Necrosis**: Death of leaf tissue
- **Shortened internodes**: Rosetting appearance in woody plants
- **Weak shoot growth**: Death of terminal buds

।। पिकातील अन्नद्रव्यांचा अभाव ।।

बोरॉन (B)
- नवीन वाढणारी कळी कोमेजून वाळते.
- हरितद्रव्य कमी होण्याचे प्रमाण पानाच्या देठापासून सुरू होऊन टोकाकडे वाढत जाते.
- शेंड्याकडील कोवळ्या पानांचा रंग फिक्कट हिरवा होतो.

लोह (Fe)
- नवीन पालवीतील हिरवेपणा नाहीसा होतो.
- शिरा हिरव्या राहतात.
- कोवळ्या पानांची वाढ थांबते.

मँगनीज (Mn)
- नवीन पानांवर हरितद्रव्याचा अभाव दिसतो.
- पानांच्या शिरांमधील भाग पिवळा पडून जाळीदार शिरांमध्ये करडे डाग पडतात.
- पाने वेडी-वाकडी होतात.

जस्त (Zn)
- पाने तपकिरी किंवा जांभळट तांबड्या रंगाची दिसतात.
- पानांच्या शिरांमधील भाग पिवळा पडतो.
- खोड वाळते व पाने पक्व होण्यापूर्वी अकाली गळतात.

मॅग्नेशियम (Mg)
- देठ, पानाच्या कडा व शिरांमधील भागांचा हिरवा रंग कमी होतो.
- कोवळी पाने पातळ व ठिसूळ बनून सुकतात.
- पानांमध्ये अन्न तयार करण्याची प्रक्रिया मंदावते.

स्फुरद (P)
- खोडांचा आकार बारीक होतो.
- देठे-वेडी-वाकडी होतात.
- खालच्या पानावर निळसर-हिरवी झाक व जांभळे ठिपके दिसतात.

कॅल्शियम (Ca)
- कळ्या, फुले व फुलोरा गळतो.
- कोवळ्या पानांच्या कडा वेड्या-वाकड्या होतात.
- शेंड्याची वाढ होत नाही.

गंधक (S)
- पाने पिवळट हिरवी दिसतात.
- पाने व देठ यांचा आकार बारीक होतो.
- मुळांची वाढ खुंटते.

तांबे (Cu)
- पानांच्या शिरांमधील हरितद्रव्ये कमी होतात.
- पानांच्या कडा वाळू लागतात.
- मुळांवर गाठी तयार होण्याची क्रिया मंदावते.

मॉलिब्डेनम (Mo)
- पाने पिवळी होऊन त्यावर तपकिरी रंगाचे ठिपके पडतात.
- पानाच्या मागच्या बाजूने तपकिरी डिंकासारखा द्रव निघतो.
- पाने लांब चाबकासारखी वळलेली दिसतात.

पालाश (K)
- पानांच्या कडा व टोके प्रथम पिवळसर पडून तो भाग करपतो.
- जुनी पाने सुकून करडी होण्यास प्रारंभ होतो.
- बिया व फळे आक्रसतात आणि फळांची गुणवत्ता बिघडते.

नत्र (N)
- पानांतील हरितद्रव्य कमी होते.
- पानांची टोके व कडा जळल्यासारख्या दिसतात.
- पाने पिवळसर दिसू लागतात.


THANK
YOU