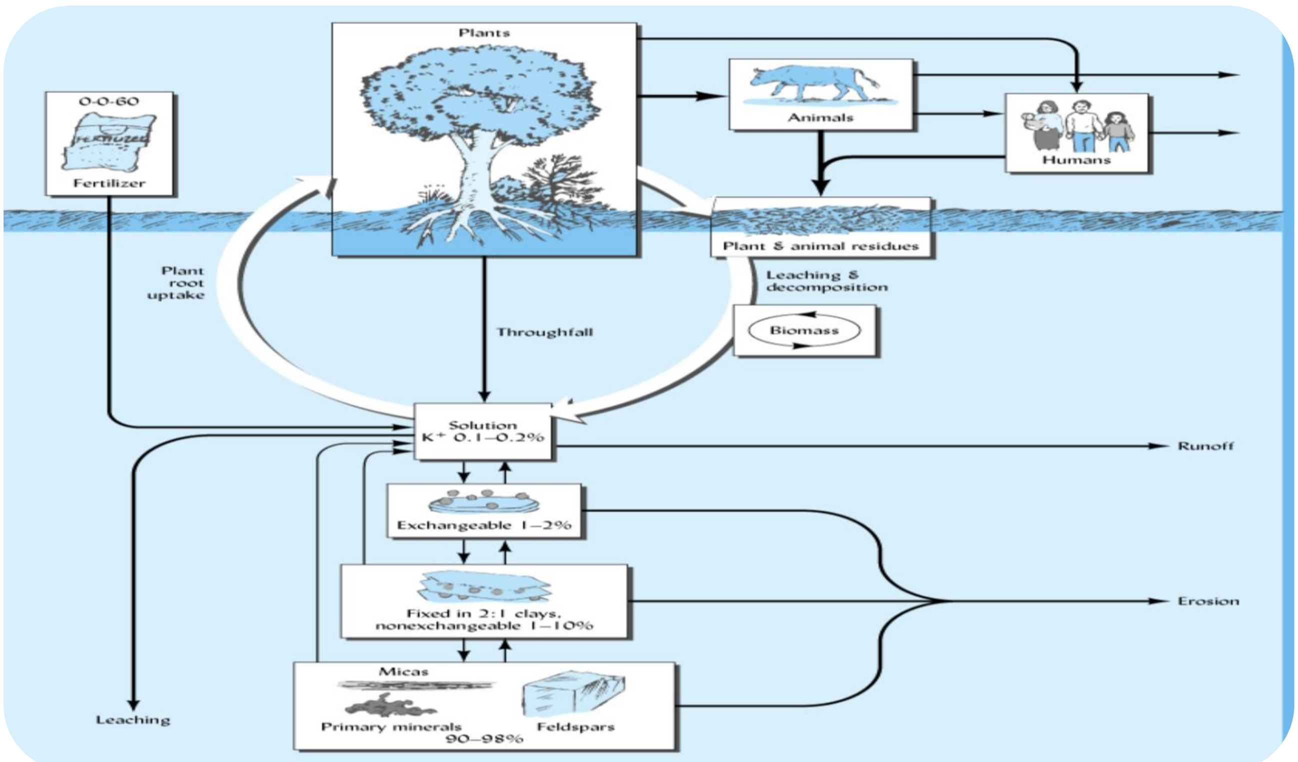
Soil Fertility and Nutrient Management

HNS 101



2. Soil Fertility and Nutrient Management (HNS 101) 2 (1+1)

Introduction to soil fertility and productivity- factors affecting. Essential plant nutrient elements- functions, deficiency systems, transformations and availability. Acid, calcareous and salt affected soil-characteristics and management. Role of microorganisms in organic matter- decomposition – humus formation. Importance of C:N ratio and pH in plant nutrition. Integrated plant nutrient management. Soil fertility evaluation methods, critical limits of plant nutrient elements and hunger signs. NPK fertilizers: composition and application methodology, luxury consumption, nutrient interactions, deficiency symptoms, visual diagnosis.

***Practical**: Analysis of soil for organic matter, available N,P,K and Micronutrients and interpretations. Gypsum requirement of saline and alkali soils. Lime requirement of acid soils.*

Lesson 5 & 6

Functions and deficiency symptoms of Secondary nutrient elements (Ca, Mg, S) and Micronutrients in plants

1. SECONDARY NUTRIENTS?
2. Functions and deficiency symptoms of Secondary nutrients
    a. Functions and deficiency symptoms of Calcium
    b. Functions and deficiency symptoms of Magnesium
    c. Functions and deficiency symptoms of Sulphur
3. Functions and deficiency symptoms of Micro nutrients
    a. Functions and deficiency symptoms of Fe
    b. Functions and deficiency symptoms of Mn
    c. Functions and deficiency symptoms of Cu
    d. Functions and deficiency symptoms of B
    e. Functions and deficiency symptoms of Mo
    f. Functions and deficiency symptoms of Cl
    g. Functions and deficiency symptoms of Zn

SECONDARY NUTRIENTS?

Ca, Mg, and S are called as secondary nutrients.

1. Calcium (Ca)

It is immobile in plants and exists as deposits of calcium oxalate, calcium pectate in the middle lamella of cell wall and $CaCO_3$ and $CaPO_4$ in cell vacuoles. Although calcium is present in plants in relatively higher proportion as compared with other elements, its actual requirement by plants is not much higher than that of a primary nutrient.

Functions:

1. It is a **constituent of the cell wall** and promotes early root development.
2. It is required for **cell divisions and chromosome stability**, cell wall construction, cell elongation of the shoot and root.
3. Stabilizing the pectin of the middle lamella in the cell wall by forming calcium pectate. Thus Ca brings resistance against diseases.
4. Effect on fruit quality and increases in the firmness of the fruit.
5. Indirectly influences many enzyme systems and maintain cation- anion balance (by acting as a counter ion).

Deficiency

- Deficiency is first observed on the young leaves and growing tips (immobile in plants).
- Leaves become small, distorted, **cup shaped, crinkled** and **malformation** of leaves (It resembles boron deficiencies)
- Terminal buds may deteriorate and die in fruits trees. Root growth is impaired.
- Destruction of cell well structure results in disturbance of nuclear and cell division.
- Fruit quality is reduced, loss of fruit fleshy, sometimes rotting of fruits and susceptible to fungal disease.
- **Blossom end rot** on a tomato (hyper link)

Calcium deficiency (blossom end rot) on a tomato

Calcium deficiency

Death of growing point and die-back of main stem from tip; die-back of leaves, progressing from terminal leaflets and of flower and fruiting trusses.

Calcium deficiency: Dying off of terminal leaflets and flowers; leaves purplish brown tinting.

Ca deficiency in coffee

Ca Deficient root   Healthy root(coffee)

(Leaves bronzed along edges, cupped downward; new leaves dead; eventual dieback of shoot tips)

2. Magnesium (Mg):

Mg is a constituent of the chlorophyll molecule and located at its centre, without which photosynthesis by plants would not occur. It is a mobile element and plant absorb as Mg^{2+} ionic form.

Functions:

- Very much essential for **photosynthesis.**
- It is involved in the regulation of cellular pH, cation-anion balance and turgur regulation of cells.

- Necessary for protein synthesis.
- Activator of enzymes in carbohydrate and ATP metabolism.
- Essential for the **formation of oils and fats**
- It is required for stabilization of cell membranes.

Deficiency:

- **Interveinal chlorosis** of lower leaves and in extreme cases becomes necrotic.
- Leaves remain in small and brittle even in final stages.
- Twigs may become weak and premature dropping of leaves results in heavy loss of fruit crops.
- Inhibits nitrate reduction and the production of photo hormones.
- Stalk necrosis or stem 'Die back' in a Vine plant.

Excess of Mg absorption becomes poisonous leads to **browning of roots** as a result growth is ceased and death of roots and leaves. It can be counteracted by CO_2 antagonistic action.

Deficiency symptoms of Mg on plants

3. Sulphur

It is abundant in plant, particularly in the leaves. Plant absorbs as sulphate (SO_4^{2-}) form. It does not easily translocated in plants.

Functions:

1. Required for synthesis of the **S-containing amino acids** like cystine, cysteine and methionine, which are important for protein synthesis.
2. Role in photosynthesis by involving in structural formation of chlorophyll in leaves.
3. It is a constituent of proteins and volatile compounds responsible for the **characteristic taste & smell of plants in the mustard** and **onion families.**
4. It enhances oil synthesis in crops
5. It is a vital part of Ferrodoxins (Non Heme iron, sulfur protein), S- adenosyl methionine.

Deficiency

1. **Pale yellow or light green leaves** in younger leaves (Deficiencies resemble those of nitrogen)

2. Stalks are short & slender, growth is retarded.
3. Fruits often do not mature fully & remain light green in colour.
4. In Brassica species, leaves shows cupping & curling.
5. Cell division is retarded & fruit development is suppressed.
6. Disrupts N metabolism, reduces protein quality & induces starch (carbohydrate) accumulation.

S- Toxicity: Sulphide injury, necrosis of the leaves.

MICRONUTRIENTS

These are essential plant nutrients required in minute quantities. There are 7 micronutrients namely Iron, Manganese, Boron, Molybdenum, Copper, Zinc and Chlorine. Micronutrients are also called minor elements or trace elements.

1. Iron: (Fe): It is the first micronutrient to be discovered as an essential element for plant life. Iron present in chloroplasts as a "ferrodoxin" compound. Plants obtain as Fe^{2+} and Fe^{3+} forms and also as chelated Fe form. Immobile element within the plant; as such iron deficiency is noticeable in younger leaves at the growing region.

Functions:

1. Involved in **biosynthesis of chlorophyll** and in the synthesis of chloroplast proteins
2. Activates several enzymes involved in respiration.
3. It brings about oxidation-reduction reactions in the plant.
4. It regulates respiration, photosynthesis, reduction of nitrates and sulphates.

Deficiency symptoms:

1. Interveinal chlorosis of younger leaves and generally called as "Iron chlorosis" or lime induced
chlorosis. On severe deficiency leaves become **"Pale white".**
2. Reddish-brown necrotic spots along the leaf margins of young shoots in tree crops.
3. In Brassica necrotic terminal buds at early seedling stage.

2. Manganese (Mn): It is absorbed by plants as Mn^{2+} form from the soil. It is translocated to the different plant parts where it is most needed.

Functions:

1. Involved in oxidation-reduction reactions and electron transport in photosystem II
2. It is directly or indirectly involved in chloroplast formation and their multiplication.
3. It activates large number of enzymes and acts as a co-factor and catalyses most of the enzymes
4. It helps in movement of Iron.

Deficiency symptoms:

1. **Interveinal chlorosis on old leaves** similar to Iron chlorosis.
2. **Speckled yellow of sugarbeet-**leaves develop interveinal yellowish green chlorotic mottling and leaf margins role upwards.
3. Depresses inflorescence and fructification and results in stunted leaf and root development.

3. Copper (Cu): Minute quantities of copper are necessary for normal growth of plants. Copper salts are poisonous even in exceedingly small concentrations. It is absorbed as cupric ion (Cu^{2+}). Its function is almost similar to those of Fe. It is immobile element in plants.

Functions:

1. It acts as electron carriers in enzymes which bring about oxidation-reduction reaction in plants.
2. Helps in utilization of iron in chlorophyll synthesis.
3. Influence on cell wall permeability and nitrate reduction.
4. Play a role in the biosynthesis & activity of ethylene in ripening fruit.
5. Promote the formation of vitamin-A in plants.
6. Influence on pollen formation & fertilization.

Deficiency:

1. Narrow, twisted leaves and pale white tips. interveinal chlorotic mottling of leaves.
2. In fruit trees “die-back” (terminal bud wither and die) is most common.
3. It affects fruit formation much more than vegetative growth.
4. The critical stage of Cu deficiency induces pollen sterility in microsporogenesis.
5. Reduced fruit set and number of flowers.

4. Boron (B): Boron is present especially at the growing points and in the conducting tissue. This element being a non metal doesn’t appear to be a part of any enzyme system. Plants absorb B as $H_3BO_3^-$, $B_4O_7^{2-}$, H_2BO^{3-}, and HBO_2^{-3} & BO_3^{2-}. It is immobile element in plants.

Function:

1. Essential for **cell division** in the meristematic tissues.
2. Involved in proper **pollination, pollen formation**, pollen tube growth/ flowering and fruit or seed set.
3. Important role in the fertilizing process of plants and during blossom period its requirement is high.
4. It influences carbohydrates and N-metabolism and also Ca.
5. **Translocation of sugars** through cellular membranes and prevents the polymerization of sugars.
6. It enhances rooting of cutting through oxidation process.
7. It has role in hormone movement and action.
8. It gives resistance for pest and disease infection, e.g.: virus, fungi & insects.
9. Role in water relations i.e., prevents hydration of root tips & thus strengthens the plant roots
10. Acts as a regulator of potassium/calcium ratio in the plant. Solubility & mobility of Ca increases.

Deficiencies:

1. Young leaves may be **deformed,** appear like a **“rosette”**, cracking and cork formation in stems, stalks and fruits, thickening of stems and leaves, reduced buds, flowers and seed production.

2. Premature seed or fruit drop.
3. **'Hen and Chicken disease'** in grapes bunches i.e. fruits of vine with small & long berries.
4. Deformed fruits of papaya tree.
5. Vine plant with thickened internodes. Poor fructification and development of the berries. In mango, leaves become pale green distorted & brittle leaves.
6. Browning or hollow stem of cauliflower.
7. Heart rot disease' in fruits of the sweet melon (*Cucumis melo*), sugar beet & marigold.
8. Interruption in cell wall formation and differentiation and then necrosis.
9. **Flowers wilt,** die and persist on the tree. This phenomenon is called "**Blossom Blast".**
10. Tissue break down and preventing sugar and starch accumulation in the leaves.
11. Excessive formation and accumulation of phenolics.
12. Bitter orange fruits with thickened peels or rinds & blackish discoloration.

- **B Toxcity-** yellowing of the leaf tip and leaf margin which spreads towards the midrib leaves become scorched and may drop early.

B -deficiency in coffee

(Youngest leaves light green, mottled, with uneven edges and asymmetric shape; new leaves with dead spots or tips).

'Hen and Chicken disease' in grapes bunches i.e. fruits of vine with small & long berries.

Deformed fruits of papaya tree due to B deficiency.

5. Molybdenum (Mo): Required by plants in small quantity, plant absorb as MoO_4^{2-} form. It is structural components of Nitrogenase enzyme and constituent of nitrate reductase.

Functions:

1. Essential role in iron absorption and translocation in plants, protein synthesis and N-Fixation in legumes.
2. Brings oxidation and reduction reactions especially in the reduction of NO_3 to NH_4.
3. It acts as a bridge or link in transferring electrons.
4. Role in phosphate system and ascorbic acid synthesis.

Deficiency:

1. **Reddish or purplish** discoloration of leaves, chlorosis and marginal necrosis of leaves.
2. Marginal scorching and rolling or cupping of leaves, "Yellow spot" disease of citrus and **"Whiptail" in cauliflower** is commonly associated.
3. NO_3 accumulation in plants thus inhibits the utilization of N for protein synthesis.

Mo Deficiency

(Bright yellow mottling between veins; leaves wither, curl and margins collapse; leaves distorted and narrow; older leaves affecter first. Rare deficiency).

6. Zinc (Zn):
Zinc is having limited mobility in plants and immobile in soil and plant absorb as Zn^{2+} form.

Functions:

1. Zn is a constituent of several enzymes systems which regulate various metabolic reactions in the plant.
2. Influences the formation of some growth hormones in the plant like IAA, and Auxin.
3. Helpful in reproduction of certain plants.
4. Role in photosynthesis and involved in chlorophyll synthesis, protein synthesis.
5. Involved in alcohol dehydrogenase activity in fruit trees.

Deficiency:

1. Chlorotic and Brown rusty spots on leaves.
2. Lower Auxin level.
3. Drastic decrease in leaf area and leaf deformation (Rosetting), stunted growth (shortage of internodes).
4. Under severe deficiency the shoot apices die (dieback) and diffusive or mottled leaf
5. The rate of protein synthesis is drastically reduced and amino acids and amides accumulate.

Zn-deficiency in coffee

(Leaves not expanding normally; narrow, often strap-shaped; veins visible against a yellow-green background; failure of inter-node to elongate properly, giving plants a compact appearance).

7. Chlorine (Cl):
Chlorine is readily taken up by plants and its mobility in short and long distance transport is high. It does not form constituents of organic substance but act only in ionic form. The plant requirement for chlorine is rather quite high as compared to other micronutrients. The exact role of Cl in plant metabolism is still obscure.

Functions:

1. Involved in the evolution of “Oxygen” by chloroplasts in photo system-II.
2. Associated with turgor production in the guard cells by the osmotic pressure exerted by K^+ ions
3. Role in stomata regulation (opening & closing).
4. Water splitting in photo system-II.
5. Act as a bridging ligand for stabilization of the oxidized state of Mn.

Deficiency

1. Chlorosis and burning of tips and margin of leaves. In tomato, leaves become chlorotic and later bronzed.
2. Over wilting effect and leaf fall, yielding ability decreases.

Chloride toxicity on many crops- Bronze or yellow colors of leaves with brown or scorched leaf margins.

Reference: 1. Soil Fertility and Fertilizers- Samual L. Tisdale, Werner L. Nelson and James D. Beaton

2. Soil Fertility and Nutrient Management by S.S. Singh

Lesson 7

Luxury consumption of nutrients and Nutrient Interactions in plants and soils.

Luxury consumption?

Consumption of Nitrogen by plants

Consumption of phosphorus by plants

Consumption of potassium by plants

Consumption of secondary nutrients by plants

Consumption of micro nutrients by plants

Nutrient interactions in plants and soils.

Luxury consumption?

It is the tendency of some crops to absorb and accumulate nutrients far in excess of their actual needs if it is present in sufficiently large quantities in the soil. Potassium is one of the nutrient elements which is subjected to luxury consumption.

The absorption pattern of different nutrients by plants is varies greatly among the plant species and also their age and growth stages.

Consumption of Nitrogen by plants

Plants absorb the N mostly in nitrate (NO_3^-) form or in ammonical (NH_4^+) form by some plants. Plants usually absorb the N more during active growing period, but they do not always absorb it at the same rate. The amount of nitrogen absorbed is at a maximum when the plants are young and gradually declines as the plants age. Plants can absorb extra nitrogen when it is available and store it to be used later if needed. An oversupply of N generally produces dark green, succulent, vegetative growth. In such cases there will be a decline in seed production of grain crops, fruit production in tomatoes and some tree crops. In sugar beets, sugar content decreases and in and potatoes, tubers become watery. The negative effects of too much of N on growing plants can be lessened if the P and K supplies are adequate.

The average utilization of applied N by crops is around 50 percent but with proper nitrogen management strategies the efficiency as high as 80 % or more can be increased. Low N use efficiency may be attributed to various losses such as Volatilization of Ammonia in alkaline soil, Denitrification of Nitrate ions in flodded soil, Leaching loss of Nitrates in coarse textured soil, soil erosion/run off and ammonium fixation in clay lattices.

Consumption of phosphorus by plants

Phosphorus application, unlike N is known to benefit the growth and productivity of more than one crop in rotation. The residual P contributes more of P to crop nutrition. Responses to applied P depend on soil properties, initial available P, variety, level of N applied and management practices.

Phosphorus is absorbed as phosphate ions such as $H_2PO_4^-$ and HPO_4^{2-} form. It is concentrated more in the reproductive parts of plant and in seeds. Harvested crops contain considerable amounts of P. In general, seed crops contain largest percentages of P, and forage crops contain moderate percentages.

Consumption of 'P' by the crops is very less after their application to soil and it accounts even less than 10 % and remaining amount will be useful later. This is mainly because; P is subjected to immobilization or fixation (retention/adsorption/precipitation/sorption) and undergoes various transformations which render it unavailable to plants. P fertilizers are not easily and completely soluble in water and their mobility is less within the soil. Therefore in order to get maximum benefit from them we have to adopt suitable methods and time of application.

Consumption of potassium by plants

Potassium uptake is often equal to or more than that of nitrogen. It is absorbed by plants by K^+ form. Crop species differ in their K requirement. Tuber crops like potato, vegetables like cauliflower and cabbage, forages like alfalfa and fruits like banana, grapes and pineapple, plantation crops like coconut, tea, rubber are among the heavy feeders of K. High crop yields and higher rates of N and P application accelerate K uptake from the soil. Crop responses to K are large on laterites, red and yellow and mixed red and black soils. Plants absorb and accumulate K far in excess of their needs if it present sufficiently in soil without affecting the metabolic activity or without any plant response. This is called as Luxury consumption.

Potassium also subjected for various losses

1) Leaching losses of K- Especially in sandy soils and soils rich in kaolinite located heavy rainfall area.

2) Soil erosion losses- It also leads to considerable loss of total K from the soil.

3) Fixation of K by clay complex of illite type

Consumption of secondary nutrients by plants

The amount of secondary nutrients removed by crops depends on the soil type, crop species, fertilizer sources and yield level. Generally, legumes and root crops remove more Ca and Mg than do cereals and other grasses. Cereals may remove 10-20 kg Ca per ha, a good crop of *Brassica oleracea* may remove 150 kg Ca per ha. A continuous cropping may result in the reduction of exchangeable Ca in soil.

Banana and pineapple crops with yield levels of 40 to 50 t/ha may remove 120 to 140 kg of Ca and Mg . As a thumb rule, S removal per tonne grain production can be taken as 3-4 kg for cereals, about 8 kg for pulses, about 12 kg for oil seeds and 18 kg for cruciferous and 38 kg for mustards. In most of the crop species, the critical limits of S in plants are 0.20 to 0.25%. Plants use approximately as much S as P.

Consumption of micro nutrients by plants

High crop yields remove substantial amounts of micronutrients from the soil, especially Zinc and Boron. Micronutrients depletion in soil depends on soil fertility level and crop yields. Maize based cropping sequence depletes the maximum micronutrients form soil, especially Zn and Fe. The deficiencies of Zn and B are prevalent in most soils especially red and laterite soils.

Nutrient interactions in plants and soils.

Interaction can be defined as the influence of an element upon another in relation to growth and crop yield. There may be positive or negative interaction of nutrients occurs either in soil or plant. The positive interaction of nutrients gives higher crop yield and such interactions should be exploited in increasing the crop production. Conversely, all negative interactions will lead to decline in crop yield and should be avoided in formulating agronomic packages for a crop.

The knowledge about interactions occurring in soils or plants or both is basic to help develop appropriate and efficient technologies. Further this will help to refine the existing ones to increase agricultural production.

There are mainly two types of interactions effect viz. **antagonistic** and **synergistic effects**. Antagonistic effect means an increase in concentration of any nutrient element will decrease the activity of another nutrient (negative effect). While synergistic effects means an increase of concentration of any one nutrient element will influence the activity of another nutrient element (Positive effect). One must understand how the negative or positive interaction takes place within or outside the plant.

The following antagonistic effects have been well established on the uptake of micronutrients by crops:

1. Excess of P adversely affects utilization of Zn, Fe and Cu

2. Excess of Fe adversely affects utilization of Zn and Mn
3. Excess of Zn, Mn, and Cu induces Fe-deficiency in crops
4. Excess of S and Cu induces Mo-deficiency in crops
5. Excess of Lime induces deficiency of all micronutrients.
6. Presence of carbonate and bicarbonate ions in soil due to sodicity or over liming reduces the availability of micronutrient cations to crops which suffer most iron deficiency.
7. Lime X P, Lime X Mo, Mo X P, and Na X K are common negative interactions.
8. Excess of Ca may induce P deficiency
9. Excess of Ca and Mg may depress K uptake
10. Excess of Ca may reduce Mg uptake, if ratio is wider than 7:1
11. Excess of K and NH+ may reduce Mg uptake
12. Excess of N, K and Ca may reduce B toxicity
13. Excess of N,P,K may induces Cu deficiency
14. Excess of NO3-N may cause Fe deficiency

Reference:

1. Fundamentals of soil Science-published by Indian Society of Soil Science
2. Soils and fertility-6th edition-F.R. Troeh and L.M. Thompson.
3. Micronutrients: Their behavior in soils and plants by Dilip Kumar Das
4. Soil Fertility and Nutrient management-By S S Singh
5. Soil Fertility and Fertilizers- Samual L. Tisdale, Werner L. Nelson and James D. Beaton

Lesson 8 And 9

Transformations and availability of nutrients in soils

N- Transformation and availability in soils

  a. **N-Cycle**
  b. **N transformation in soils**

Phosphorus transformation & availability in soils:

  a. **P-Cycle**
  b. **P transformation in soils**

K-transformations & availability in soils:

  a. **K-Cycle**
  b. **K- Transformations**

Calcium, Magnesium & Sulphur availability in soils:

  a. Ca &Mg Cycle in soils
  b. **Ca & Mg Transformations**

Sulphur availability & transformations in soil

  a. **S-Cycle**
  b. **S-Transformations**

Micronutrients availability and their Transformations in soil

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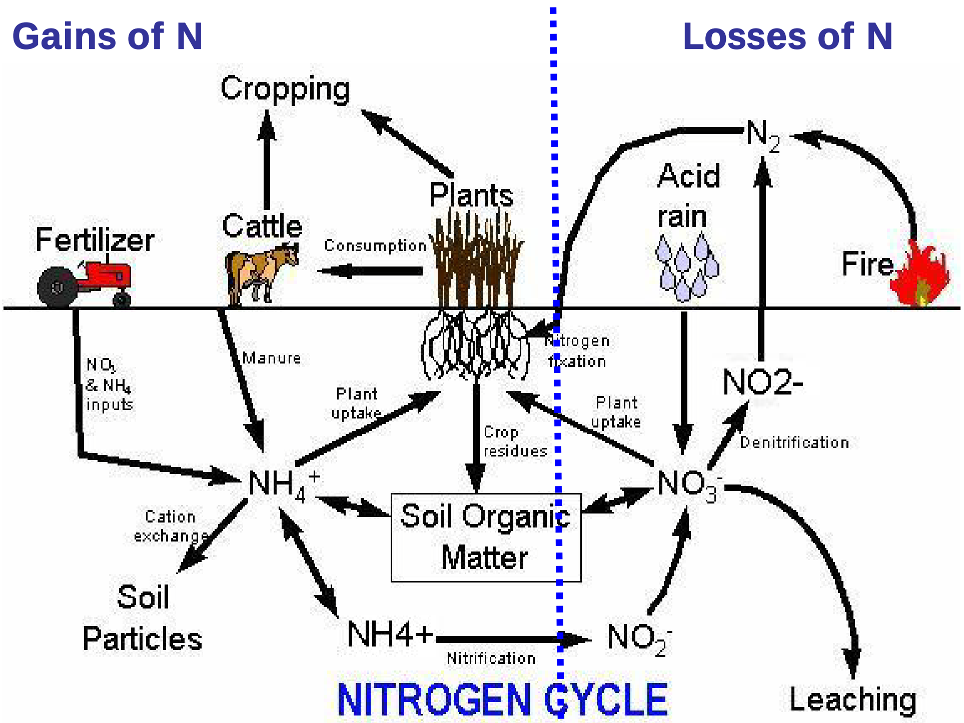
N- Transformation in soils

N- Availability in soil.

Dynamics and transformation of nitrogen in soil is very important with respect to plant nutrition. A bulk of total N is present in the organic form (98%) and only about 2% in inorganic form. However there are continuous transformations between these two pools. The crops utilize nitrogen in the inorganic forms only such as NO_3-N and NH_4-N. The inorganic form of N is also liable to undergo different types of loses like runoff, ammonia volatilization, leaching, denitrification and fixation by clay minerals.

Nitrogen Cycle in soil



Nitrogen cycle

The cycling of N in the soil – plant – atmosphere system involves many transformations of N between inorganic and organic forms.

N transformations in aerobic soils

In aerobic soils, NO_3-N is the dominant form of available N. The mineralization/transformation of added or native organic matter in soil proceeds up to nitrification stage and giving predominantly NO_3-N and small amount of NH_4-N. There is a quick transformation of NH_4^+ to NO_3-N in the aerobic soils occur which will be utilized by plants. Any fertilizer containing ammonium nitrogen when added to soil gets dissociated to NH_4^+ which readily gets oxidized to NO_3^- ion which is either taken up by the crop or leaches down to the lower horizon as it is readily soluble in water. Some amount of NO_3^-N is also immobilized by soil microbes during the process of mineralization of organic matter.

The organic form of N, particularly hydrolyzable form is slowly mineralized and is transformed to mineral nitrogen through following process

a. Amminization
b. Ammonification.
c. Nitrification
d. Denitrification

Nitrogen mineralization

Mineralization is the conversation of organic N to inorganic forms of N as a result of microbial decomposition. Mineralization increases with a rise in temperature and is enhanced by adequate, soil moisture and a good supply of O_2. Mineralization of organic N involves in two reactions.

Aminization

Aminization is the decomposition of proteins and the release of amines, amino acids and urea. A large number of soil microorganisms bring about this change.

Bacteria NH_2 NH_2

| |

Proteins ⟶ R – C – COOH + R NH_2 + C = O + CO_2 + Energy

Fungi H_2O | |

H amines NH_2

Amino acid Urea

Under aerobic condition the major end products are CO_2, $(NH_4)_2$ SO_4 and H_2O. Under anaerobic conditions the end products are ammonia, amides, CO_2 and H_2S.

The organic compounds and proteins are mainly decomposed by various species of Pseudomonas, Bacilli, clostridium, serrotia, Micrococcus.

Conversion of urea

Urea is a product of aminization. The hydrolysis of urea by the action of urease enzyme is effected by *Bacilli micrococcus, Pseudomonas, clostridium,* Acromobactor and coryne bactor.

$$Co\ (NH_2)\ + H^+ + 2H_2O \longrightarrow 2NH_4^+ + HCO_3^-$$

$$NH_4^+ \longrightarrow NH_3 + H^+$$

$$2NH_3 + H_2\ CO_3 \longrightarrow (NH_4)_2\ CO_3 \longrightarrow NH_4^+ + CO_3^-.$$

The optimum water holding capacity for these reactions is 50 – 75% and optimum temperature is 30 – 50°C.

Ammonification

"Amines and Amino acids produced during aminization of organic N are decomposed by other heterotrophs with release of NH_4^+ is termed **Ammonifcation**

$$R - NH_2 + H_2O \longrightarrow NH_3 + R - OH + energy$$

$$\searrow$$

$$H_2O \quad NH_4^+ + OH^-$$

Nitrification

Nitrification is the process of biological oxidation by which the ammonical (NH_4^+) form of N converts to nitrate (NO_3^-) form of N. There are two steps.

(a) NH_4 is converted first to NO_2^- and then to NO_3^-.

Nitrosomonas

$$2NH_4 + 3O_2 \longrightarrow 2\ NO_2^- + 2\ H_2O + 4\ H^+$$

(b) In the second reaction NO_2^- is further oxidized to NO_3^- by nitrobactor

Nitrobactor

$$2\ NO_2^- + O_2 \longrightarrow 2\ NO_3^-.$$

Nitrosomonas are obligate autotropic bacteria that obtain their energy from the oxidations of N and their C from CO_2.

Denitrification

Denitrification is the biochemical reduction of NO_3-N or NO_2-N to gaseous N forms, either as molecular Nitrogen or an oxide of Nitrogen. The most probable bio chemical pathway is

$$\mathbf{NO_3 \longrightarrow NO_2 \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2}$$

Nitrate   Nitrite Nitrogen   Nitrous monoxide   Nitrous oxide   Dinitrogen

This is loss mechanism of nitrogen happening in anaerobic soil conditions.

Nitrogen immobilization

"Immobilisation is the process of conversion of inorganic N (NH_4^+ or NO_3^-) to organic N and it is basically the reverse of N mineralization". By this process plant available N forms are converted to unavailable organic forms.

The Microorganisms accumulate NH_4- N and NO_3- N in the form of protein, nucleic acid and other complexes. If C:N ratio is wider than 30, it favors immobilization and lesser C:N ratio encourage mineralization.

Losses of Nitrogen

The major losses of N from the soil are due to (1) crop removal and leaching, however under certain conditions inorganic N ions can be converted to gases and lost to the atmosphere. The primary pathway of gaseous N losses are

1. Denitrification
2. NH_3 volatilization.

Nitrogen fixation

The conversation of atmospheric nitrogen to plant available forms readily usable by biological process mediated by microorganisms.

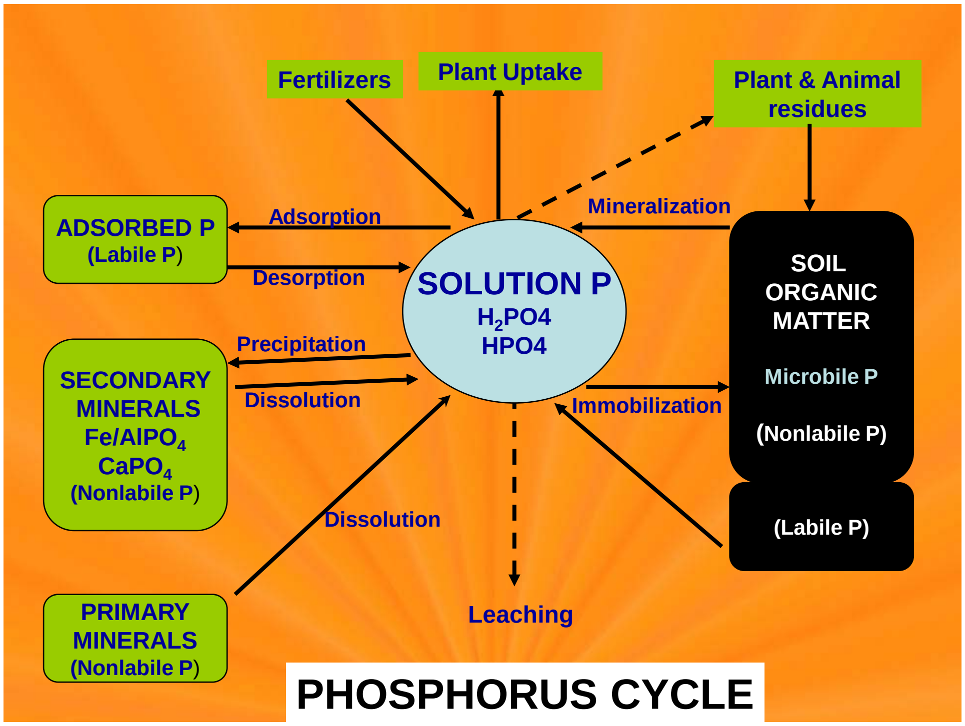
Nitrogen Transformation in anaerobic soils

The N-transformations from added or native sources stops at NH_4^+ stage, since nitrification is not possible due to lack of oxygen. When NH_4^+-N containing fertilizers are added to soil, then NH_4^+ is oxidized to NO_3^- in the top layer (aerobic) of flood water or oxidized layer and later which moves down to reduced layer. On the reduced layer NH_4^+-N remains as NH_4-N only for plant uptake. If NO_3-N exists, then it moves down to the reduced layer, where it undergoes denitrification by bacteria (NO_3-NO_2-N_2). The denitrified NO_3^- is lost from the soil to the atmosphere in the form of N_2O or N_2.

If NH_4^+ ions present in the flood water it is subjected to volatilization to atmosphere as NH_3 (ammonia gas) because of higher partial presence of CO_2 and high pH value developed due to alkalinity. Therefore, there is an accumulation of NH_4^+ ions in the reduced layer, which is either absorbed by root or gets oxidized in the rhizosphere to NO_3^- ions and are lost due to dentrification. Some of the NH_4^+ and NO_3^- ions also get immobilized by the soil microbes & some NH_4^+ may get fixed by the clay lattice.

Phosphorus transformation & availability in soils:

Phosphorus Cycle in soil



In P cycle the phosphorus is not involved in any exchange process with the atmosphere. The amount of dissolved or solution P mostly $H_2PO_4^-$ and HPO_4^{2-} ions in the soil is very small and crops will utilize P from this source. The soil solution P can come from mineralization of organic matter, added fertilizers, adsorbed phosphate ions and solid P compounds (primary & secondary minerals). Any P present in solution P form and it is available to plants is called **Labile P,** where as any P which is bounded in solid P compounds such as primary and secondary minerals is called **Non Labile P** which is not available to plants.

P transformation in aerobic soils: P transformation depends on their solubility, interaction with other soil components. When a water soluble phosphate fertilizer, such as super phosphate is applied to a soil, P dissolves immediately and enters the soil solution and readily forms new compounds with Ca as Ca-PO_4 and carbonates of hydroxyapatite in calcareous and alkaline soils respectively. While in acid soils rich in Al, Mn and Fe, applied P is converted as Al-PO_4 , Mn – PO_4 and Fe-PO_4. All these gets newly formed compounds are precipitated thus reduce the availability of P to crops.

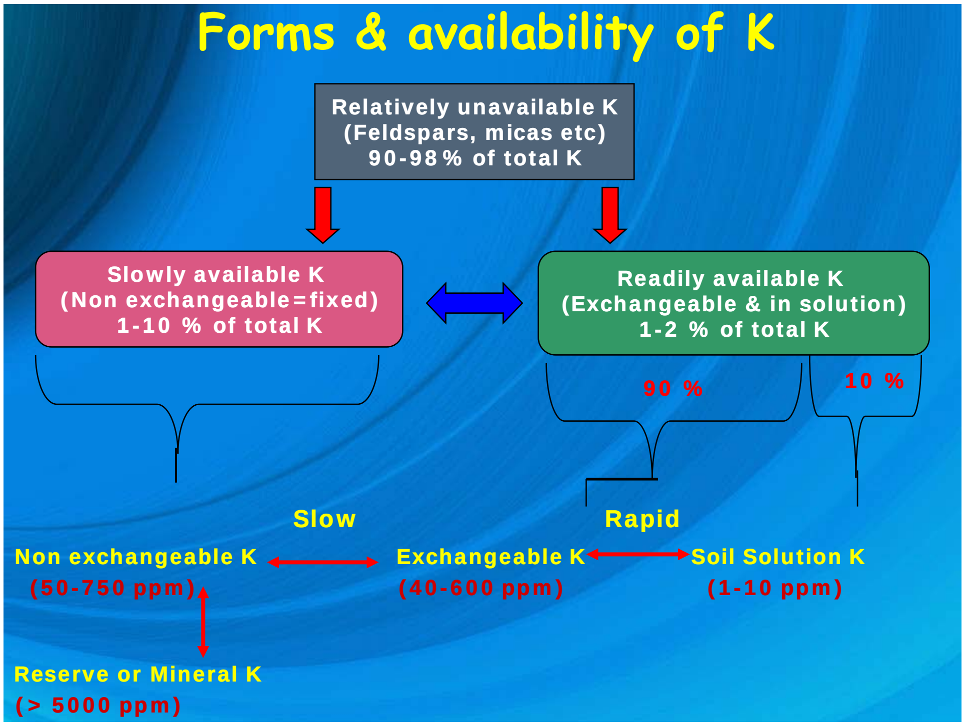
P transformation in Anaerobic soils

P- Transformation in submerged or flooded conditions/soils with a wide range of pH create reducing conditions which lead to reduction of Ferric-PO_4 to ferrous PO_4 resulting in greater availability of P in the reduced soil. Organic acids formed under submerged conditions also solubilize PO_4.

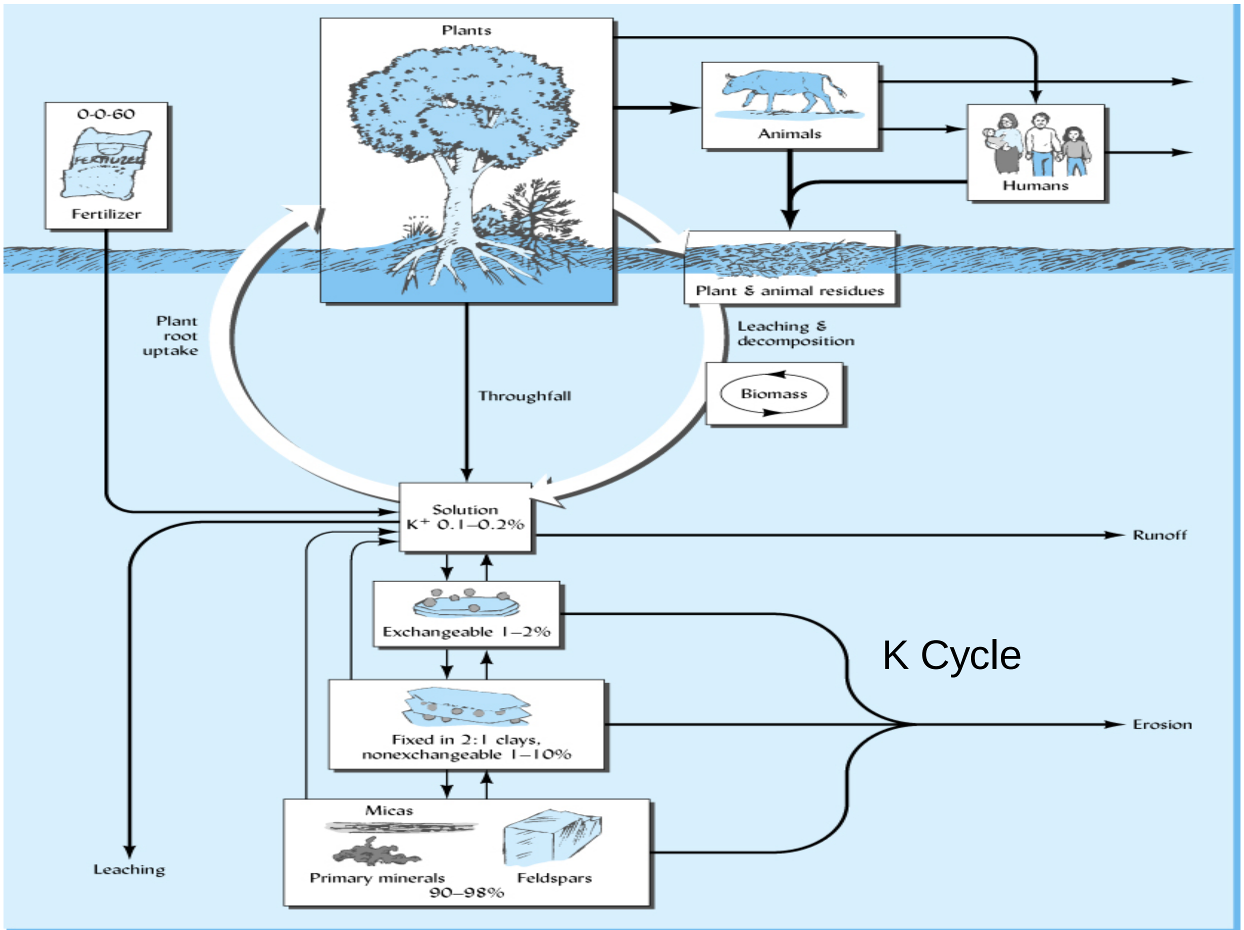
K-transformations & availability in soils:

K- Availability

Potassum is present in soil solution as K^+ ion which is readily available to plants. But this form is in dynamic equilibrium with exchangeable K which intern with fixed K. Fixed K is in equilibrium with mineral K.

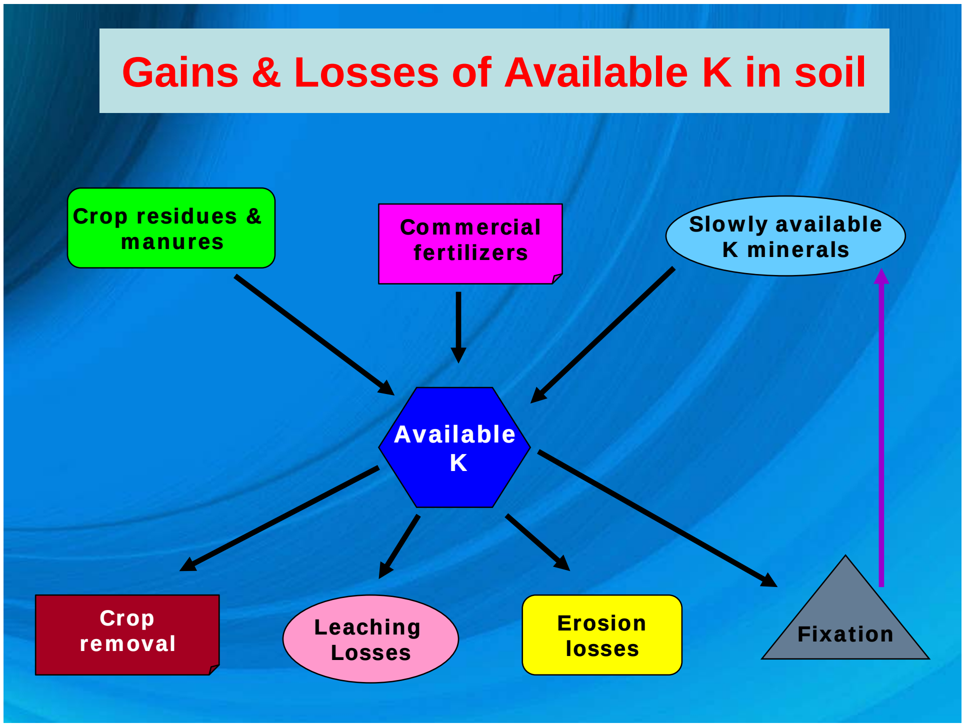


K Cycle



K- Transformations:

When potassic fertilizers are added to the soil, K may either remain in soil solution or in exchangeable form on the clay surface or in non-exchangeable form held by illitic clay minerals as fixed K as it is not available to plants. Plants get K mainly from solution-K and exchangeable-K. As and when the exchangeable K fraction is depleted substantially or exhausted by cropping, the non exchangeable form of K replenishes the exchangeable K and supply of K to plants is maintained and equilibrium is attained. The reservoir source of K is mineral lattice K which undergoes weathering and releases K. In all these transformations equilibrium is maintained always.



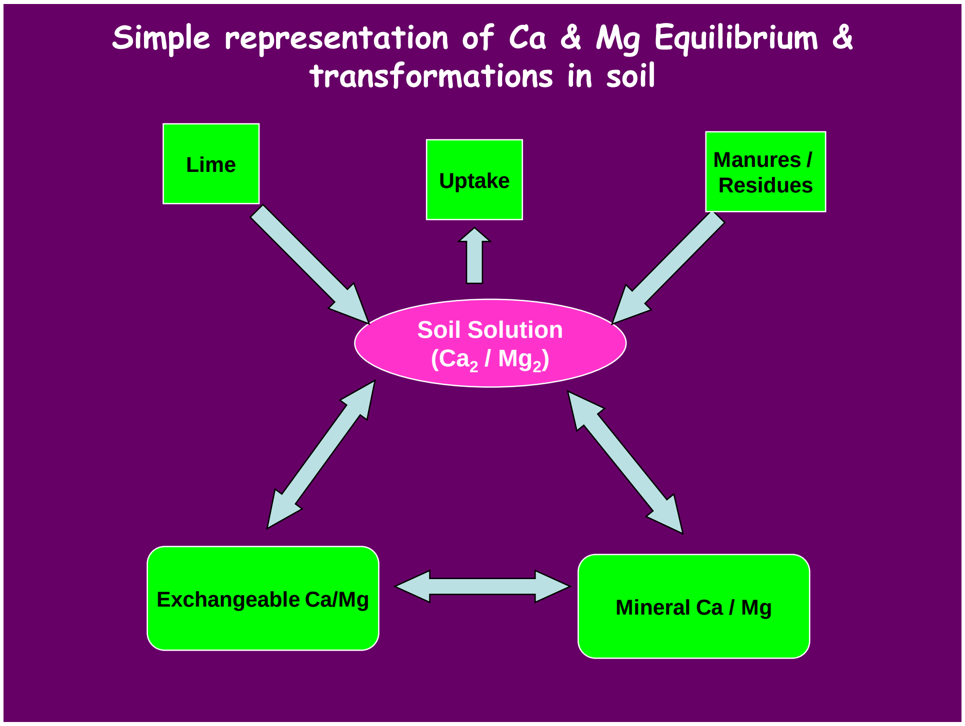
Calcium and Magnesium availability in soils

Ca &Mg availability in soils:

Ca and Mg are the most abundant cations occupying the exchange sites of the soil colloids of both inorganic (clay) and organic (humus). Thus most soils contain enough Ca and Mg except highly weathered leached acid soils and alkali soils. Deficiencies of Ca and Mg frequently occur in coarse textured as well as acidic soils developed under high rainfall conditions. The critical limits of exchangeable Ca and Mg vary widely among soils. However average value of <2.0 m.eq/100g for exchangeable Ca and < 0.5 m.eq/ 100g for exchangeable Mg are considered critical limits for availability.

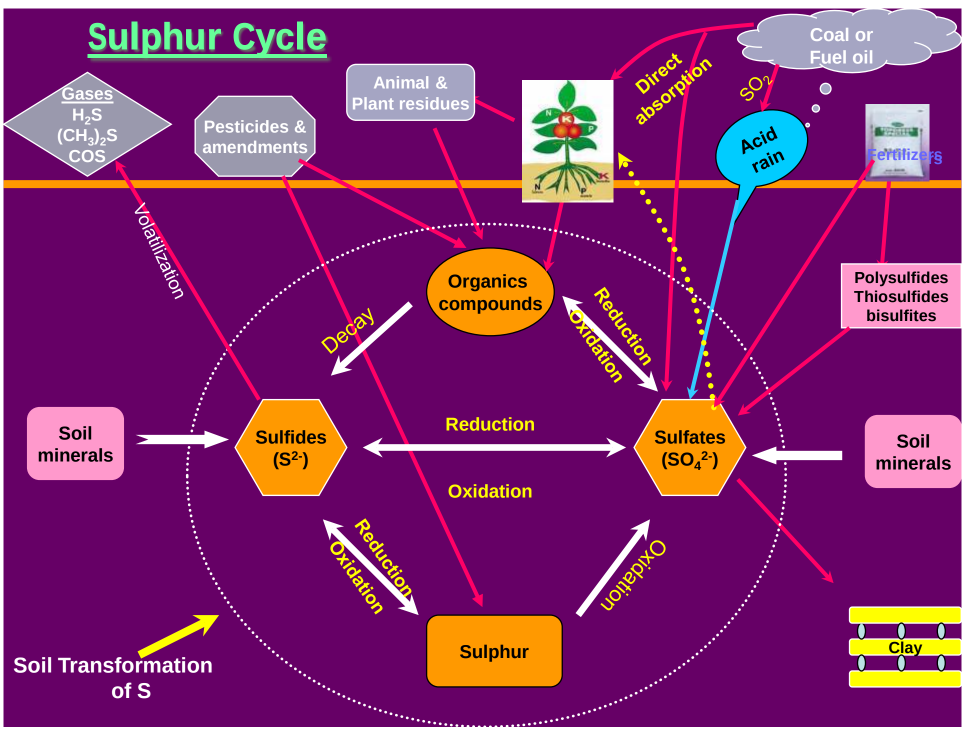
Ca & Mg Transformations:

Ca & Mg occupying the exchange sites of the soil colloids (clay & humus) are subjected to cation exchange reactions then released into soil solution for plants absorption or adsorbed on the clay and organic matter surfaces. Soils usually contain less Mg than Ca because Mg^{2+} ions are not adsorbed as strongly by clay and organic matter as Ca^{2+} ions and further Mg^{2+} ions are more susceptible to leaching than Ca^{2+}ions.



Sulphur Cycle and Transformation in soils

Sulphur Cycle in soil



S-Transformations

In aerobic soil

The sulphur in soil is being cycled continuously between inorganic and organic forms just like Nitrogen. The nature of compounds formed and their transformations are influenced by the biologically mediated process. Organic matter is the major of source of S, it undergoes oxidation to SO_4^{2-} . This is brought about by autotrophic bacteria belonging to the genus *Thiobacillus* under aerobic conditions of soil.

$$\text{Organic S (Proteins, Amino acids)} \xrightarrow{\text{Aeration } (O_2)} SO_4^{2-} + H^+$$

The released SO_4^{2-} ion is taken up by plants and microorganisms. The rate of mineralization is affected by factors such as moisture (60% field capacity), aeration, temperature (35-40^oC) and Soil pH.

In anaerobic soil

Under anaerobic conditions or flooded soils, the soil aeration is completely cut off. The SO_4^{2-} ion is reduced to sulphides (S^{2-}) by the autotrophic bacteria such as *Desulpho vibrio and Desulpho maculans* which use SO_4^{2-} for their O_2 requirements.

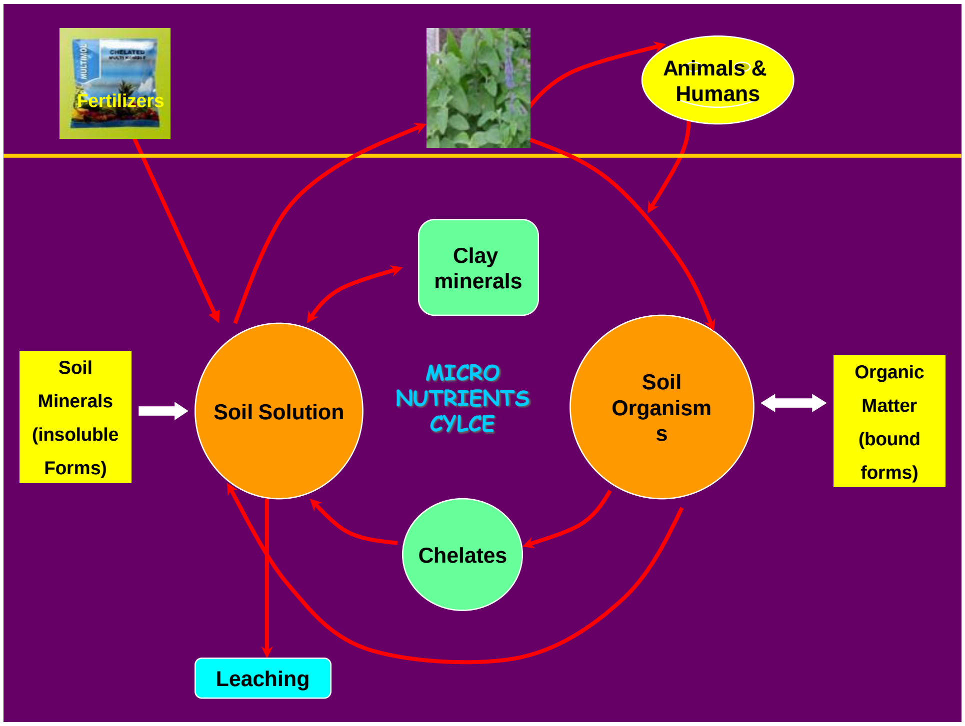
$SO_4^{2-} + 8\ H^+ + 8^{e-} = S^{2-} + 4H_2O$.

Micronutrients Cycle and their Transformations in soil

The total content of Fe, Mn, Zn, Cu, Co, Cl & B varies considerably in different soils. Except Zn, Cu and B, all other micronutrients (Fe, Mn, Cl, Mo) are present in Indian soils in sufficient amounts to sustain agricultural productivity. Zn and Boron deficiency is found in all the soils of agro ecological regions of the country.

The availability of micronutrient cations in soil is highly affected by inorganic ions in soil solution, soil solid constituents like free oxides of Fe & Al, soil organic matter, fertilizers and amendments applied to soil

Micronutrients Cycle



Reference: 1. Soil and Soil Fertility-6th edition by Frederick R. Troeh and Louis M. Thompson

Lesson 10

Acid Soils and Calcareous soils, their Formation and Management

1. Acid soil?

2. Causes of soil acidity

3. Problem of soil acidity

4. Management or Amelioration of soil acidity

a. Lime requirement (LR):

b. Liming reaction in soils

c. Benefits of liming on acidic soils

5. Calcareous soil

6. Formation, characteristics & management of calcareous soil

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Soil acidity is an important agricultural problem while evaluating the production potential of most of the crops. Millions of hectares of land lie idle because of strong soil acidity. In India 49 million hectares of land have problems of soil acidity. Soil acidity is more common in regions with high rainfall. This leads to leaching of appreciable amounts of calcium and magnesium from the surface layer leading to build up of H and Al species causing soil more acidity.

Acid soil?

Acid soil is a base unsaturated soil with enough amount of adsorbed exchangeable H^+ & Al^{3+}ions with the soil pH of <6.0 is called acid soil. An acid soil is actually a mixed H-Al system, i.e. such a soil has both H^+ and Al^{3+} ions as exchangeable ions.

Causes of soil acidity

1. Leaching of bases like Ca, Mg, Na etc., due to heavy rainfall
2. Acidic parent material like granite
3. Use of acid forming fertilizers like Urea and ammonium sulphate
4. Decomposition of organic matter leading to release of various organic acids
5. Continuous cultivation of crops leads to more absorption of basic cations form the soil
6. Acid rains containing sulphate and nitrate ions
7. Aluminium and Iron polymers- One Al species release 3 H^+ ions upon step wise hydrolysis and similar reactions are possible with Fe^{3+} also.
8. Laterization, podzolization and accumulation of undecomposed organic matter under marshy conditions contribute to soil acidity.

Problem of soil acidity

Soil acidity causes physical, chemical and biological problems in soil.

1. **Physical Problems-** in extreme acid soil, soil will be heavily aggregated and very compact like laterite.
2. **Chemical problems** are
   a. Acid toxicity
   b. Toxicity of different nutrient elements- such as Fe, Al and Mn are more soluble form
   c. Nutrient availability is reduced especially N, P, K Ca, Mg, Na,
   d. Nutrient imbalances due to fixation of PO_4 by Fe, Al and Mn,

e. Boron and Mo availability decreased

3. **Biological problems**: Microbial activity decreases
   a. Bacteria and actinomycetes will not show their activity when the soil pH drops below 5.5.
   b. Nitrogen fixation in acid soils is greatly affected by lowering the activity of Azatobacter sp., and Rhizobium species.
   c. Fungi can grow well under very acid soils and cause various diseases **like Foot rot of Black pepper and blights of potato etc.**

Management or Amelioration of soil acidity

In general the fertility status of acid soils is very poor and under strongly to moderately acidic soils, the plant growth and development is affected to a great extent. The crops grown on such problematic soils do not give remunerative returns. One of the most important and practically feasible management practices is the use of LIME AND LIMING MATERIALS to ameliorate the soil acidity. The addition of lime raises the soil pH, thereby eliminating most major problems of acid soils. Cultivation of acid tolerant crops/varieties is also possible option.

Lime requirement (LR): Is defined as the amount of liming material that must be added to raise the pH to some desired value (pH 6.0 to 7.0). There are a number of liming materials available in the market and may be used according to their availability, convenience and economy. Some of the important liming materials are;

1. Lime oxide (CaO)- Burnt lime/quick lime or oxide of lime. Caustic in nature and
   difficult to handle.
2. Lime hydroxide {$Ca(OH)_2$}- hydrated lime or slaked lime. Caustic in nature and
   difficult to handle.
3. Lime carbonate ($CaCO_3$)- ground lime stone occurs as Boglime or marl, Calcite,
   Oysters shells and precipitate carbonates. It is most commonly used and it is

largely sold in the market as pulverized or ground lime stone, called **agriculture lime**.

4. Basic slag: Byproduct of Iron industry.
5. Dolomite ($CaMgCO_3$)

Liming reaction in soils

$$H+ [Soil] + CaCO_3 \text{-------} Ca^{2+} [Soil) + CO_2 + H_2O$$

or

$$CaCO_3+H_2CO_3 \text{-------} Ca (HCO_3)_2$$

$$H+ [Soil] + Ca(HCO_3)_2 \text{--------} [Soil]Ca^{2+} + 2 H_2O + 2CO_2$$

Benefits of liming on acidic soils

1. Direct benefits
   a. Addition of lime raises the soil pH to a desired level.
   b. It eliminates major problems of Fe, Al, Mn and H toxicities.
2. Indirect benefits
   a. The nutrients like Ca^{2+} and Mg^{2+} are added to the soil if lime is dolomite (Ca, $MgCO_3$)
   b. The raised pH also reduces excess soluble Mn and Fe by forming insoluble hydroxides.
3. Phosphorus availability is improved or increased because of liming precipitates Fe and Al in other forms (P is fixed as Fe and $AlPO_4$).
4. It makes K^+ more efficient in plant nutrition.

5. It increases the availability of N by creating a more favorable environment for microbes.
6. Bacterial activity is enhanced and help in control of certain plant pathogens like club rot disease of cole crops.

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Calcareous soil, their formation, characteristics & management

Calcareous soils are those that contain enough free calcium carbonate ($CaCO_3$) and give effervescence visibly releasing CO_2 gas when treated with dilute 0.1 N hydrochloric acid. The pH of calcareous soil is > 7.0 and also regarded as an alkaline (basic) soil.

Formation

The soil is formed largely by the weathering of calcareous rocks and fossil shell beds like varieties of chalk, marl and lime stone and frequently a large amount of phosphates. Soils are often very fertile, thin and dry. They are found in large part of arid and semiarid regions, which may prove very fertile when sufficient moisture for crops is available. Soils also can become calcareous through long term irrigation with water contains small amounts of dissolved $CaCO_3$ that can accumulate with time. Calcareous soils can contain from 3% to >25% $CaCO_3$ by weight with pH values with a range of 7.6 to 8.3.

Management of Calcareous soil

Fertilizer management in calcareous soils is different from that of non calcareous soils because of the effect of soil pH on soil nutrient availability and chemical reactions that affect the loss or fixation of some nutrients. The presence of $CaCO_3$ directly or indirectly affects the chemistry and availability of nitrogen (N) Phosphorus (P), Magnesium (Mg), Potassium (K), Manganese (Mn), Zinc (Zn) and iron (Fe). The availability of copper (Cu) also is affected. Application of acid forming fertilizers such as ammonium sulphate and urea fertilizers, sulphur compounds, organic manures and green manures is considered as effective measures to reduce the pH of soil to neutral pH value.

Reference: 1. Principles of soil chemistry by Kim H. Tan

2. The Nature and Properties of Soils by Nyle C. Brady and Ray R. Well

Lesson 11 And 12

Salt affected soils, their formation & management

1. Salt affected soils?

2. Classification of salt affected soils;

3. Formation of salt affected soils:

A. SALINE SOILS & THEIR MANAGEMENT

a. Characteristics of saline soil

b. Formation/Development of saline soils:

c. How to diagnose salinity problems in the field?

d. Soil salinity classes and crop growth:

e. Effect of salinity on crop growth:

f. Methods of Reclamation and Management Saline soils.

I. Physical methods

II. Agronomic and cultural methods

B. ALKALI SOILS & THEIR MANAGEMENT

a. Characteristics of Alkali soils

b. Formation of Alkali soil and their classification

c. How to diagnose Alkali Soils in the field?

d. Problems of alkali soils an plant growth

e. Reclamation and management of alkali soils

1. Use of Chemical/Industrial amendments
2. Organic amendments
3. Cultural practices.
4. Watermanagement
5. Method of application of amendments

f. Sodicity classification according to the FAO

1. Salt affected soils?

All soils contain some amounts of soluble salts. Many of these salts act as a source of essential nutrients for the healthy growth of plants. However, when the quantity of the salts in the soil exceeds a particular limit, the growth, yields and/or quality of most crops is adversely affected depending upon the kind and amount of salt present. According to Central Salinity Research Institute, Karnal, the area of salt affected soils (Soil salinity plus alkalinity) in India is 7421 thousand hectares (approximately).

Soil that contains excess amount of soluble salts such as chlorides, sulphates, carbonates and bicarbonates of calcium, magnesium and sodium so as to impair productivity of crops is called **salt affected soil.**

2. Classification of salt affected soils;

Indian system of classification: Classified in to 2 major types of salt affected soils based on pH, EC and ESP.

Soil Characteristics	Saline soils	Alkali soils
pH(s)	< 8.2	> 8.2
ESP	< 15	> 15
EC(e)	>4 ds/m	Variable, mostly <4dS/m
Nature of Soluble salts	Neutral mostly Cl^- & SO_4^{2-}, HCO_3^- may be present but CO_3^{2-} is absent	Capable of alkaline hydrolysis, preponderance of HCO_3^- & CO_3^{2-} of Na^+.

3. Formation of salt affected soils:

Nature and amount of soluble salts play an important role in the formation salt affected soils. Soluble salts are those inorganic chemicals that are more soluble than gypsum. Soluble salts in soils are mainly composed of the cations like sodium (Na^+), Calcium (Ca^{2+}) and magnesium (Mg^{2+}) and potassium (K^+) and ammonium (NH_4^+) in small amount. The anions like chlorides (Cl^-). Sulphates (SO_4^{2-}) carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-). The salt formation is therefore expected to result from a combination of these groups such as NaCl, Na_2SO_4, $MgSO_4$, $CaCl_2$, $CaSO_4$, Na_2CO_3, $NaHCO_3$, and $MgCO_3$ and $CaCO_3$.

Salt affected soils formed mainly in 2 phases or process:

1. Salinization process: Process of accumulation of soluble salts in the soil results in the formation of saline soil.
2. Alkalization process: Process of accumulation of exchangeable sodium in the soil & formation of sodic soils is termed as alkalization.

A. SALINE SOILS & THEIR MANAGEMENT

Saline soils?

They are defined as soils containing appreciable amounts of soluble salts like chlorides, sulphates of Ca, Mg, K, and Na etc. that interfere with plant growth.

Characteristics of saline soil

The EC of saturation paste extract of these soils is > $4dSm^{-1}$, pH of the saturation paste is < 8.2 and the ESP is < 15. They are also known as **white alkali soils or solon chalks**. These soils lack structural B horizon and contain very little organic matter (<1%). Soluble salts mostly consist of chlorides and sulphates of Na^+, Ca^{2+} and Mg^{2+}. Bicarbonates may or may not be present. However carbonates are generally absent.

Formation of saline soils:

Saline soils are formed whenever climate, soil and hydrological conditions favour accumulation of soluble salts in the root zone. Arid and semi-arid regions of low rain fall and high temperature leads to less leaching, more evaporation of water and less transport of soluble salts. Irrigation with salt-laden underground water and their indiscriminate use under inadequate drainage creates more salinity problems. Excessive use of chemical fertilizers may also leads to form saline saline soils.

How to diagnose salinity problems in the field?

In the field, saline soils can be identified by:

- Presence of **white crust layer of salts** on the surface of soils in a dry region. It is a mixture of NaCl and Na_2SO_4 salts.
- Good physical conditions and high permeability of soil.
- Natural vegetation consisting of mainly small bushes and some halophytes such as *Cressa cretica*, *Cyperus rotudus*, *Chloris gayana* etc.
- In cultivated fields patchy and stunted growth of crops
- **Wilting sign** due to water stress in plants even when the soil apparently contains enough water due to plasmolysis
- A thin soil crust that may prevent emergence of seedlings of sensitive crops.

Soil salinity classes and crop growth:

Sl. No	Soil salinity class	EC(e).dSm^{-1}	Effect on crop growth
1.	Non saline	<2	Salinity effects negligible
2.	Slightly saline	2- 4	Yields of sensitive crops may be restricted.
3.	Moderately saline	4 - 8	Yield of many crops restricted.
4.	Strongly saline	8 - 16	Only tolerant crops yield satisfactory.
5.	Very strongly saline	>16	Only a few very tolerant crops yield is satisfactory.

Equations for relating EC with OP and TDS

Conversions

Total cations (m eq/L)=10 X EC(dS/m) at 25^{o}C

Salt Concentration(mg/L)= 640 X EC(dS/m) at 25^{o}C

Osmotic Pressure= 0.36 X EC (dS/m) at 25^{o}C

% Salt in solution= 0.064 X EC (dS/m) at 25^{o}C X $\frac{\text{Saturation percentage(SP)}}{100}$

Effect of salinity on crop growth:

Excess amount of soluble salts affects the plant in the following ways;

1. **Water availability to plants decreases**: with increase in salt concentration of the soil the osmotic pressure of the soil solution increases and plants are not able to extract water as easily as they can from the soil. Therefore, EC (e) of the soil increases the water becomes less available to the plant even though the soil may contain water and appears quite moist. Due to high osmotic pressure water comes out of the plant which is called reverse osmosis or plasmolysis. The plant show wilting symptoms which referred as physiological drought.

2. **Specific Toxic effect of ions**: Higher concentration of individual ions in the root environment or in the plant may prove toxic to the plant or may retard the uptake (absorption) and metabolism of the essential plant nutrients and thus affect the normal growth of the plant. Antagonism between Cl^- and $H_2PO_4^-$, $C1^-$ and NO_3^-, $C1^-$ and SO_4^{2-} and Na^+ and K^+ may disturb the normal nutrition of plants.

Methods Of Reclamation Or Management Of Saline Soils

I. Physical methods

- **Scraping:** The salts accumulated on the surface can be removed by mechanical means. This is the simplest & most economical way to reclaim saline soils if the area is very small e.g. small garden lawn or a patch in a field. This improves plant growth only temporarily as the salts accumulate again & again.
- **Flushing:** Washing of surface salts by flushing water. This is especially practicable for soils having a crust & low permeability. However this is not sound method of practice.

- **Leaching:** leaching with good quality water, irrigation or rain is the only practical way to remove excess salts from the soil. It is effective if drainage facilities are available, as this will lower the water table & remove the salts by draining the salt rich effluent.

Leaching requirement: The amount of water needed to remove the excess soluble salts from the saline soils is called leaching requirement or The fraction of the irrigation water that must be leached through the root zone or soil profile to control soil salinity at any specific level(Salt balance)

$$\text{Leaching Requirement (LR)} = \frac{EC_{iw}}{EC_{dw}} \times 100 \quad \text{or} \quad \frac{D_{dw}}{D_{iw}} \times 100$$

Where, EC= Electrical Conductivity in dSm^{-1}

iw= EC of Irrigation water in dSm^{-1}

dw= EC of Drainage water in dSm^{-1}

Ddw= Depth of drainage water in inches

Diw= Depth of irrigation water in inches

II. Agronomic and cultural methods: In areas where only saline irrigation water is available or when shallow saline water table prevails and soil permeability is low, the following cultural practices are adopted .

1. Selection of crops and crop rotations:

On the basis of crop tolerance to quality of irrigation water or soil salinity the crops can be classified in four groups viz.

- Highly tolerant crops: Barley, Sugar beet, datepalm
- Tolerant: Tapioca,mustard,coconut, spinach, amaranthus, pomegranate, guava, ber
- Semi-tolerant:Ashguard, bittterguard, brinjal, cabbage, cluster bean, Pea, lady's finger, muskmelon, onion, potato, dolichos, sweet potato, tomato, turnip, water melon
- Sensitive: Radish, carrot, Coriander, Cumin, Mint, Grape, sweet orange.

2. Method of raising plants:

a. crop should be raised by transplanting seedlings (especially vegetables, flowers, fruit trees) than germinating the seeds.

b. Wild root stocks grafted with a good quality but salinity sensitive scion. (Mango, citrus, Guava and ornamental plants like rose).

3. Irrigation practices:

a. Method of water application- follow furrow or drip irrigation, sub surface irrigation systems and sprinkler irrigation.
b. Frequency of irrigation- irrigation more often (frequent) can maintain better water availability & decrease the salinity should not too much irrigations.

4. Use of mulching materials to prevent evaporation losses like straws, plastic sheets etc.

ALKALI SOILS & THEIR MANAGEMENT

Alkali soil?

Alkali soils are those that contain measurable amounts of soluble salts mostly as carbonates and bicarbonates of sodium.

Characteristics of Alkali soils

These soils have pHs > 8.2 and ESP > 15. The EC_e of alkali soils is variable but normally <4 dSm^{-1}. Neutral salts like NaCl and Na_2SO_4 are present in very small quantities. The alkali soils are also known as sodic or solonetz. They are also called as **Black alkali soils**. It is mainly because of high pH and Na_2CO_3 the finely decomposed organic matter is dissolved along with the water that imparts a dark black or brown colour to the soil.

Formation of Alkali soils:

1. Sodication due to repeated cycles of wetting & drying.
2. Sodication due to shallow brackish ground waters.
3. Sodication due to the use of high RSC water.
4. Sodication due to the use of saline irrigation waters low in Cl: SO_4 ratio.

In contract to saline soils the saturation extract of alkali soils contains measurable amounts of CO_3^{2-} and HCO^{3-}; $C1^{-}$ and SO_4^{2-} may also be present in appreciable amounts. Among the cations, sodium ($Na+$) is the dominant one followed by Mg^{2+} and Ca^{2+}.

Sodicity classification according to the FAO:

Class	ESP	Description
a	<10	Sodic free soil
b	10-20	Slightly sodic
c	20-30	Moderately sodic
d	30-50	Straggly sodic
e	>50	Very sodic

Characteristics of Sodic soils

- There will not be any natural vegetation except some very hardy grasses.
- When wet, alkali soils turn black because of the humic acid fraction of organic matter, which is dissolved by Na_2CO_3 at high pH.
- They are very slippery and soft when wet but very hard when dry.
- Upon drying deep cracks, 1-2 cm wide develops in the soil which closes when wetted.
- The surface soil develops a hard crust with typical convex surfaces.
- Water movement is restricted due to the sealing effect of Na- clays. A few centimeters below the surface may therefore be almost saturated with water while the surface is dry & vice versa.
- Runoff water is always turbid because of the bad physical conditions.
- Clay pan formation or kankar pan formation at variable depths.

Problems of alkali soils on plant growth

- Poor water and air permeability as a result of high dispersion of soil aggregates and clay particles.
- Low availability of water due to poor conductance from the lower soil layers.
- Seedling emergence & germination is greatly affected due to hard crust surface.
- Seed bed preparation is very difficult because it does not come to proper moisture conditions.
- Deficiency of Ca and there is an antagonistic effect on K and Ca nutrition.
- Toxic concentration of HCO_3^- and CO_3^{2-} ions.
- Decreased solubility of Fe & Zn.
- Increased solubility and accumulation of toxic elements such as F, Se & Mo in plants that may affect crop yield.

RECLAMATION or MANAGEMENT OF ALKALI SOILS

I. Use of Amendments: For successful crops in alkali soils ESP of the soil must be lowered which can be achieved by application of amendments.

Gypsum ($CaSO_4.2H_2O$) is the most commonly used amendment for reclamation. Elemental S and pyrite are also used.

Gypsum requirement (GR): The amount of gypsum needed for removal of exchangeable sodium from alkali soil and also to decrease the soil pH to a desired level is called gypsum requirement.

1 milli equivalent of Ca^{2+} is required to replace 1 milli equivalent of Na^+ ion from the exchange complex of sodic soil.

Method of application of amendments: Amendment should normally be broadcasted and incorporated in the surface 10 cm soil. Deeper depth of mixing of gypsum becomes inactivated and thereby reduces the effectiveness of the applied gypsum and yield of crops. To ensure proper dissolution of gypsum and leaching of replaced exchangeable Na^+, the water is to be ponded/stagnated continuously on the soil for a period of 8-10 days (80% of gypsum gets dissolved). It brings down soil exchangeable sodium percentage (ESP) to a desired level before sowing. When pyrites or elemental Sulphur are used as an amendment, then a cycle of wetting and drying is needed to maintain proper moisture and aerobic conditions to ensure maximum oxidation and higher production of H_2SO_4.

Reactions amendments in soil

If Gypsum used

Na_2CO_3 + $CaSO_4^-$ --------→ $CaCO_3$ + Na_2SO_4

$2NaHCO_3$ + $CaSO_4^-$ --------→ $Ca(HCO_3)_2$ $^+$ Na_2SO_4.

Or

$2Na^{+-}$-$Soil^+$ + $CaSO_4^-$ -----------→ Ca^{2+} - Soil + Na_2SO_4.

If Elemental Sulphur used

$2S$ + $3O_2$ ------------→ 2 SO_3 (Microbial oxdation)

SO_3 + H_20 -----------→ H_2SO_4.

H_2SO_4 + $CaCO_3$--------------→ $CaSO_4$ + CO_2 + H_2O

2Na X +$CaSO_4$----------------→ Ca-X_2 + Na_2SO_4.

B. **Organic Amendments:** Addition of crop residues and other organic materials have got a tremendous influence on maintaining soil physical, chemical and biological properties of these soils. Organic amendments like straw, rice husk. Ground nut and safflower hulls, FYM, compost, poultry droppings, green manures, tree leaves and saw dust. They Produce CO_2 (carbonic acid) and organic acids, they increase the solubility of calcite and lower the ESP.

C. **Industrial by products as Amendments:** Phospho-gypsum, Press mud, Molasses, Acid wash and Effluent from milk plants. They are used to provide soluble Ca directly/indirectly by dissolving soil lime.

D. Cultural practices:

- Land leveling and shaping:- To ensure proper water management and uniform leaching of salts the field should be leveled properly.
- Maintain Plant population: Crop stand in alkali soils can be improved by increasing the **seed rate and reducing the planting distance.**
- Age of seedlings - planting old seedlings has proved to be beneficial.
- Green manuring: Increases organic matter content, there will be releasing of CO_2 and formation carbonic acid. This lowers the pH and it enhances solubility of native $CaCO_3$ and adds a considerable amount of plant nutrients in the soil.
  Ex: Sesbania, diancha, subabul

- Continuous cropping: the land should be continuously cropped to keep the downward movement of replaced Na & soluble salts. Growing of rice crop, along with other practices has been observed to enhance the reclamation of alkali soils.

E. Water management:

1. Drainage: Alkali soils have got low infiltration rate and all the rain water accumulates to create surface water logging. This results oxygen stress. So, to avoid this problem provide surface and subsurface drainage system in the field.
2. Good irrigation management: Normally surface method of irrigation such as furrow or basin type flood method is used for alkali soils. However the sprinkler method could be promising because of its ability to supply water uniformly and in small quantities

Reference: 1. The Nature and Properties of Soils by Nyle C. Brady and Ray R. Well

Lesson 13 to 14

Soil fertility evaluation

Soil fertility evaluation?

Methods of soil fertility evaluation-

I. Nutrient deficiency symptoms on plants

II. Plant analysis

III. Biological tests

IV. Soil testing

V. Modern approaches of soil fertility evaluation and fertilizer recommendation

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Soil fertility evaluation?

The diagnosis of the nutrient status of the soil by using different techniques or methods is known as soil fertility evaluation.

Methods of soil fertility evaluation

There are various diagnostic techniques that are commonly used to evaluate fertility of the soils. They are;

I. Nutrient deficiency symptoms of plants

It is a qualitative measurement of availability of plant nutrients. It is the visual method of evaluating soil fertility and diagnosing the malady affecting the plant. An abnormal appearance of the growing plant may be caused by a deficiency of one or more nutrient elements. The appearance of deficiency symptoms on plants has been commonly used as an index of soil fertility evaluation. If a plant is lacking in a particular element, more or less characteristics symptoms may appear. This visual method of soil fertility evaluation is very simple, not expensive and does not require elaborate equipments but it becomes difficult to judge the deficiency symptoms if many nutrients are involved. In such cases it requires experienced person to make proper judgment.

The common deficiency symptoms are;

1. Complete crop failure at seedling stage
2. Retarded/stunted growth
3. Abnormal color pattern. e.g.: Chlorosis (yellowing), necrosis (dying of tissue)
4. Malformation of different plant parts. E.g.: rosette appearance of leaves
5. Delayed maturity
6. Poor quality of crops like low protein, oil, starch content, keeping/ storage quality reduced.
7. Internal abnormality like **Hidden hunger** (It is a situation in which a crop needs more of a given
element, yet has been shown no deficiency symptoms).

II. Plant Analysis

It is a valuable supplement to soil testing in the task of soil fertility evaluation. Plant analysis indicates the actual removal of nutrients from the soil and identifies nutrient status of plant and deficiency of nutrient element. It is a direct reflection of nutrient status of soil.

Advantages of plant analysis are;

a. Diagnosing or confirming the diagnosis of visible symptoms

b. Identifying hidden hunger

c. Locating areas of incipient (early stage) deficiencies.

d. Indicating whether the applied nutrients have entered the plant

e. Indicating interactions or antagonisms among nutrient elements.

Plant analysis consists of three methods

1. Rapid tissue tests: It is a rapid test and qualitative or semi quantitative method. Fresh plant tissue or sap from ruptured cells is tested for unassimilated N, P, K and other nutrients. The cell sap is added with certain reagents to develop color. Based on intensity of color low, medium and high color is categorized which indicates the deficiency, adequate and high nutrients in the plants respectively. It is mainly used for predicting deficiencies of nutrients and it is possible to forecast certain production problems.

2. Total analysis: It is a quantitative method and performed on whole plant or on plant parts. The dried plant material is digested with acid mixtures and tested for different nutrients quantitatively by different methods. The determination gives both assimilated and unassimilated nutrients such as nitrogen, phosphorus, potassium calcium, magnesium, suphur, iron, manganese, copper, boron, molybdenum, cobalt, chlorine, silicon, zinc, aluminum etc., in plants. Recently matured plant material is preferable for accurate analysis.

Critical levels of nutrients in plants

Element	General range (%)	Critical level (%)
N	2.0 - 4.0	<2
P	0.2 - 0.5	<0.1
K	1.5 - 3.0	<1.0
Ca	0.5 - 3.0	<0.1
Mg	0.2 - 0.5	<0.2
S	0.2 - 0.5	<0.15
Fe	50 – 150 ppm	<5 ppm
Cu	5 – 20 ppm	<4 ppm
Zn	20 – 100 ppm	<15 ppm
Mn	20 – 500 ppm	<20 ppm
B	2 – 100 ppm	<20 ppm
Mo	0.1 - 2.0 ppm	<0.1 ppm
Cl	0.2 - 2.0 ppm	-

III. Biological methods

It is conducted for calibrating the crop responses to added nutrients. Different methods are adopted for evaluating fertility status of soil.

1. Field tests: Field tests are conducted on different fertilizers and crops with treatments impositions in replications. The treatment which gives highest yield will be selected. These experiments are helpful for making general recommendations of fertilizer to each crop and soil and we can also choose right type and quantity of fertilizer for various crops. It is laborious, time consuming, expensive but most reliable method. They are used in conjunction with laboratory and greenhouse studies as final proving technology and in the calibration of soil and plant tests. Thy widely used by experiment stations.

2. Indicator plants: These are plants that are more susceptible to the deficiency of specific nutrients and develop clear deficiency symptoms if grown in that nutrient deficient soil. Hence these are called as indicator plants. Some indicator plants are;

Nutrients	**Indicator plants**
N, Ca	Cabbage, Cauliflower
P	Rape
K, Mg	Potato
Fe	Cauliflower, cabbage, potato, oats
Zn	Maize
Na, B	Sugar beet
Mn	Sugarbeet, oats, potato
Mo	Lucerne
Cu	Wheat

3. Microbiological test: By using various cultures of microorganisms soil fertility can be evaluated. These methods are simple, rapid and need little space. **Winogradsky** was one of the first to observe in the absence of mineral elements certain microorganisms exhibited a behavior similar to that of higher plants. Microorganisms are sensitive to deficiency of nutrients and could be used to detect the deficiency of any nutrient. A soil is treated with suitable nutrient solutions and cultures of various microbial species (bacteria, fungi) and incubated for a few days. Then observing the growth and development of organisms in terms of weight or diameter of the mycelia pad, the amount of nutrient present in the soil is estimated.

Ex: a. *Azotobactor* method for Ca, P and K.

b. *Aspergillus niger* test for P and K

c. Mehlich's Cunninghamella (Fungus)- plaque method for phosphorus

d. Sackett and Stewart techniques (Azotobacter culture) to find out P and K status in the soil.

4. Laboratory and Green house Tests: These are simple and more rapid biological techniques for soil fertility evaluation. Here, higher plants and small amounts of soils are used for testing. All these techniques are based on the uptake of nutrients by a large number of plants grown on a small amount of soil. It is used to assess availability of several nutrients and they are quantitatively determined by chemical analysis of the entire plant and soil. Some common methods are;

E.g.: a. Mitscherlich pot culture method for testing N,P, K status in oat

b. Jenny's pot culture test using lettuce crop with NPK nutrients

c. Neubauer seedling method for NPK

d. Sunflower pot-culture technique for boron

III. Soil Testing

A soil test is a chemical method for estimating the nutrient supplying power of a soil. It is much more rapid and has the added advantage over other methods of soil fertility evaluation. One can determine the needs of the soil before the crop is planted. A soil test measures a part of the total nutrient supply in the soil.

Soil testing plays a key role in today's modern and intensive agriculture production system as it involves continuous use and misuse of soil without proper care and management. Soil analysis is helpful for better understanding of the soils to increase the crop production and obtaining sustainable yield. **Soil testing is an indispensable tool in soil fertility management for sustained soil productivity.**

Objective of soil testing

a. To evaluate fertility status of soil by measuring available nutrient status
b. To prescribe or recommend soil amendments like lime and gypsum and fertilizers for each crop
c. To assess nutrient deficiencies, imbalances or toxicities in soil and crop
d. To test the suitability of soil for cultivation or gardening or orchard making
e. To know acidity, alkalinity and salinity problems

f. To know morphology, genesis and classification of soil
g. To find out the effect of irrigation on soil properties.
h. To prepare a soil fertility map of an area (village, taluk, district, state)

In the soil testing programme, **"soil sampling"** is most important step to be followed for getting accurate results. Soil sampling is a process by which a true representative sample of an area or orcahrd can be obtained. The soil sampling must be done scientifically by adopting appropriate time and depth of sampling given for each crop for accurate analysis of soils.

Interpretation of soil test results and critical levels of nutrients in soils.

Nutrients	**Low**	**Medium**	**High**
Avail. Nitrogen(Kg/ha)	280	280-580	>580
Avail.Phosphorus(P_2O_5 Kg/ha)	22.5	22.5-55	>55
Avail. Potassium(K_2OKg/ha)	125	125-300	>300
Organic carbon (%)	0.5	0.5-0.75	>0.75
pH	<6.5 = Acidic 6.5-7.5 =Normal/Neutral 7.5-8.5 = Saline >8.5 =Alkaline		
EC(dSm^{-1})	<0.80 = Normal 0.8-1.60 = Critical for some crops		

	1.6-2.5 = Critical for salt tolerant crops >2.5 = Injurious to all crops
Ca	<50% of CEC
Mg	<4% of CEC
S	<10ppm
Zn	<0.6 ppm (0.5-1.2ppm)
Fe	2.5-4.5 ppm
Mn	<2 ppm
Cu	<0.2 ppm
B	<0.5 ppm(WS)
Mo	<0.2 ppm
Cl	<2 ppm(WS)

V Modern approaches of soil fertility evaluation and fertilizer recommendation

1) Soil Test Crop Response (STCR)/Targeted Yield Concept

2) Diagnosis and Recommendation Integrated System (DRIS) Approach

1) SOIL TEST CROP RESPONSE (STCR)

After introduction of high yielding varieties and hybrid crops, the need for systematic soil test crop response research in different soil agro-climatic regions become evident. ICAR established the AICRP on STCR in 1967 and the STCR concept was developed by Ramamoorthy, in 1987. STCR provides the relationship between a soil test value and crop yield. The soil test values are needed to be correlated with actual crop response obtained under field conditions.

Separate calibration charts are needed for each crop and soil. Fertility gradient and regression approach and targeted yield concepts were evolved.

This is also called as “rationalized fertilizer prescription approach” in which inherent soil fertility and yield level of the crop are taken in to account while recommending the fertilizer doses.

Objective of STCR

1. To prescribe fertilizer doses for a given crop based on soil test values to achieve the “Targeted yields” in a specific soil agro-climatic region under irrigation or protective irrigation conditions by using mathematical equations for different crops and different soil agro-climatic zones separately.

2. This takes in to consideration-the efficiency of utilization of soil and added fertilizer nutrient by the crops and its nutrient requirements for a “desired yield level”.

Concept of STCR

STCR approach is aiming at obtaining a basis for precise quantitative adjustment of fertilizer doses under varying soil test values and response conditions of the farmers and for targeted levels of crop production. These are tested in follow up verification by field trials to back up soil testing laboratories for their advisory purpose under specific soil, crop, and agro climatic conditions. The fertilizers are recommended based on the following criterias.

- Fertilizer recommendations based on regression analysis approach
- Recommendations for certain % of maximum yield

STCR methodology takes in to account the three factors;

i) Nutrient requirement (NR) in kg/ quintal of the produce

ii) Percentage contribution from soil available nutrients (SE)

iii) Percentage contribution from added fertilizers towards making effective fertilizer prescriptions for specific yields.

i) Nutrient Requirement (NR) <u>Total nutrient uptake (grain+straw) kg/ha</u>

(in kg for producing = Yield of grain (q/ha)
1 Quintals of grain)

ii)Fertilizer Efficiency (FE in %) =

$$\frac{\text{Total nutrient uptake (kg/ha)-soil test value in treated Plot (kg/ha) X soil nutrient efficiency (\%)}}{\text{Fertilizer dose applied (kg/ha)}} \times 100$$

iii) Soil Efficiency (SE in %) =

$$\frac{\text{Total nutrient uptake in control kg/ha}}{\text{Soil test value in control kg/ha}} \times 100$$

1) With the help of above parameters, adjustment equations have been developed for a number of crops in various soils.

E.g.: For Rice crop.

a. Fertilizer N = 4.39 T -0.6723 Soil N

b. Fertilizer P_2O_5 = 2.83 T – 6.110 Soil P

c. Fertilizer K_2O = 1.41 T – 0.329 Soil K

Where T= Targeted yield of rice

Advantages:

1) Efficient and profitable site specific fertilizer recommendation for increased crop production and for maintenance of soil fertility.

2) Aims to provide balanced, efficient and profitable nutrient application rates for pre- set yield targets giving due consideration to basic fertility status of soil

Targeted yield concepts:

These are soil test based recommendations but given for different yield goals and not for a single optimum yield level. A large variety of fertilizer prescription have been made available by putting soil test values in to certain mathematical equations and finding out the amounts of nutrients needed for a given yield target.

2. DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM (DRIS Method)

Concepts of DRIS:

DRIS is a new approach to interpreting leaf or plant analysis which was first developed by “Beaufils” (1973) named as Diagnosis and Recommendation Integrated System (DRIS). It is a comprehensive system which identifies all the nutritional factors limiting crop production and increases the chances of obtaining high crop yields by improving fertilizer recommendations. The DRIS method uses **“nutrient ratios”** instead of absolute and or individual nutrient concentrations for interpretation of tissue analysis. There is a set of optimum ratios among the nutrient elements (N/P or N/K or K/P) within a given plant for promoting the growth of the plant. DRIS mainly uses the “nutritional balancing” concept (Relationship among nutrients) in the detection of nutritional deficiencies or excess in the plant. Nutrient balance is a part of the proper interpretation of DRIS system because nutrient interactions to a larger extent determine crop yield and quality.

The nutrient ratios are helpful to obtain special indexes which are called “Nutrient Index” or “Beaufills nutrient Indexes” (BNI). The nutrient index values are used to rate the nutrients in order of their need by the plants analyzed. It also measures how far particular nutrients in the leaf or plant are from optimim are used in the calibration to classify yield factors in order of limiting importance.

BNI are actually expression of the supplies of nutrients relative to each other. The concentration of each nutrient in the plant has an effect on the index value for each of the other nutrient. An abnormally high concentration of one or more nutrients will decrease the index values of other nutrients. There will be positive and negative values for the nutrient index. The nutrients with positive indexes appeared to be in “excess” and nutrients with negative indexes appeared to be “deficient” in plants. DRIS indices can be calculated individually for each nutrient using the average nutrient ratio deviation obtained from the comparison with the optimum value of a given nutrient ratio.

DRIS is a mathematical technique to apply plant analysis information (Nutrient concentration) for diagnosing the most limiting nutrient in a production system. The evaluation is made by comparing the relative balance of nutrient content with norms established for that crop under high yield conditions. The evaluation is made by comparing the relative balance of nutrient content with norms established for that crop under high yield conditions.

To develop a DRIS for a crop, the following requirements must be met whenever possible.

1. All factors suspected of having effect on crop yield must be defined
2. The relationship between these factors and yield must be described
3. Calibrated norms must be established
4. Recommendations suited to particular sets of conditions and based on correct and judicious use of these norms must be continually refined.

Advantage;

- The importance of nutritional balance is taken in to account in deriving the norms and making diagnosis. It helps to quantify the nutrient balance in the plant.
- The norms for nutrient content in leaves can be universally applied to the particular crop.
- Diagnosis can be made over a wide range of stages of crop development.
- The nutrient limiting yield through either excess or insufficient can be readily identified and arranged in order of their limiting importance for yield.

Reference: 1. Soil Fertility and Fertilizers- Samual L. Tisdale, Werner L. Nelson and James D. Beaton

2. Soil Fertility and Nutrient Management by S.S. Singh

Lesson 15 &16

Role of microorganisms in organic matter Decomposition in soil and Importance of pH in Plant Nutrition

Organic matter and its composition

Decomposition

Types microorganisms involved

Enzymes involved in decomposition process?

Major Process of organic matter decomposition **Hyper link**

1. Mineralization
   A. Nitrogen mineralization
   a. Aminization
   b. Ammonification
   c. Nitrification
   d. Denitrification
   B. Phosphorus mineralization
   C. Sulphur mineralization
2. Immobilization

Rate of decomposition of organic compounds

Products of Decomposition of organic matter

Factors affecting decomposition

Formation of humus

Fractions and properties of humus

C: N ratio and its importance
Importance of pH in plant nutrition

Organic matter?

Soil organic matter is a complex matter obtained from the plants and animal residues containing both organic and inorganic chemical compounds.

Composition of Organic matter

A. Organic compounds

1. Nitrogenous compounds eg: Amine, amide compounds and amino acids (water soluble) proteins (simple, combined, derived), peptone, purine, peptide, nucleoprotein, protease, pyridine, alkaloid, pirimidin.
2. Non nitrogenous compounds
   Eg : -Carbohydrates (mono, di, poly and oligosaccharides, amino sugars, sugar acids, sugar alcohol),lignin (aliphatic hydroxyl and carbonyl group found), Cellulose and hemicelluloses, tannin, fat, wax and resin, pigments, organic acids (acetic, oxalic, saccharic, propionic, benzoic, pomitic), organic phosphorus compounds (nucleic acids, phospholipids, inositol phosphate) and organic sulphur compounds (cystein, cystine, methionine).

B. **Inorganic compounds**: Organic matter contains several inorganic elements such as H, O, N, P, Ca, Mg, S, Na, K, Fe, Al, Mn, Zn, Mo, Si, B, Co, Cl etc. All these are in metallic complex form hence organic matter is water insoluble and do not destroy by leaching.

Decomposition?

It is the decaying or rottening of organic materials by various groups of microorganisms and enzymes and converted in to simple inorganic elements or compounds. It helps to improve softness of the materials for further mineralization process. It is basically a burning or oxidation process.

Two types of decomposition

1. Aerobic decomposition- oxygen is required
2. Anaerobic decomposition- oxygen is not required.

What types microorganisms involved in organic matter decomposition?

Decomposition is a purely microbial process involves several species of microorganisms. They are; Bacteria, actinomycetes, fungi, protozoa

- Supporting organisms are: Insects, worms, rodents, termite, ants

All the soil organic matter is not decomposed by the same group of microorganisms. At different stages of decomposition different species of microorganisms enter into the degradation process. As the degradation proceeds newer materials are synthesized by soil microorganisms.

What Enzymes involved in decomposition process?

Cellulase-breaks cellulose

Urease – breaks urea {CO(NH2)2 } to CO_2 and NH_4

Phosphatase – breaks humus –O-P-$(OH)_2$ bond to produce humus, OH & H_3PO_4

Sulfatase-breaks the humus O-S-OH bond to produce humus, OH & H_2SO_4

Protease – breaks bond linking two amino acids to separate amino acids

Decomposition processes

Two major decomposition processes involved

1. Mineralization
2. Immobilization

1. Mineralization: is the conversion of an element from organic form to an inorganic/mineral form is called mineralization. Mineralization occurs for each element present in the organic matter individually especially for N, P and S

A. Nitrogen mineralization:

It is the conversion of organic nitrogen into inorganic Nitrogen NH_4 and NO_3 by microorganisms

Organic N ----------→ Proteose------------→Peptone--------------→Amino compounds- ammonia ->nitrite -> (proteins and amino acids)
nitrate

Different steps involved in N-mineralization

1. **Aminisation**: proteins and other complex nitrogenous compounds are converted into amino acids and amino compounds by the action of enzymes and microorganisms, CO_2 and energy is released.
2. **Ammonification**: it is the biochemical conversion of amino compounds and amino acids into ammonia by bacterial decomposition.

Enzyme

Amino acids + Water ------------------→ Ammonia + energy
+amino compounds hydrolysis

Or

$$R\text{-}NH_2 + HOH \text{ --------------------- } R\text{-}OH + NH_3 + \text{energy}$$

This process is governed by aminase and deaminase enzymes. The liberated NH_3 is utilized by plants.

3. **Nitrification:** It is the biochemical oxidation of ammonia into nitrite and then finally into **nitrate**. This process carried out by by autotropic bacteria (Nitrosomanas and Nitrobacter) in aerobic condition. Two steps are involved.

Nitrosomanas and nitroso coccus

$$2NH^+_4 + 3O_2 \xrightarrow{\text{Enzymatic oxidation}} 2NO_2 + 2H_2O + 4H^+ + \text{energy}$$

Enzymatic oxidation (unstable)

Nitrobacter

$$2NO_2^- + O_2 \xrightarrow{\text{Enzymatic oxidation}} 2NO_3^- + \text{energy}$$

Enzymatic oxidation (available)

Rate of nitrification depends on suitable temperature, humidity, pH, season, aeration, addition of lime (increases), nature of organic matter etc.

4. Denitrification

It is the biochemical reduction of nitrate or nitrite to gaseous nitrogen (N_2), either as molecular N or oxides of N.

Anaerobic decomposition

NO_2^-/NO_3^- ------------------------------→ N_2

Reduction

Loss of nitrate by reduction and assimilation

B. Phosphorus mineralization

The process of conversion of organic forms of P into inorganic forms of P by P decomposing microorganisms especially by micorrhiza species is known as P-mineralization.

The organic-P found in organic manures mainly as nucleic acids, phytin, phospho lipids, inositol PO_4, lecithin etc. The organic P is not directly available to plants and it has to undergo decomposition by micro organisms especially mycorrhyzal species.

$C_6H_{24}O_{27}P_6 + 6O_2$ ----------------------------- $6H_3PO_4 + 3H_2O + 6CO_2$.

(Phytic acid)

C. Sulphur mineralization

The organic forms of S compounds such as methionine, cystine, cysteine are converted into inorganic sulphate forms (available) by aerobic bacteria species especially Thiobacillus and thiobacter.

1. Cystine + Water --------------→ Pyruvic acid + H_2S + NH_3

Oxidised

2. H_2S ----------------------→ SO_4 (sulphate)

2. **Immobilization**: the conversion of an element from the inorganic to the organic form in microbial tissues or in plant tissues, thus rendering the element not readily available to other organisms or to plants.

Rate of decomposition of organic compounds

Rate of decomposition varies with the types of organic compounds, some may undergo decomposition very fast and others may very slow. The following is the decreasing order of rate decomposition.

Starch , sugars and simple proteins > Crude proteins> Hemi cellulose > Cellulose > Lignin

> fat > Fatty compounds and waxes etc.(Most resistant)

When fresh organic manures are added to soil 60% of it decomposed within the first 6 months, 20% in the next 3-4 years and remaining 20% decomposed beyond 4 years. This results in accumulation of lignins, fats and waxes in large quantities.

Products of Decomposition of organic matter

Under well drained, aerated (oxidised) soil: CO_2, NO^-_2, NO^-_3, H_2O, PO^-_4, SO_4^{2-}, H_2 and other essential plant nutrients. Antibiotics, Auxins, hormones, phytohormones.

Under anaerobic condition (water logged and compacted soil): Methane (CH_4) (swamp gas), organic acids (R-COOH, NH_4 and amine groups ($R-NH_2$), Toxic gases like H_2S, dimethyl sulphide and ethylene ($CH_2=CH_2$) etc.

Factors affecting decomposition

The most important conditions that affect the rate of decomposition are

1. **Temperature:** Cold periods retard the organic matter decomposition and there will be more accumulation of organic matter on the top soil compared to that of warm climates. The most suitable temperature is 30-40^o C for proper decomposition.

2. **Soil moisture:** Near or slightly wetter than field capacity moisture conditions are most favorable for decomposition. About 60-75 % water holding capacity (WHC) is optimum.
3. **Soil pH**: 6-8 pH or neutral pH is required for optimum growth of microorganisms. Bacteria at 6 - 7 pH, Actinomycetes is more at pH 8 -10, Algae pH of 5.5 - 7.5, Fungi- pH 4.0, Protozoa – pH 3.0
4. **Nutrients:** Lack of nutrients, particularly N reduces microbial growth and it slows decomposition. Addition of nutrients by N fertilizers (urea) increases the speed of decomposition
5. **Soil texture**: Soils higher in clays tend to retain larger amounts of humus, other condition being equal.
6. **Aeration**: Good aeration increases the rate of decomposition and supply oxygen.
7. **Nature of plant matter**: composition and age of plants and vegetations affect much their decomposition. It is fast in young, tender, and juicy material, But slow with more cellulose and hemicelluloses content.

Formation of humus

Definition of humus

Humus is defined as they are more or less stable fraction of the soil organic matter remaining after the major portions of added plant and animal residues have decomposed. Usually it is dark or brown in colour. They are high molecular weight compounds, complex, resistant, polymeric compounds. They are amorphous and colloidal organic substances.

Composition of humus :

Humus is a heterogeneous mixture of complex organic compounds. It is mainly made up of 58% C, 3-6% of N- and C:N ratio of 10:1 to 12:1.

Humus formation

Humic substances are produced when plant residues and other organic debris are broken down and/or chemically altered by microorganisms and subsequently recombine under the influence of enzymes. Humus formation is a complex two stage process in which organic residues of plant and animal origin undergo profound transformation.

1. The decomposition of the original components of tissues and their conversion by microorganisms in to simpler chemical compounds and partially to products of complete mineralization (CO_2, NO_2, NO_3, NH_3, CH_4, H_2O etc.)
2. The synthesis of organic compounds with the formation of high molecular weight humic substances of specific nature.

   Ex. Lignin --------------broken into polyphenols, phenolic acids

   Proteins-----------polypeptides and amino acids

   Carbohydrates ------------ simple sugars

   High molecular weights humic acids (HAs) and Fulvic acids (FAs).

Fractions of humus: Humus is mainly composed of two major groups, they are

I. Humic group
II. Non-humic group

I. Humic group: The humic substances make up about 60-80 % of the soil organic matter.

On the basis of resistance to degradation and of solubility in acids and alkalis, humic substances have been classified into five chemical groupings.

1. **Fulvic acid**: lowest in molecular weight, lightest in colour, soluble in both acid and alkali and most susceptible to microbial attack. Contain uronides, simple carbohydrates and their sugars, phenolic glycosides, tannin and other organics, also rich in N and P.
2. **Humic acid :** Medium in molecular weight and colour, soluble in alkali but insoluble in acid and intermediate in resistance to degradation forms largest bulk, responsible for importing its characteristics properties to humus.
3. **Humin:** Highest in molecular weight, darkest in colour, insoluble in both acid and alkali and most resistant to microbial attack. Polymerized product of a part of the FA and HA fractions.
4. **Apocremic acid**
5. **Hematomelanic acid**.

All the five fractions are amorphous and show no signs of crystallization.

II. Non humic group: It comprises about 20-30% of the organic matter in soils. They are less complex and less resistant to microbial attack than those of humic group. They are comprised of specific organic compounds with definite physical and chemical properties.

E.g.: a. ***Polysaccharides***- Polymers with sugar like structures. They are effective in enhancing soil

aggregates stability.

b. ***Polyuronoids***- They are not found in plants but have been synthesized by the soil

microbes and held as part of the organisms body tissues.

c. Organic acids and protein like materials.

Properties of humus

1. It is a light bulky amorphous material of dark brown to black colour. The black colour of surface soil is usually due to the presence of humus.
2. It has a great water absorbing and water holding capacity. 100 part humus-181 part of water.
3. It possesses the power of adhesion and cohesion (but less than clay) so it acts as a cementing agent in crumb formation. In Sandy soils- adhesive capacity and in clay soils – cohesive capacity increases
4. It has a high ion adsorbing capacity (4-6 times that of clay) and CEC is very high (300-350 m.eq./100gm)
5. It is insoluble in water.
6. It behaves like a weak acid and forms salts with bases.
7. It acts as buffering agent and also as an oxidation reduction buffer.
8. It serves as a source of energy and food for the development of various microorganisms.
9. An important source of nutrients for higher plants.

C: N ratio and its importance

C:N ratio?

It is defined as the ratio of the weight of organic carbon to the weight of total nitrogen in a soil or organic matter. It is the relationship between organic matter and nitrogen content of soils or plants.

$$\text{C: N ratio} = \frac{\%\ OC}{\%\ N}$$

Importance of C:N ratio

1. **C:N ratio mainly controls decomposition rate in soil**

- The wide C:N ratio leads to slow decomposition rate, nutrient immobilization may occur, carbon and energy wastage in large quantities. Activity of microorganisms restricted total amount of N is limited
- In Narrow C:N ratio, Carbon and energy starvation occur. Plant residues decompose quickly and release nitrates readily. Amount of CO_2 released/unit of carbon decomposed is less as more of it is metabolized and converted into microbial tissues.

When the residue with high C/N ratio is added to soils, there will be intense competition among the microorganism for available N.

The C/ N ratio in residues helps determine their rate of decay and the rate at which N is made available to plants.

Ex : Speed of decomposition becomes slow with more/wide C/N ratio residue or low N percentages. On the contrary low/narrow C/N ratio or high N percentages speeds the decomposition rate.

2. It is a source of food and energy for plants

Soil organisms require carbon for building essential organic compounds and to obtain energy for life process, but they must also obtain sufficient N to synthesize N containing cellular components, such as amino acids, enzymes and DNA. (Microbes need to find about 1 g of N for every 24 g of C in their food. Microbes have 8:1 ratio means – microbes must incorporate into their cells about 8 parts of carbon for every 1 part of N.

3. Influence of C/N ratio on N release: It controls N availability in soils/plants: It controls N availability in soils/plants. If C/N ratio of OM is about 25:1, the soil microbes will have to scavenge the soil solution to obtain enough N. Thus, the incorporation of high C/N residues will deplete the soil native N, causing higher plants to suffer from N deficiency. While low C/N ratio (<20) Organic matter helps in increase in N content of soil for plants and organisms.

5. **The decay of organic matter can be delayed** if sufficient nitrogen to support microbial growth is neither present in the material nor available in the soil

6. Influence of C/N ratio on Soil ecology: The soil ecosystem consists of saprophytic bacteria and fungi and nematodes, protozoa and earthworms that grow rapidly on organic residues as food source.

7. It is related to release of available N, total organic content and accumulation of humus.

C:N ratio's of some of the organic materials

1. Alfalfa 20:1
2. Microbial population 10:1
3. Soil organic matter 10-12:1
4. Maize stalk 40:1
5. Rice straw 100:1
6. Rye straw 200:1
7. Saw dust 400:1
8. Clovers (mature) 20:1
9. Soil humus 11:1

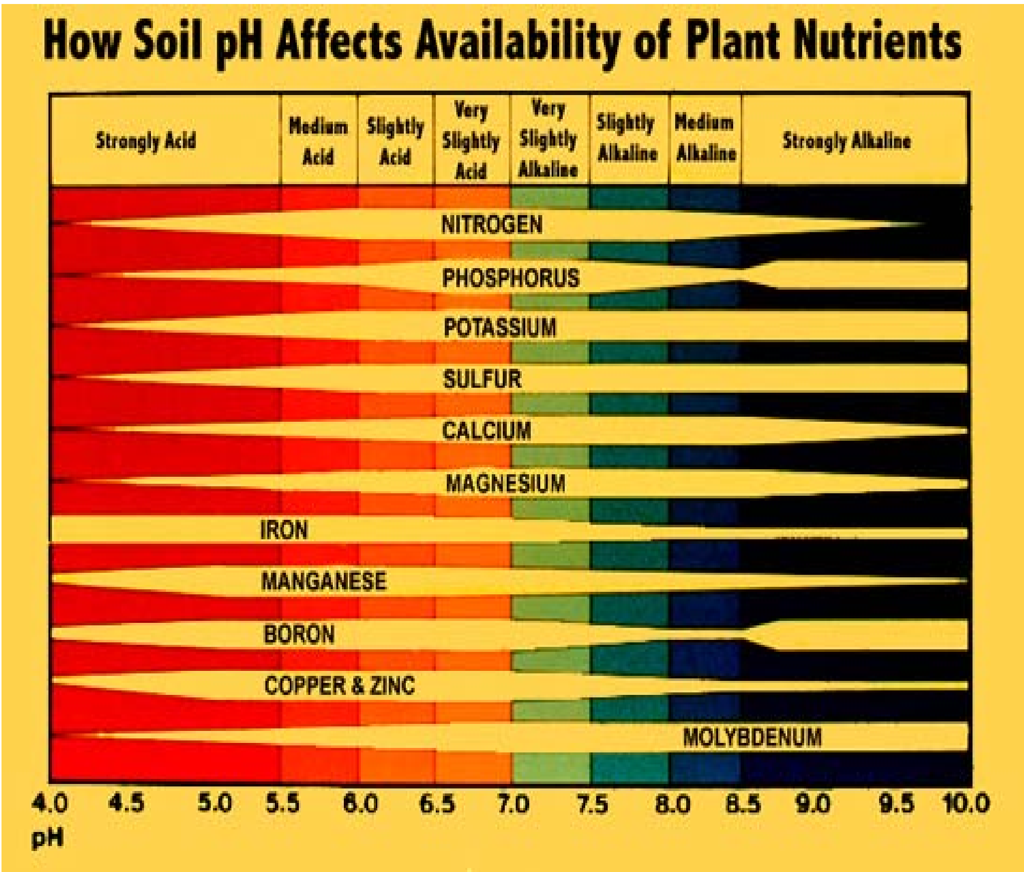
Ratio varies from about 10 for leguminous and young plant materials and >100 for cereal straws.

Importance of pH in plant nutrition

The soil pH or soil reaction is the chemical properties/characteristics of the soil showing the degree of acidity, alkalinity or neutral condition of soil. The pH is having many roles in crop production and particularly in plant nutrition.

1. It significantly influences other chemical as well as biological properties and also affect the availability of most of the chemical elements of importance to plants and microbes.
2. The soil pH greatly affects the solubility of minerals.
3. The soil pH determines the amount and type of nutrient element availability in soils.

   Eg : In strongly acidic soils (pH 4-5) usually have high and toxic concentration of soluble Al and Mn.
4. The soil pH also influences plant growth by the effect of pH on activity of beneficial microorganisms.
5. Soil pH affects the mobility of many pollutants in soil by influencing the rate of their biochemical breakdown, their solubility and adsorption to colloids.
6. Better nutrient availability found at neutral pH (6.5-7.5) like N, P, K, S, Ca, Mg but in low pH acid soil toxicity of Fe, Al, Mn etc., and deficiency of P, Mo etc. while in saline and alkaline soils Fe, Mn, Zn and Cu may be deficient. Mo availability is more.
7. It helps in recommendation of soil amendments and fertilizer applications.
8. It is a good guide for predicting which plant nutrients are likely to be deficient.
9. It determines the microbial activity and the rate of decomposition.
10. Availability and mobility of both macro and micro nutrients in soil is greatly affected by soil pH.
11. The pH level affects soil physical properties ex: dispersion of clays and formation of stable aggregate structure.
12. Suitability of soil for crop production.



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Lesson 17

Fertilizers

Definition of Fertilizer

Classification of In-organic fertilizers

I. Nitrogenous fertilizers
II. Phosphatic fertilizers
III. Potassic fertilizers
(I–III: Primary nutrient fertilizers)
IV. Secondary nutrient fertilizers
V. Micronutrient fertilizers

Fertilizer?

Fertilizers are defined as materials having definite chemical composition with a high analytical value that supply essential plant nutrients in available form. They are usually manufactured by industries and sold with a trade name. They are commonly synthetic in nature and also called as chemical fertilizers/inorganic fertilizers/commercial fertilizers other than lime and gypsum.

Most of the chemical fertilizers are inorganic in nature. The only exception to this is urea and calcium cyanamide ($CaCN_2$), the solid organic N fertilizer.

In India the use of artificial fertilizers was first initiated in 1896 when imported Chilean nitrate was used as a fertilizer.

Presently fertilizers have become an integral part of agricultural economy as they increase the fertility of soils and enable them to support high yields. About 50% of the increase in crop production during recent times has been attributed to fertilizer use; though the fertilizer use efficiency is very poor.

Classification of inorganic fertilizers

A. Based on number of nutrients present

1. Straight fertilizers: Are those fertilizers containing or supplying only one plant nutrient element at a time. For e.g., Urea, Ammonium Sulphate (NH_4SO_4), Ammonium nitrate(NH_4NO_3), Single super phosphate (SSP), Muriate of potash(MOP- KCl).

2. Complex fertilizers

Fertilizers containing at least 2 or more of the primary essential nutrients (NPK). They are chemical mixtures, granular and free flowing and easy to apply.

There are two types of complex fertilizers;

a. Complete or compound fertilizer: They are the chemical mixtures of three or more primary or major nutrient elements (NPK) in one compound or mixture. They are usually in granular form and easy to apply.

Ex: 10-26-26, 17:17:17, 19:19:19

b. Incomplete complex fertilizers: A fertilizer material lacking any one of three major nutrients or containing only two of the primary nutrients like N, P and K

Ex: N-P complex fertilizer : -Nitro-phosphate(Suphala:-15-15-0,20:20:0,
-Diammonium phosphate: 18-46-0

Characteristics of complex fertilizers (CF)

1. They usually have a high content of plant nutrients. As such they are also called **high analysis fertilizers**.
2. They usually have a uniform grain size, granular form and good physical condition during storage.

Advantage of complex fertilizers

1. In one application we can supply more nutrients and need not apply separately.
2. Balanced nutrition can be achieved.
3. Less cost is involved in transportation and application.
4. They are available in different grades according to need of the soils and crops.
5. Being granular, it is easy to apply by broadcasting.
6. Some complex fertilizers also provides some micronutrients to soil.
7. Transport and distribution is easy
8. They are non-caking and non- hygroscopic, thus safer for storage

3. Mixed Fertilisers Or Fertiliser Mixtures

A mechanical/physical mixture of two or more straight fertilizer materials in suitable proportion is referred to as fertilizer mixture or mixed fertilizers. Sometimes, complex fertilizers containing two plant nutrients are also used in formulating fertilizer mixtures. Specific fertilizer grades are recommended for specific crops depending upon the soil and climatic conditions of the region. The mixed fertilizers are usually in powder form or sometimes granular form. Fertilizer mixture (FM) are free flowing and easy to apply. The mixed fertilizers can be made according to the need of the crop and there is wide scope for adjusting the fertilizer ratio..

Guide for mixing fertilizers

Some fertilizers cannot be mixed with other fertilizers. Mixing of incompatible fertilizer leads to a loss of some of the nutrients in the form of gas, converting soluble nutrients into insoluble form or caking. Certain fundamental principles are to be followed in mixing fertilizers are.

1. Ammonium sulphate, ammonium chloride and other ammonical fertilizers and nitrogenous organic manures should not be mixed with lime.
2. Urea should not be mixed with Super phosphate(SP)
3. Calcium cyanamide, basic slag, quick lime slaked lime should not be mixed with N in NH_4-N form.
4. Super phosphate should not be mixed with lime or $CaCO_3$ or wood ashes.
5. $NaNO_3$ or KNO_3 should not be mixed with Super phosphate.
6. Ammonium sulphate, nitrate should not be mixed with lime.
7. Nitrochalk should not be mixed with SP or lime.

The commonest fertilizer mixture can be made from SSP, Ammonium sulphate, SOP, Bonemeal, and MOP.

Advantages of fertilizer mixtures

1. Less labour is required to apply fertilizer mixture to soil. Individual crop wise fertilizer mixture can be made.
2. Balanced nutrition can be achieved.
3. The residual acidity of fertilizers can be effectively controlled by adding liming materials in the mixtures.
4. Micronutrients can be incorporated in fertilizer mixtures.
5. They have a better physical condition and more easily applied.
6. There is no need of purchasing straight fertilizers separately.

Disadvantages of fertilizer mixtures

1. Does not permit application of individual nutrients according to the needs of crops during specific times.
2. The unit cost of plant nutrients is higher than of straight fertilizer.
3. Lack of knowledge about proper mixing and their use.
4. Fertilizer mixture of particular grade suitable for particular crop cannot be applied for all crops.

B. Classification of fertilizers based on particular plant nutrient element: The element forms their principal constituent in the fertilizer.

1. Nitrogenous fertilizers
2. Phosphatic fertilizers
3. Potassic fertilizers

(1–3: Primary nutrient fertilizers)

4. Secondary nutrient fertilizers
5. Micronutrient fertilizers.

I. Nitrogenous fertilizers: There are 6 groups.

a. <u>Ammonium fertilizers</u>

i. Ammonium sulphate $(NH_4)_2 SO_4$ – 20% N

ii. Ammonium chloride : NH_4Cl_2 -24-26%

iii. Ammonium phosphate : $NH_4H_2 PO_4$ -20%N + 20% P_2O_5 or 16% N and 20% P_2O_5

iv. Anhydrous ammonium (82%N)

v. Ammonium solution- 20-25%N

vi. Ammonium carbonate- 21-24%N

vii. Ammonium bicarbonate- 17%N

b. <u>Nitrate fertilizers</u>

i. Sodium nitrate or Chilean nitrate : $NaNO_3$ – 16%N

ii. Calcium nitrate: $CaNO_3$ – 15.5% N

iii. Nitrophosphate

c. <u>Both Ammonium and nitrate fertilizers</u>

i. Ammonium nitrate: NH_4NO_3- 33-34%N

ii. Calcium ammonium nitrate (CAN) – 25, 26 and 28% N

iii. Ammonium sulphate nitrate (ASN) – 26%N

d. Amide fertilizers

i. Urea – 46% N

ii. Calcium cyanamide- 21 %N

iii. Urea phosphate

iv. Urea sulphate

e. Nitrogen solutions

i. Anhydrous ammonia

ii. Aqueous ammonia

iii. Solution containing one or more of the following urea, ammonium nitrate, ammonia

f. Slowly available nitrogenous fertilizers

i. Urea formaldehyde compounds

ii. Neem Cake coated Urea NCU

iii. Lac Coated Urea(LCU)

iv. Sulphur Coated Urea(SCU)

v. Urea super granules (USG)

vi. Prilled urea (PU)

II. Phosphatic fertilizers.

They are broadly classified into 3 major groups on the basis of their solubility either in water or in citrate or citric acid.

a. **Water soluble phosphatic fertilizers** (Contain phosphoric acid or mono calcium phosphate. Ex;

1. Single Super phosphate (SSP)- 16-18 % P_2O_5
2. Triple super phosphate (TSP) – 46-48 % P_2O_5
3. Double super phosphate (DSP)- 32% P_2O_5
4. Di-Ammonium phosphate (DAP)- 18%N and 46% P containing dicalcium phosphate

b. **Citric acid soluble phosphatic fertilizers**

1. Dicalcium phosphate (DCP) - 34-39% P_2O_5

2. Rhenamia phosphate- 23-26% P_2O_5

3. Basic slag- 14-18% P_2O_5

4. Raw or steamed bone meal- part of P_2O_5 soluble in citric acid.

5. Fused calcium magnesium phosphate- 16.5% P_2O_5

c. **Water insoluble or citric acid insoluble phosphatic fertilizers**. Containing tricalcium phosphate ($Ca_3(PO_4)_2$]

Ex: Rock phosphate- 20-40% P_2O_5

Raw bone meal- 20-25% P_2O_5

Steamed bone meal- 22% P_2O_5

Pyrophos - 17% P_2O_5

III. Potassic Fertilizers

A. Fertilizers having K in the Chloride form

1. Muriate of Potash (MOP) – KCl- 60-62 % K_2O

B. Fertilizers having K in Non-chloride form

1. Sulphate of potash (SOP) -K_2SO_4: 48-52% K_2O
2. Potassium nitrateKNO_3 - 44% K_2O

IV. Secondary Nutrient Fertilizers

Secondary elements are as important as primary elements because they help in uptake of primary elements by plants. They are required in very little quantity as compared to primary elements. The most important secondary nutrients are Ca, Mg and S. The fertilizers carrying secondary nutrients are;

1. Calcium cyanamide(39.57% Ca)

2. Calcium Ammonium Nitrate (8.0% Ca & 4.5% Mg)

3. Calcium nitrate (1.5% Mg)

4. Super phosphate (20.0% Ca)

5. Bone meal (23.1% Ca)

6 Limestone (32.58% Ca)

7. Dolomite (20.0% Mg)

8 Gypsum (29.40% Ca & 21.0% S)

9. Potassium sulphate18.5% S & 0.6 to 0.9% Mg)

10. Ammonium sulphate (24% S)

V. Micronutrient Fertilizers

Micronutrients are those which required by plants in very minute quantities by plants but they have equal role as that of primary nutrients. They govern most of the physiological as well as biochemical reactions of plant growth and development. The most important micronutrients are iron, manganese, zinc, copper, molybdenum, chlorine, boron and nickel. The fertilizers carrying micronutrients are;

Fe carrying fertilizers

1. Ferrous sulphate(19.0% Fe)
2. Ferric sulpahte(23.0% Fe)
3. Ferrous ammonium sulphate(29.0%Fe)
4. Ferric and ferrous oxide70.0 and 77.0% Fe)

Boron carrying fertilizers

1. Borax(11.0% B)
2. Boric acid(17.0% B)
3. Sodium tetra borate(14.0% B)
4. Borosite(21.0% B)

Manganese carrying fertilizers

1. Manganese sulphate (20.0 to 28.0% Mn)
2. Manganese carbonate (31.0% Mn)
3. Manganese chloride(17.0% Mn)

Zinc carrying fertilizers

1. Zinc sulphate (55.0% Zn)
2. Zinc oxide (67.0% Zn)
3. Zinc sulphide (67.0% Zn)

4. Zinc ammonium sulphate(33.5% Zn)

Molybdenum carrying fertilizers

1. Sodium molybdate (39.0% Mo)
2. Ammonium molybdate (54.0% Mo)

Copper carrying fertilizers: Copper sulphate.

Reference: Soil Fertility and Nutrient Management by S. S. Singh

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