

01. Manures – types, composition and value – sources

There are many ways of classifying the fertilizers and manures, the classification being based on one or two properties of the materials.

Nature of source

- 1.Natural manures
- 2.Artificial manures
- 3.Mineral manures

Nutrient content

- 1.Single manures
- 2.Compound manures

Nutrient element present

- 1.Complete manures
- 2.Incomplete manures

Nature of the materials

- 1.Organic manures
- 2.Inorganic manures
- 3.Indirect manures

Nature of action

- 1.General manures
- 2.Special manures
- 3.Stimulative substances
- 4.Soil amendments or soil conditioners

Critical consideration of the above-mentioned classification reveals that none of the classification is satisfactory. Each of the classification is based on only one property and may not be suitable to cover wide range of materials.

They are generally classified in to Bulky organic manure and concentrated organic manures

ORGANIC MANURES

The word manure derived from the French "Manoeuvrer", means to manipulate, to work, to produce crop. In general manure means excreta of animals. The term bulky organic manure generally includes those materials of natural origin, organic in composition having greater volume per unit content of nutrients and being used to

increase the nutrient status of the soils as well as organic matter content of soils. They are obtained mainly as natural products. The materials included in this group are farmyard manure, compost, sewage sludge and green manure. Of these FYM, compost and green manure are the most important and widely used bulky organic manures.

Farm Yard Manure (FYM)

The FYM refers to the refuse from farm animals, mainly sheep, cattle and poultry. This is one of the oldest manure known and is highly valued for its many of the beneficial properties that are said to be produced when this manure is added to the soil. It not only adds the constituents to the soil but also adds organic matter to the soil.

Composition of farm manure

Several factors influence the composition of farm manure and they are the following

1. Source of manure
2. Feed of the animals
3. Age of the animals
4. Condition of the animals
5. Manner of storage and handling
6. Litter use etc.,

On an average the composition of FYM is usually 0.5 % N, .25 % P_2O_5 and 0.5 % K_2O .

Methods of collection

Many methods of collecting the cattle manure are in vogue and this include,

1. Use of ordinary cattle shed with kacha floor
2. Use of cattle shed with impermeable floor and provision for collecting urine in separate urine pit
3. Dry earth system
4. Loose box system
5. Other special methods

The method of collection and storage is the most important factor which decides the final composition of the manure. The following are recognized methods of storing FYM

1. The heap method

2. The pit method

Various losses during collection and storage of FYM can be prevented or atleast minimized by adopting the following procedures

1. Better methods of collection
2. Better methods of storage
3. Use of cow dung gas plant
4. Use of chemical preservatives like gypsum, superphosphate etc

Organic Wastes :

Organic wastes are the wastes of biological / animal / agro-industry origin and can be converted to valuable manure by composting. The various organic wastes can be classified as follows,

Sources of Organic Wastes			
<i>Agriculture</i>	<i>Animal Husbandry</i>	<i>Agro-industries</i>	<i>Municipal Activities</i>
* Crop residues (paddy straw, sugacane trash etc) * Weeds	* Dairy * Goat / Sheep * Poultry * Piggery	* Sugar Industry (Pressmud) * Coir Industry (Ciorpith) * Fruits / vegetables processing industries * Sago Industry	* Household / municipal solid waste * Market waste (Vegetable/ fruit / flower market)

02. Green manures-Oilcakes-Sewage sludge-Biogas plant slurry-Plant and animal refuges

GREEN MANURES

Green manure:

Growing the plants *in-situ* and incorporation in the field.

Green leaf manure

Addition of green or plant tissues obtained from elsewhere *viz.*, trees, herbs, shrubs pruning and unwanted weeds.

Benefit of Green manure or Green leaf manures

- a. Addition of organic matter.
- b. Adds Nutrient – Macro, Secondary and micro nutrients.
- c. It improves physical condition of soil.
- d. Act as a soil amendment to reclamation of problem soils.
- e. It act as a cover or catch crop to prevent soil erosion, conserve moisture, prevent nutrient leaching.
- f. Leguminous crops fix the atmospheric – N by the roots and improves N status of the soil.

Characteristics of Green manure

1. It should have rapid growth and shorter duration so that can be fitted in a crop rotation
2. It should yield abundant biomass and should be succulent to have rapid decomposition
3. It should have the ability to grow on poor soils.

Nutrient content of agricultural wastes

Agricultural wastes	N	P ₂ O ₅	K ₂ O
Sugarcane Begasse	0.25	0.12	0.20
Sugarcane Begasse compost	1.40	0.45	0.60
Sugarcane Begasse Press mud	1 – 1.5	2.0	-

Press mud – compost	1.5	1.5	-
Saw dust	Traces	0.2 0.25	-
Tobacco waste	0.5 – 1.0	0.8	1.0
Tobacco seed cake	4 – 4.5	7 – 15	5 – 5.5
Tea waste	2.8 – 3.6	0.3 – 0.4	1 – 2
Cotton dust	1 – 1.5	-	-
Textile waste	1 – 1.5	-	-

Nutrient content of Commonly used Concentrated manures

Oil cake	N	P2O5	K2O
Groundnut cake (Decordicated)	7.8	1.5 – 1.9	1.4
Lin seed cake	5.5	1.4	1.2
Mustard cake	4.5	1.5	1.0
Neem cake	5.2	1.0	1.4
Niger cake	4.8	1.8	1.0
Pungam cake	2.5	1.0	1.0
Safflower (decordicated)	7.8	2.2	2.0
Sesamum	6.2	2.0	1.2
Castor	5.8	1.8	1.0
Coconut	3.2	1.8	1.7

Slaughter House wastes

Wastes	N	P2O5	K2O
Blood meal	10 – 12	1.2	1.0
Meat meal	10.5	2.5	0.5
Fish meal	4 -10	3 – 9	0.3 – 1.5
Horn – Hoff meal	13	-	-

Leather - waste	7	0.1	0.2
Hair and wool waste	12.3	0.1	0.3
Sewage water	25ppm	5 ppm	15 ppm
Sludge	1.5 – 3.5	0.75 – 4	0.3 – 0.6

Nutrients content of Commonly used Green manures

Green manure	N %	P2O5%	K2O %
Sunhemp	0.5	0.1	0.4
Danicha	1.1	0.2	0.4
Sesbania	0.7	0.1	0.6
Pelli pesera	0.7	0.2	0.4
Cluster bean	0.3	0.1	0.3
Cow pea	0.7	0.2	0.6
Green leaf manure			
Kolungi	0.7	0.1	0.4
Calotropis	0.3	0.1	0.6
Pungam	1.2	0.2	0.8
Glyricidia	0.8	0.1	0.7
Puvarasu	0.8	0.2	0.9

Guano - Birds Excreta or bat Dung

Guano	2.6	4.2	0.6
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03. Composting of organic wastes – composting technologies

COMPOSTING OF ORGANIC WASTES

Composting is a process of allowing organic materials to decompose more or less controlled conditions to produce stabilized product that can be used as a manure or soil amendment. Composting is basically a microbial process, which change the property of the organic material or mixtures.

Compost is the material resulting from the decomposition of plant residues under the action of bacteria and fungi. Composting is simply an acceleration of natural process or organic matter mineralization. The final product is dark brown in colour and resembles FYM in its properties and appearance.

Essential requirements for composting

- A bulky organic manure
- A suitable starter
- Addition of enough water
- Aeration

Main systems of composting

- ADCO process (Hutchinson and Richards of England)
- Activated compost process (Fowler and Rege)
- The Indore process (Howard and Wad)
- The Bangalore process (C.N.Acharya)
- The coimbatore method

Benefits of composting:

- * Enables clean environment
- * Absorbs odors, degrade toxic substances and heavy metals
- * Avoids un-necessary dumping of wastes
- * Supply valuable organic manure

Composting technologies

1. Crop residue composting

- Collect the available crop residues and weeds
- Shred them to a size of 2 to 2.5 cm length
- Mix these wastes with green residues (freshly collected), if available
- Form the compost heap (4 feet height)
- Add the bio-inoculants (2 kg of bio-mineralizer or 40 kg of cowdung for 1 tonne of waste)

- Properly aerate the compost either by providing perforated PVC pipes or by mechanical turning
- Maintain the moisture at 60 % by regular watering
- The compost will mature in 60 days

2. Vermi-composting

Vermicomposting is a process of degradation of organic wastes by earthworms. The species like *Eisenia foetida* and *Eudrilus eugeniae* are effective in converting the agricultural wastes into compost. The various steps involved in making vermicompost are as follows

Methods followed:

Heap method

Pit method – aboveground and belowground

Belowground method pit size : 10 X 1 X 0.3 m

Each layer : 6-7cm thick

Sprinkle water once in 8-10 days

Release : 2-2.5 kg worms / pit

Steps:

Collect the predigested wastes and mix cattle dung @ 30 %.

Place it in the pit/container layer by layer

Moist the residues at 60 % moisture

Allow the verms in to the feed material / residues @ 1 kg/ tonne of residue

Protect the pit or container from ants and rats (which are the enemies of verms)

The residue will be composted in 30 to 40 days

Remove the composted materials layer by layer at a weekly interval so as

To avoid any damage /disturbance to the feeding verms.

Nutritive value of vermicompost

The nutrients content in vermicompost vary depending on the waste materials that is being used for compost preparation. If the waste materials are heterogeneous one, there will be wide range of nutrients available in the compost. If the waste materials are homogenous one, there will be only certain nutrients are available. The common available nutrients in vermicompost is as follows

Organic carbon = 9.5 – 17.98%

Nitrogen = 0.5 – 1.50%

Phosphorous = 0.1 – 0.30%

Potassium = 0.15 – 0.56%

Sodium = 0.06 – 0.30%

Calcium and Magnesium = 22.67 to 47.60 meq/100g

Copper = 2 – 9.50 mg kg⁻¹

Iron = 2 – 9.30 mg kg⁻¹

Zinc = 5.70 – 11.50 mg kg⁻¹

Sulphur = 128 – 548 mg kg⁻¹

3. Coirpith composting

Coirpith is an agricultural waste produced from the coir industry. Approximately 180 grams of coirpith is obtained from the husk of one coconut. Coirpith contains Carbon : Nitrogen in the ratio of 112:1 and contains 75 per cent lignin which does not permit natural composting as in other agricultural wastes.

Mushroom *Pleurotus* has the capacity to degrade part of the lignin present in coirpith by production of enzymes like cellulases and lactases. The carbon: nitrogen ratio of coirpith is reduced from 112:1 to 24:1 as a result of composting.

Composting method

Select a shaded place of 5 x 3 m dimension and level it after removing weeds. Spread 100 kg of coirpith uniformly. Spread 100 g of *Pleurotus* spawn on this and cover with a second layer of 100 kg of coirpith. On the surface of the second layer, spread one kg of urea uniformly.

Repeat this sandwiching of one layer of coirpith with spawn followed by another layer of coirpith with urea up to one metre height.

Sprinkle water to keep the heap moist. Allow the heap to decompose for one month.

Manure conversion

The coirpith is converted into good manure after 30 to 40 days and the lignin content is reduced from 40 per cent to 30 per cent. The nitrogen content is increased from 0.20 per cent to 1.06 per cent. Coirpith compost contains macronutrients and micronutrients. It can absorb water up to eight times its weight. Coirpith, when added to sandy soil at 2 per cent increases the water holding capacity up to 40 per cent. It can be applied to a wide variety of crops and can be used to prepare potting mixture and can be applied as organic manure in kitchen gardens.

4. Composting of crop residues and weeds:

Composting is one of the useful ways for utilizing the some of the weeds and noncommercial plants like *Parthenium*, Water hyacinth, *Ipomoea* etc. instead of their eradication. The plants can be composted using *Trichoderma viridi* and *Pleurotus sajor-caju* as a microbial consortium with supplementation of urea. Select an elevated shady area of a thatched shed and mark an area of 5x1.5 meter. Cut the composting materials into 10 – 15 cm size. Spread 100 kg of these materials over the marked area. Sprinkle 1 bottle of microbial consortia over this layer. Again spread another 100 kg of composting materials over this layer. Spread 1 kg of urea uniformly over this layer. Likewise repeat these processes of spreading composting materials, then microbial consortia, again composting materials followed by urea application until a minimum of 1-meter height is reached. Sprinkle water to attain a moisture level of 50% to 60%. The surface of the heap is covered with a thin layer of soil. Water should be sprinkled depending upon the necessity to maintain the moisture around 50%. A turning is given at the end 20 days to give a thorough mixing of outside material with that of the inside ones. The bio-converted compost will be ready in about 40 days time.

5. Method of composting the Municipal Solid Wastes

Biodegradable municipal solid waste should be separated and collected for composting. Five hundred kg of material should be heaped in the compost yard. In that heaped waste, 1 kg of TNAU microbial consortium should be applied in the form of slurry to cover the full waste material. This 1 kg microbial consortium can be mixed with 5 litres of water to make slurry. This slurry is sufficient to cover 0.5 tonne of material. Then, 50 kg of cowdung should be mixed with 30 litre of water to form cowdung slurry. This cowdung slurry should be sprayed over the heap of municipal solid waste. Then, 1 kg of urea should be mixed with solid waste. 60% moisture should be maintained through out the period of composting. Compost should be turned up once in 15 days to create good aeration, and for thorough mixing. Because of this practice, a uniform composted material will be obtained. Solid waste can be composted with in 90 days by this method with the indication of reduction in the volume, appearance of dark coloured materials and a small of earthy odour. After the completion of composting, compost should be sieved through normal mesh to separate unwanted and partially composted material.

6. Value addition of poultry waste compost

A known quantity of poultry droppings and coir pith @ 4:5 ratio should be mixed well to attain a C/N ratio of 25:1 to 30:1 which is considered to be the optimum C/N ratio

for composting. *Pleurotus sajor-caju*, a lignocellulolytic organism, should be inoculated into the mix @ 2 packets per tonne of waste in order to speed up the composting process. The mix should be heaped under the shade. The moisture content of the mix should be maintained within 40 – 50%. Periodical turning should be given on 21st, 28th and 35th day of composting. Another two packets of *Pleurotus sajor – caju* is to be added when turning is given on the 28th day of composting. A good quality compost will be obtained in 45 days, which contains 2.08% N, 1.93 % P and 1.41 % K with C/N ratio of 10-16

7. Enriched Farm Yard Manure (EFYM)/ Reinforced FYM

Phosphorus content in FYM is relatively low and complete utilization of nitrogen and potassium in the manure is seldom realized. Hence, heavy quantities intended to supply the needed quantity of phosphorus will result in wastage of nitrogen in most soils. To overcome this P insufficiency, addition of superphosphate to the manure is recommended and the process is called reinforcing / enriching and the resultant material is called “enriched farmyard manure”. The Single Super Phosphate (SSP) can be sprinkled either in the cattle shed or on the manure heap. Rock phosphate can also be recommended for this purpose.

Factors affecting the Composting Process

- I. The Type and Composition of the Organic Waste
- II. The Availability Of Microorganism
- III. Aeration
- IV. The C, N and P Ratios
- V. Moisture Content
- VI. Temperature
- VII. pH
- VIII. Time

Preparation of Coir Waste Compost Using Yeast Sludge:

Yeast sludge is a waste product by alcohol distilleries @ 2t/day. This waste contain 6% N, 0.3% P and 0.9% K with other micronutrients, vitamins and growth promoting substances. The coir waste should be sieved so as to remove all the fibrous materials. For one tone of coir waste 200 kg of yeast sludge and 10 kg of rock phosphate should be added and mixed thoroughly. Moisture should be maintained at 60%. After mixing the material should be formed as heap. Within 4-5 days the temperature of the heap will be raised to 50-60° C. Within 40 to 50 days the coir waste and yeast sludge will become as mature compost. The matured compost will turn from

brown to black. There will not be any odor. The volume of the compost heap will be reduced to 1/3. The temperature of the heap will be 25-30°C and it should be constant. The compost will be very light and fine textured. The compost prepared by this means of above method contains N-1.09%, P-1.35%, K-1.95% besides copper, manganese, iron and zinc. This compost doesn't have any phytotoxicity and used for all agricultural crops.

C. Preparation of sugarcane trash compost using yeast sludge:

sugarcane trash collected from sugarcane field has to be cut into small bits using chaff cutter or shredder to a size of 1-2cm. for every tone of sugarcane trash 200 kg of yeast sludge and 10kg of rock phosphate are added and mixed thoroughly. Moisture is maintained at 60%. the heap is formed to a height of 1-1½ m. within 45-50 days sugarcane trash compost will be ready for application to crops. The sugarcane trash compost consists of N-1.2%, P-0.7%, K-1.5% and considerable quantities of micronutrients. This compost can be applied at the rate of 5t/ha.

d. Japanese method of composting:

Instead of pits in conventional composting system, vats of 18-30' in length, 3-4' in width and 2.5-3.0' height are made of bamboo stakes of 2.5-3.0' width. For growth a non-leaky surface is prepared with broken stone stable or brick and plastered with cement. About 2 feet space is kept free on one side of the vat to facilitate turning the residues regularly. Sliced and broken pieces of coconut, shells, leaves, fibrous materials, tender tree barks or pieces form the bottom 10-15 cm layer. Second layer of dry leaves, grass residues, groundnut haulms are of 10-15 cm height. Cow dung, urine, biogas slurry are sprinkled over and this layer of soil and ash is spread over. Nitrogen rich green leaves of pongamia, albizzia, daincha, sesbania and crop residues forms third layer of 10-15 cm. Fourth layer of 10-15cm contains organic wastes rich in phosphorous and potash. Over these 2-3 buckets of cow dung and biogas slurry are sprinkled. Fifth layer contains paddy or ragi straw that is rich in carbon and provides energy for microorganisms. Sixth layer contains exclusively of dried and powdered cow dung of 20-30cm. Over these small quantities of old compost, tank silt and ash are sprinkled. For rapid degradation *Aspergillus*, *Penicillium*, *Trichoderma* should be inoculated. *Pleurotus* and *Polyporus* should be inoculated for degradation of high lignin contained residues. *Azotobacter* and Phosphobacteria can be mixed for enriching the composts.

General Properties Of Commercially Accepted Compost.:

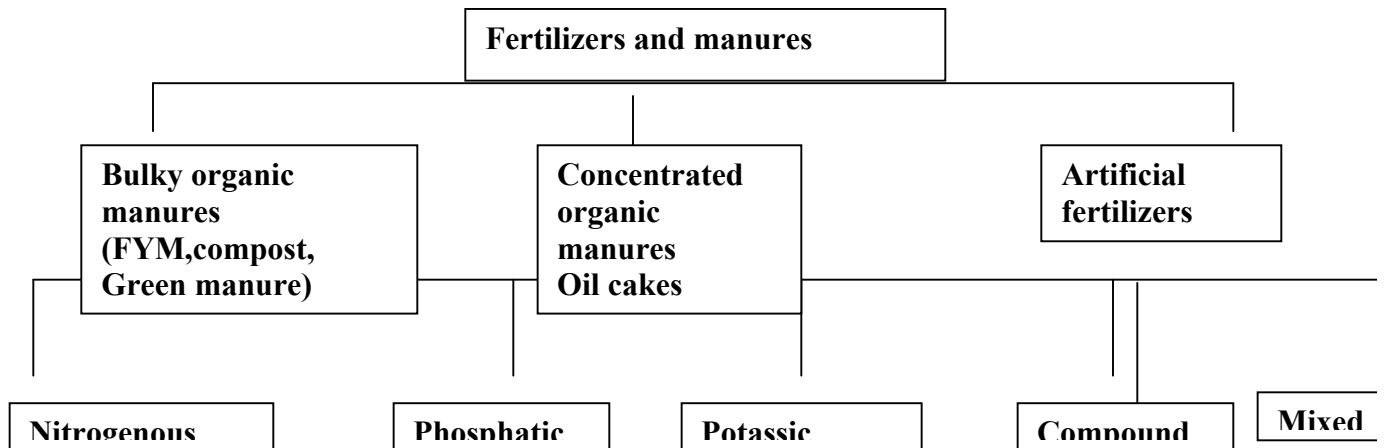
N %	>2	Color	Brown Black
C: N	<20	Odor	Earthy
Ash %	10-20	Water Holding Capacity (%)	150-200

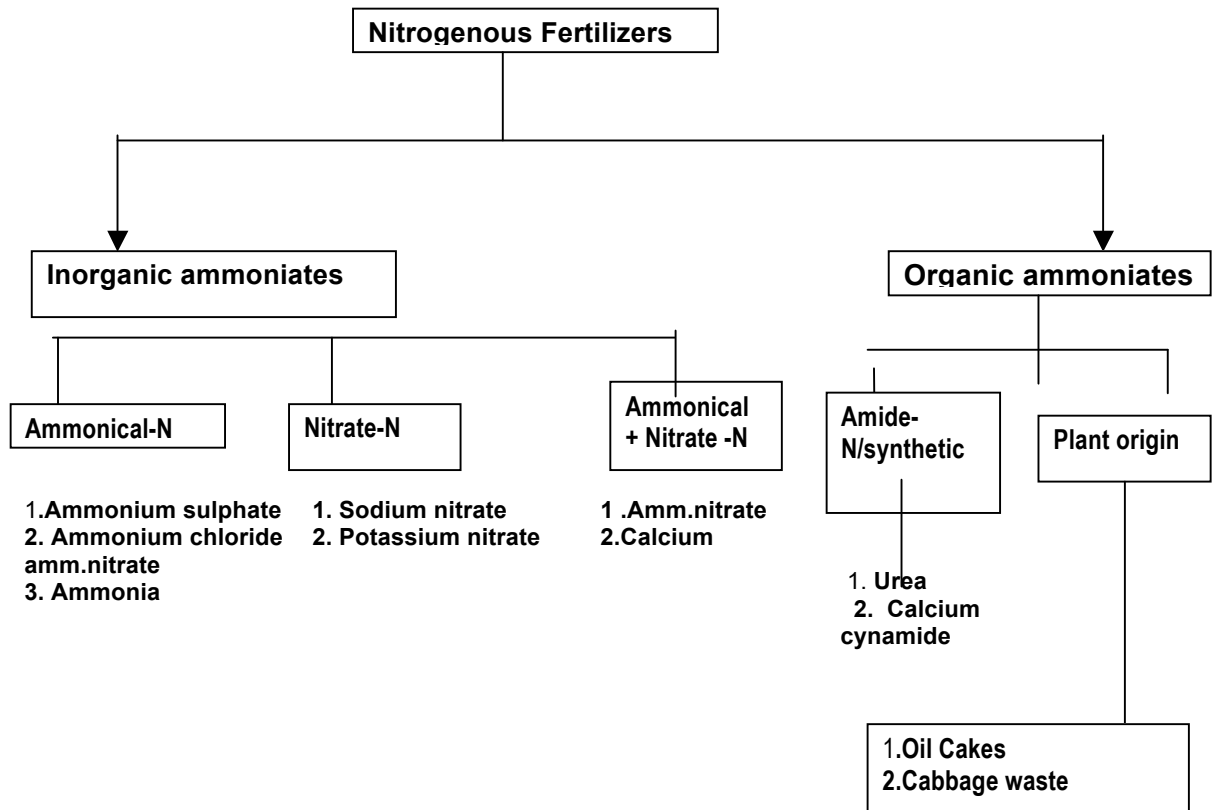
Moisture %	10-20	CEC (Meq 100 g ⁻¹)	75-100
P %	0.15-1.5	Reducing Sugar (%)	<35%

04. Classification of fertilizers – N, P and K fertilizers

Classification of fertilizers

Commercial N, both organic and inorganic is desired from a wide variety of materials which are found to differ very widely in their sources, properties, method of preparation and their reactions in the soil. Classification based on chemical form seems to be more satisfactory as indicated below.

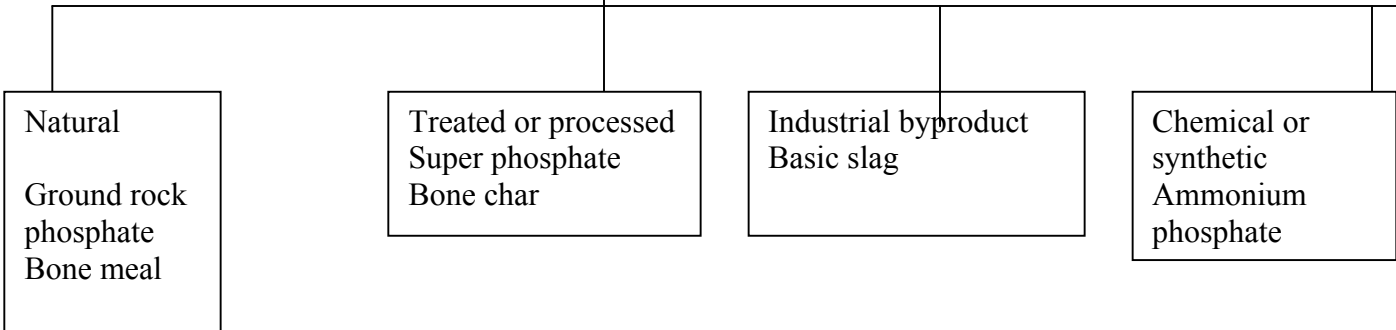




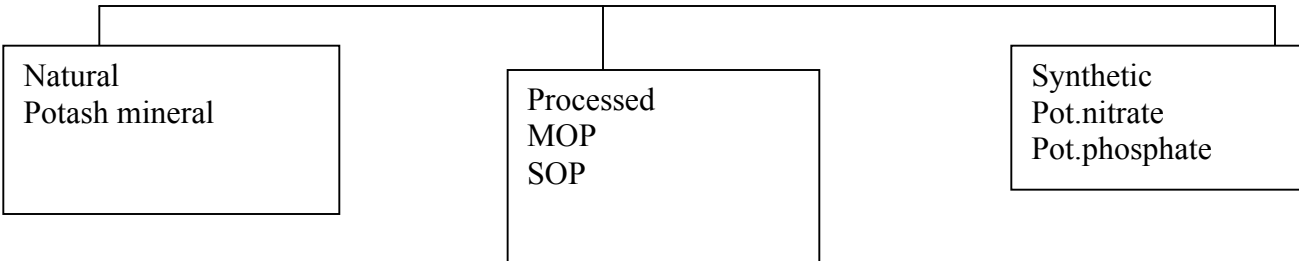
The nitrogen content of different nitrogenous fertilizers is given below

Sl.No	Name of the fertilizer	N content (%)	Form of N
1	Sodium nitrate (NaNO ₃)	16.0	Nitrate (NO ₃)
2	Potassium nitrate (KNO ₃)	12.5-13.5	Nitrate
3.	Ammonium sulphate (NH ₄) ₂ SO ₄	20.6	NH ₄ (Ammonia)
4.	Ammonium chloride (NH ₄ Cl)	26.0	NH ₄
5.	Ammophos - A	11.0	NH ₄
6.	Ammophos – B	16.0	NH ₄
7.	Ammonium Nitrate (NH ₄)	33.0	NH ₄ – 16.5 NO ₃ – 16.5
8.	Ammonium sulphate nitrate	25.6	NH ₄ – 19.5 NO ₃ – 6.6
9.	Urea (CO (NH ₂) ₂)	46.0	Amide
10.	Calcium cyan amide (CaCN ₂)	20.6	Amide
11.	Dried blood	3-14	Protein(organic)
12.	Groundnut cake	8.0	Protein(organic)
13.	Meat meal	09.0-11.	Protein (organic)
14.	Guano	10.0	Protein (organic)

PHOSPHATIC FERTILIZERS



POTASSIC



13. SECONDARY AND MICRONUTRIENT FERTILIZERS-Manufacturing of Zinc sulphate and Ferrous sulphate

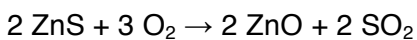
Zinc

Zinc is the fourth most common metal in use, trailing only iron, aluminium, and copper with an annual production of about 12 million tonnes.[14] The world's largest zinc producer is [Nyrstar](#), a merger of the Australian [OZ Minerals](#) and the Belgian [Umicore](#). [74] About 70% of the world's zinc originates from mining, while the remaining 30% comes from recycling secondary zinc. [] Commercially pure zinc is known as Special High Grade, often abbreviated *SHG*, and is 99.995% pure.

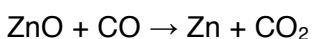
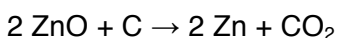
Worldwide, 95% of the zinc is mined from [sulfidic](#) ore deposits, in which sphalerite ZnS is nearly always mixed with the sulfides of copper, lead and iron. [77] There are zinc mines throughout the world, with the main mining areas being China, Australia and Peru. China produced 29% of the global zinc output in 2010.

Zinc metal is produced using [extractive metallurgy](#). [78] After grinding the ore, [froth flotation](#), which selectively separates minerals from [gangue](#) by taking advantage of differences in their [hydrophobicity](#), is used to get an ore concentrate. [78] A final concentration of zinc of about 50% is reached by this process with the remainder of the concentrate being sulfur (32%), iron (13%), and SiO₂ (5%). [78]

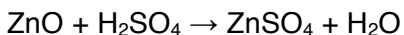
[Roasting](#) converts the zinc sulfide concentrate produced during processing to zinc oxide: [77]



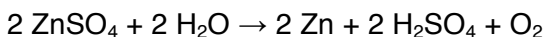
The sulfur dioxide is used for the production of sulfuric acid, which is necessary for the leaching process. If deposits of zinc carbonate, zinc silicate or zinc spinel, like the [Skorpion Deposit](#) in Namibia are used for zinc production the roasting can be omitted. For further processing two basic methods are used: [pyrometallurgy](#) or [electrowinning](#). Pyrometallurgy processing reduces zinc oxide with [carbon](#) or [carbon monoxide](#) at 950 °C (1,740 °F) into the metal, which is distilled as zinc vapor. [80] The zinc vapor is collected in a condenser. [77] The below set of equations demonstrate this process



Electrowinning processing leaches zinc from the ore concentrate by [sulfuric acid](#)



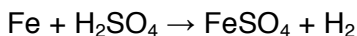
After this step [electrolysis](#) is used to produce zinc metal.[77]



The sulfuric acid regenerated is recycled to the leaching step.

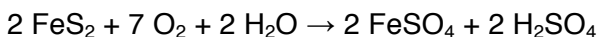
Ferrous Sulfate

In the finishing of [steel](#) prior to plating or coating, the steel sheet or rod is passed through [pickling baths](#) of sulfuric acid. This treatment produces large quantities of iron(II) sulfate as a by-product.[2]



Another source of large amounts results from the production of [titanium dioxide](#) from [ilmenite](#) via the sulfate process.

Ferrous sulfate is also prepared commercially by oxidation of pyrite:



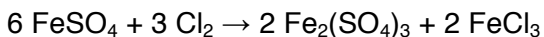
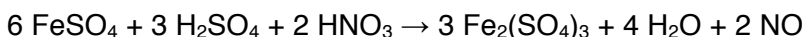
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Reactions

On heating, iron(II) sulfate first loses its [water of crystallization](#) and the original green crystals are converted into a dirty-yellow anhydrous solid. When further heated, the anhydrous material releases [sulfur dioxide](#) and white fumes of [sulfur trioxide](#), leaving a reddish-brown iron(III) oxide. Decomposition of iron(II) sulfate begins at about 480 °C.

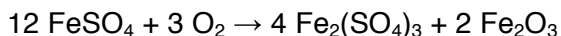


Like all iron(II) salts, iron(II) sulfate is a reducing agent. For example, it reduces nitric acid to nitrogen oxide and chlorine to chloride:



Ferrous sulfate outside [titanium dioxide](#) factory in Kaanaa, [Pori](#).

Upon exposure to air, it oxidizes to form a corrosive brown-yellow coating of basic ferric sulfate, which is an adduct of [ferric oxide](#) and [ferric sulfate](#):



15. Mixed fertilizers – sources – preparations- their compatibility – advantages

Mixed fertilizers

For over hundred years the mixed fertilizers are in use besides straight fertilizers. Many fertilizer mixtures are made available now and this account for a major portion of the consumption of N, P and K. Present day statistics show that numerous grades of fertilizers mixtures are manufactured and the fertilizer mixing industry is being considered as one of the major agro- industry.

The following are some of the common term frequently used in the mixed fertilizer industry.

Fertilizer : The substance which is used for the supply of plant nutrients

Mixed fertilizer : A mixture of more than one straight fertilizer which can supply more than one plant nutrient element

Complete fertilizer : A single fertilizer material containing the entire three major plant nutrients viz, N, P and K

Fertilizer grade : This refers to the minimum guarantee with regard to the nutrient content of the fertilizer mixture in terms of N, P and K.

Fertilizer formula : This related to the quantitative expression of the analysis of the different ingredients included in the mixed fertilizer in terms of N, P and K.

Fertilizer ratio : This indicates the relative percentage of N, P_2O_5 and K_2O in the manure mixture.

Acidic fertilizer : Fertilizer capable of increasing the acidity of the soil by continued applications.

Basic fertilizer : Fertilizers which increase the pH and the soil on continued use by leaving a basic residue in the soil.

Neutral fertilizer : Materials which are neither increasing nor decreasing the pH of the soil

Filler : It is called as the 'make-weight' material added to the fertilizer mixtures. Filler materials are inert materials like sand, saw dust etc, are added to make up the difference between weight of ingredients added to supply the plant nutrients in a tonne and the final weight viz., 1,000 kg.

Advantages

All the three major plant nutrients are made available in one and the same material. There is saving of time and labour. The residual effects will not be there. The fertilizer mixtures are usually prepared taking into account the acidic or alkaline nature of the ingredients, and other chemical reactions. Hence, some of the residual effects like acidity

will not be there. Usually mixed fertilizer are prepared to suit a group of crops and soils.

Disadvantages

- Specific needs of crops and deficiency of individual nutrient elements cannot be satisfied by using mixed fertilizers as efficiently as in the case of straight fertilizers.
- The use of mixed fertilizer in such cases of specific needs will be a waste as other nutrients are also added to the soil.
- Unit cost of the various nutrients contained in the mixed fertilizer will always be higher when compared to the unity cost of nutrients contained in the straight fertilizers.

Improper mixing and storage of fertilizers can result in large nutrient losses. Some important aspects to consider in fertilizer mixing and storage include the following:

- Urea should not be mixed with ammonium calcium nitrate (CAN), KCl, SSP or TSP.
- Urea can be mixed with most other fertilizers but fertilizer mixtures containing urea should be applied immediately after mixing. Do not store fertilizer mixtures containing urea.
- Ammonium phosphates and super phosphates should not be mixed with lime, slag, rock phosphate or CAN.
- Potassium chloride and sulfate of potash can be mixed with most fertilizers, but mixtures of these fertilizers with urea and calcium ammonium nitrate should not be stored.
- CAN should not be mixed with basic slag but can be mixed with urea, single superphosphate, and ammonium phosphates immediately prior to application.

Do not store fertilizers in damp or dirty places. Make sure that bags of fertilizer in the store do not absorb moisture from leaky roofs or water seepage through walls and floors.

Preparation of mixed fertilizers

Many kinds of materials are used in the manufacture of fertilizer mixtures. The materials are found to be highly varying in their properties. However, only a limited number of materials are being used like $(\text{NH}_4)_2\text{SO}_4$, $\text{CO}(\text{NH}_2)_2$, Super phosphate, ammonium phosphate, muriate of potash, limestone, gypsum and some fillers.

The manufacture of fertilizer mixtures usually involves the weighing and proportioning of ingredients that are used, sieving and sizing of the various ingredients, mixing the different materials and packing. All the above operations are done both mechanically and by hand operation. Different kinds of machineries are being used.

Guide for mixing

To determine the amount of individual fertilizer in a mixture, the quantity is calculated as follows.

$$\frac{\text{(Percentage of plant nutrient desired x (Weight of final mixture))}}{\text{in the mixture}}$$

Quantity =

(The Percentage of the plant nutrient in the straight fertilizer)

$$A = \frac{R \times T}{P}$$

R = Percentage in the mixture

T = Final weight of the mixture

P = Percentage in the straight fertilizer.

To prepare a mixture of 10: 5: 10 using $(\text{NH}_4)_2\text{SO}_4$, (20% N), Super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), the following quantities will be required per tonne (1,000 kg).

$$1. \text{ Ammonium sulphate} = \frac{10 \times 1000}{20} = 500 \text{ Kg.}$$

$$5 \times 1000$$

2. Super phosphate	=	$\frac{\quad\quad\quad}{16}$	= 312.5 Kg.
3. Muriate of potash	=	$\frac{10 \times 1000}{60}$	= 166.5 Kg.
		Total	$\underline{\quad\quad\quad} = \underline{979.0 \text{ Kg}}$

Filler = 1000 – 979 = 21 Kg.

If the total calculated weight exceeds the final weight, a mixture of that ratio can not be prepared.

Changes that occur while manufacturing mixed fertilizer

The ingredients used in fertilizer mixtures vary widely in their physical and chemical characteristics. When such widely varying materials in physical and chemical properties are mixed together, naturally many changes are expected to take place during or after the mixing. Some changes will be of physical nature and some will be of chemical nature. The following are the most important physical changes that will take place during or after the mixing of fertilizers.

Hygroscopicity

It is a property of any substance which absorbs from air and gets converted to semi- solid or liquid condition. Fertilizer like $\text{Ca}(\text{NO}_3)_2$, NH_4NO_3 , NaNO_3 and $\text{CO}(\text{NH}_2)_2$ are capable of absorbing moisture from air and become hygroscopic. In such cases handling will be very difficult for such mixtures.

Caking up

Moisture present in some of the ingredients is responsible for caking up. Moisture dissolves some of the easily soluble ingredients and forms a saturated solution. This saturated solution on evaporation gives out crystals which knit together forming larger lumps.

The caking up can be prevented by the use of certain kind of materials called as ‘conditioners’. The commonly used conditioners are groundnut hulls, lime, clay etc. Another way of preventing the caking up is manufacture of granulated fertilizer mixture.

The granulation aims at preparation of uniform sized particles with reasonable stability, which presents caking up.

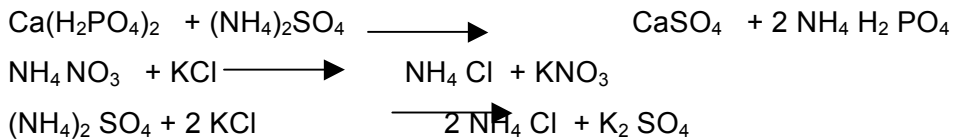
Segregation

This relates to separation of different sized particles individually. When ingredients of different sizes and densities are included there will be the tendency for the segregation (sorting out to different sizes) to take place. To prevent this bad effect, granulation is conveniently followed.

The following are some of the most important chemical changes that take place either during or after the manufacture of fertilizers mixtures. These changes are found to be influenced by temperature, moisture content and particle size of the ingredients.

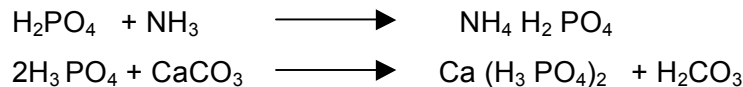
(a) Double decomposition

The reaction is between two compounds without a common ion in the presence of moisture. New compounds are formed which may have different physical and chemical properties.



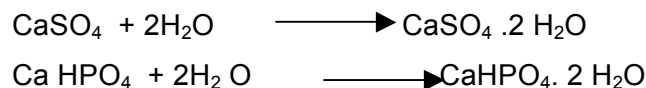
(b) Neutralization

This reaction takes place when free acids present in some of the fertilizers are neutralized by alkalis or Ca containing salts included in the mixture.



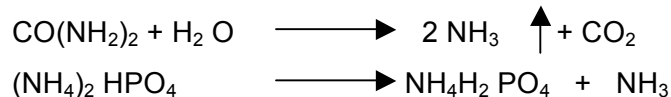
(c) Hydration

The process of tying up of water by the anhydrous form of salts is called hydration. Some of the fertilizers are found to have this property.



(d) Decomposition

Under certain conditions of moisture and temperature, there will be break down in the composition of molecules forming new compounds.



However, the following important principles must be taken into consideration while preparing mixed fertilizers.

1. All fertilizers containing ammonia are not mixed directly with the basic fertilizers (e.g. RP, limestone, basic slag, CaCN_2) as reaction will take place resulting in the loss of gaseous NH_3 .
2. The water – soluble phosphates are not mixed with those materials which contain free lime (e.g) lime stone, CaCN_2) as there will be reaction towards the reversing of water – soluble phosphate to water – insoluble phosphates.
3. Hygroscopic fertilizers are not included as they will facilitate caking up.
4. The acidic fertilizers are likely to produce some free acids which may damage the container or packing materials.

Manufacturing process

The principal steps in the manufacture of solid mixed fertilizers are calculating, weighing, sieving, sizing, mixing the materials and packing the product.

Calculating and weighing

With a good weighing device the calculated quantities of the various ingredients are weighed accurately for preparing mixtures.

(1) Sieving and sizing

If the raw materials have undergone too much of caking in the storage piles, it may be necessary to subject them to preliminary grinding, sieving and sizing. The raw materials must be converted into uniform sized particles to have effective making and to avoid segregation during subsequent handling.

(2) Mixing

Many kinds of fertilizer mixing machines have been proposed and used at present. Rotary drum type is found to be more common than the vertical cylinder type. Weighed quantities of different materials are introduced into the mixer and mixed thoroughly.

(3) Packing

Equipments for packing fertilizer mixture range from the simplest types of hand operated facilities to highly sophisticated automatic machines.

Granular mixtures

Compared to pulverized or powdered mixture, the advantages of granular mixtures are reduced caking up tendency, less dusting loss and easy handling. Of late, attention is found in the manufacture of only granular mixtures.

19.FERTILIZERS CONTROL ORDER (FCO) 1985

ORDER

Under the Essential Commodities Act, 1955 (10 of 1955), the Central Government makes the Fertilizers (Control) Order, 1985. It shall come into force on the date of its publication in the Official Gazette. In this Order, some of the definitions are used

Act means the Essential Commodities Act, 1955 (10 of 1955).

"certificate of source" means a certificate given by a State Government, Commodity Board, manufacturer, + importer, pool handling agency

Commodity Board means the Coffee Board constituted under section 4 of the Coffee Act, 1942 (7 of 1942) or the Rubber Board constituted under section 4 of the Rubber Act, 1947 (24 of 1947)

compound or complex fertilizers means a fertilizers containing two or more nutrients during the production of which chemical reaction takes place

controller means the person appointed as Controller of Fertilizers by the Central Government and includes any other person empowered by the Central Government to exercise or perform all or any of the powers, of the Controller under this Order.

"dealer" means a person carrying on the business of selling fertilizers whether wholesale or retail or industrial use* and includes a manufacturer, +Importer, and a pool handling agency carrying on such business and the agents of such person, manufacturer, +importer or pool handling agency.

fertilizer means any substance used or intended to be used as a fertilizer of the soil and/or crop and specified in Part A of Schedule I and includes a mixture of fertilizers and special mixture of fertilizers.

"grade" means the nutrient element contents in the fertilizer expressed in percentage

"granulated mixture" means a mixture of fertilizers made by intimately mixing two or more fertilizers with or without inert material, and granulating them together, without involving any chemical reaction.

"importer" means a person who imports fertilizers in accordance with the Export and Import Policy of the Central Government, as amended from time to time.

inspector" means an Inspector of Fertilizers appointed under clause 27.

"manufacturer" means a person who produces fertilizers or mixtures of fertilizers and the expression "manufacture" with its grammatical variations shall be construed accordingly.

"mixture of fertilizers" ***means a mixture of fertilizers made by physical mixing two or more fertilizers with or without inert material in physical or granular form and includes a mixture of NPK fertilizers, a mixture of micronutrient fertilizers and a mixture of NPK with micronutrient fertilizers.

"physical mixture" means a mixture of fertilizers made by physically mixing two or more fertilizers with or without inert material necessary to make a required grade, without involving any chemical reaction.

"prescribed standard" means-in relation to a fertilizers included in column 1 of Part A of Schedule-I, the standard set out in the corresponding entry in column 2, subject to the limits of permissible variation as specified in Part B of that Schedule

PRICE CONTROL-Fixation of prices of fertilizers

The Central Government may, with a view to regulate equitable distribution of fertilizers and making fertilizers available at fair prices, by notification in the Official Gazette, fix the maximum prices or rates at which any fertilizers may be sold by a dealer, manufacturer, +importer or a pool handling agency. The Central Government may consider the local conditions of any area, the period of storage of fertilizers and other relevant circumstances, fix different prices or rates for fertilizers having different periods of storage or for different areas or for different classes of consumers. No dealer, manufacturer +importer or pool handling agency shall sell or offer for sale any fertilizers at a price exceeding the maximum price or rate fixed under this clause.

Display of stock position and price list of fertilizers

Every dealer, who makes or offers to make a retail sale of any fertilizers, shall prominently display in his place of business:-**the quantities of opening stock of different fertilizers** held by him on each day & a list of prices or rates of such fertilizers fixed under clause 3 and for the time being in force.

Issue of cash/credit memorandum

Every dealer shall issue a cash or credit memorandum to a purchaser of a fertilizers in FormM*

CONTROL ON DISTRIBUTION OF FERTILIZERS BY MANUFACTURER/ IMPORTER

Allocation of fertilizers to various States

The Central Government may, with a view to secure equitable distribution and availability of fertilizers to the farmers in time, by notification in the Official Gazette, direct any manufacturer/importer to sell the fertilizers produced by him in such quantities and in such State or States and within such period as may be specified in the said notification.

AUTHORISATION OR REGISTRATION OF DEALERS”

Registration of Industrial dealers and authorization of other dealers

No person shall sell, offer for sale or carry on the business of selling of fertilizer at any place as wholesale dealer or retail dealer except under and in accordance with clause 8:

Application for intimation or registration

Every person intending to sell or offer for sale or carrying on the business of selling of fertilizer as Industrial Dealer shall obtain a certificate of registration from the controller by making an application in Form A together with the fee prescribed While, a manufacturer, an importer, a pool handling agency, wholesaler and a retail dealer intending to sell or offer for sale shall make a Memorandum of Intimation to the Notified Authority, in Form A1 duly filled in, in duplicate, together with the fee prescribed under clause 36 and certificate of source in Form O. On receipt of a Memorandum of Intimation, complete in all respects, the Notified Authority shall issue an acknowledgement of receipt in Form A2 and it shall be deemed to be an authorization letter granted and the concerned person as authorised dealer for the purposes of this Order.

A certificate of registration granted before the commencement of the Fertilizers (Control) Amendment Order, 2003, shall be deemed to be an authorization letter granted under the provisions of this Order: when the applicant is a State Government, a manufacturer or an importer or a pool-handling agency, it shall not be necessary for it or him to submit Form O.

Grant or refusal of certificate of registration

The Controller, shall grant a certificate of registration in Form 'B' within thirty days of the receipt of application to any person who applies for it under clause 8; no certificate of registration shall be granted to a person: -if his previous certificate of registration is under suspension; or it has been cancelled within a period of one year immediately preceding the date of application; or if he has been convicted of an offence under the Act, or if he fails to enclose with the application a certificate of source ; or if the application is incomplete in any respect;

Period of validity of certificate of registration and letter of authorization

Every certificate of registration granted, **be valid for a period of three years from the date of its issue.**

Renewal of certificates of registration and authorization letters

Every holder of a certificate of registration granted make an application for renewal to the Controller, in Form C, or to the Notified Authority in Form A1, respectively, in duplicate, together with the fee prescribed under clause 36 for such renewal and a certificate of source as required under clause 8.

Manufacture of Mixtures of Fertilizers - Restriction on preparation of mixtures of fertilizer

No person shall carry on the business of preparing any mixture of fertilizers. or special mixture of fertilizers except under and in accordance with the terms and conditions of a certificate of manufacture granted to him under clauses 15 or 16.

Standards of mixtures of Fertilizers

Subject to the other provisions of the order, no person shall manufacture any *mixture of fertilizers whether of solid or liquid fertilizers unless such mixture conforms to the standards set out in the notification to be issued by the Central Government in the Official Gazette;

Application for certificate of manufacture of mixtures of fertilizers

Every person desiring to obtain a certificate of manufacture for preparation of any mixture of fertilizers or special mixture of fertilizers shall possess such mixture, *and possess the minimum laboratory facility as specified in clause 21A of this Order. An applicant shall make an application to the registering authority if he is an applicant for a certificate of **manufacture for any mixture of fertilizers** in Form D, in duplicate, together with the fee prescribed there for under clause 36; or, if he is an applicant for a certificate of manufacture for any **special mixture, in Form E, in duplicate**, together with the fee prescribed there for under the said clause 36 and an attested copy of the requisition of the purchaser.

Grant or refusal of certificate of manufacture for preparation of mixtures of fertilizers

On receipt of an application under clause 14, the registering authority shall, by order in writing, grant or refuse **within forty-five days from the date of receipt of the application, furnish to the applicant a copy of the order so passed;** to the applicant in Form G

Period of validity of a certificate of manufacture for preparation of mixtures of fertilizers

Every certificate of manufacture granted under clause 15 for preparation of a mixture of fertilizers shall, unless suspended or cancelled, be valid for a period of three years from the date of issue.

Renewal of certificate of manufacture for preparation of mixtures of fertilizers

Every holder of a certificate of manufacture for preparation of a mixture of fertilizers desiring to renew the certificate, shall, before the date of expiry of the said certificate of manufacture make an application to the registering authority in Form D in duplicate, together with the fee prescribed for this purpose under clause 36.

Manufacturers/Importers pool handling agencies to comply with certain requirements in regard to packing and marking, etc.2

Every manufacturer/importer and pool handling agency shall, in regard to packing and marking of containers of fertilizers, comply with the following requirements, namely:-Every container in which any fertilizers is packed shall conspicuously be Superscribed with the word "FERTILIZERS" and shall bear only such particulars in case of containers the gross weight of which is 5 kg or less, no such printing of superscription and other particular shall be necessary

if such super superscription and other particulars are printed on a separate label which is securely affixed to such container. in case fertilizer bags are in cut, torn or damaged condition during transportation or is handling during loading or unloading operation, the manufacturer of such fertilizer may, under intimation to the State Government and the Central Government, repack the fertilizer in new bags or restandardise the quantity in terms of declared weight. Every fertilizers bag in which any fertilizers is packed for sale shall be of such weight and size as may be specified by the Central Government from time to time in this behalf

Manufacturers to comply with certain requirements for laboratory facilities:-

Every manufacturer shall, in order to ensure quality of their product, possess minimum laboratory facility, as may be specified from time to time by the Controller.

Disposal of non-standard fertilizers

Notwithstanding anything contained In this Order, a person may sell, offer for sale, stock or exhibit for sale or distribute, [any fertillser except any fertillser imported by the Central Government] which, not being an adulterated fertilizers, does not conform to the prescribed standard (hereinafter in this Order referred to as non-standard fertilizers) subject to the conditions that:- the container of such non-standard fertilizers is conspicuously super scribed in red colour with the words "non-standard" and also with the sign "X"; and an application for the disposal of non-standard fertilizers in Form H is submitted to the [Notified authority] to grant a certificate of authorization for sale of such fertilizers and a certificate of authorization with regard to their disposal and price is obtained in Form such non-standard fertilizers shall be sold only to the manufacturers of mixtures of fertilizers or special mixtures of fertilizers or research farms of Government or Universities or such bodies. The price per unit of the non-standard fertilizers shall be fixed by the notified authority If a manufacture or importer detects or as reasonable doubt about the standard of the fertilizer manufactured or imported by him, and dispatched for sale as deteriorated in quality during transit due to natural calamity and is not of the prescribed standards, he may, within fifteen days from the date of dispatch from factory or port, apply with detailed justifications to the Central Government for obtaining permission for reprocessing the same in a factory to meet the prescribed standards and the Central Government may, after considering the facts, permit the re-processing of such fertilizer on the terms and conditions as may be notified by the Central Government in this behalf.

ENFORCEMENT AUTHORITIES

Appointment of registering authority The State Government may, appoint such number of persons, as it thinks necessary, to be registering authorities for the purpose of this Order for industrial dealers, and may, define the limits of local area within which each such registering authority shall exercise his jurisdiction.

Notified Authority- The State Government may, appoint such number of persons, to be Notified Authorities for the purpose of this Order and define the local limits within which each such Notified Authority shall exercise his jurisdiction.

Appointment of inspectors-The State Government, or the Central Government may, by notification in the Official Gazette appoint such number of persons, to be inspectors of fertilizers for the purpose of this Order, and may, in any such notification, define the limits of local area within which each such inspector shall exercise his jurisdictions.

Qualifications for appointment of fertilizers Inspectors

No person shall be eligible for appointment as Fertilizers Inspector under this Order unless he possesses the following qualifications, namely:-Graduate In agriculture or science with chemistry as one of the subjects, from a recognized university; and Training or experience in the quality control of fertilizers and working in the State or Central Government Department of Agriculture.

Powers of Inspectors

An inspector may, with a view to securing compliance with this Order:- require any manufacturer, +importer, pool handling agency, wholesale dealer or retail dealer to give any information in his possession with respect to the manufacture, storage and disposal of any fertilizer manufactured or, in any manner handled by him draw samples of any fertilizers in accordance with the procedure of drawal of samples laid down in Schedule II. Provided that the inspector shall prepare the sampling details in duplicate In Form J, and hand over one copy of the same to the dealer or his representative from whom the sample has been drawn; enter upon and search any premises where any fertilizers is manufactured/ Imported or stored or exhibited for sale,; seize any books of accounts or documents relating to manufacture, storage or sale of fertilizers, etc. in respect of which he has reason to believe that any contravention of this

Order has been or is being or is about to be committed; Where any fertilizers is seized by an inspector under this clause, he shall forthwith report the fact of such seizure to the collector whereupon the provisions of sections 6A, 6B, 6C, 6D and 6E of the Act, shall apply to the custody, disposal and confiscation of such fertilizers. Every person, if so required by an inspector, shall be bound to afford all necessary facilities to him for the purpose of enabling him to exercise his powers under sub-clause (1).

ANALYSIS OF SAMPLES

Laboratory for analysis

A fertilizer sample, drawn by an inspector, shall be analyzed in accordance with the instructions contained in Schedule II in the **-Central Fertilizers Quality Control and Training Institute, **Faridabad or Regional Fertilizers Control Laboratories at Bombay, Madras or Kalyani (Calcutta)** or in any other laboratory notified for this purpose by the State Government [with the prior approval of the Central Government. Every laboratory in order to ensure accurate analysis, of fertilizers samples, possess minimum equipment and other laboratory facilities, as may be specified from time to time by the Controller in this behalf

Qualifications for appointment of fertilizers analyst in the fertilizer control laboratories

No person shall be eligible for appointment as fertilizers analyst for analysis of fertilizers samples in the laboratories notified under clause 29 of the Order, unless he possesses the following qualifications, namely:-graduate in Agriculture or Science with chemistry as one of the subjects from a recognized university; and training In fertilizers quality control and analysis at **Central Fertilizer Quality Control and Training Institute, Faridabad.** Provided that the fertilizers analysts appointed before the commencement of this Order, who do not possess the requisite training, shall undergo prescribed training, within a period of three years, in the Central Fertilizers Quality Control " and Training Institute, Faridabad from the date of commencement of this Order.

Laboratories for referee analysis

Every laboratory referred to in sub-clause (1) of clause 29 shall be designated as referee laboratory for the purpose of analysis of any sample of fertilizers : Provided that no such laboratory which carried out the first analysis of the fertilizers sample shall be so designated in respect of that sample: Further in respect of any sample the analysis of which has been challenged, may be sent for referee analysis to any one of the other laboratories except those which are located in the State or where the first analysis has been done. Central Fertilizers Quality Control and Training Institute and Regional laboratories shall be considered as one group of laboratories and a sample first analysed by any one of them, shall not be sent for referee analysis to any other in that group, but only to any other laboratory notified by a State Government.

Time limit for analysis, and communication of result

Where sample of a fertilizer has been drawn, the same shall be dispatched along with a memorandum in Form K to the laboratory for analysis within a period of seven days from the date of its drawl. The laboratory shall analyze the sample and forward the analysis report in Form L within [30 days] from the date of receipt of the sample in the laboratory to the authority specified in the said memorandum.

The authority to whom the analysis report is sent under sub-clause (2) shall communicate the result of the analysis to the dealer/manufacturer/Importer/pool handling agency from whom the sample was drawn within [15 days] from the date of receipt of the analysis report of the laboratory.

Maintenance of records and submission of returns, etc.

The controller may by an order made in writing direct the dealers. manufacturers/ importers, and pool handling agencies:- to maintain such books of accounts, records, etc. relating to their business in Form 'N'. and to submit to such authority, returns and statements in such form and containing such information relating to their business and within such time as may be specified in that order. Where a person holds certificates of registration for retail sale and wholesale sale of fertilizers, he shall maintain separate books of accounts for these two types of sales made by him.

Fees

The fees payable for grant, amendment or renewal of an authorization letter or certificate of registration or certificate of manufacture a duplicate of such certificates or, renewal thereof

under this Order shall be such as the State Government may, from time to time fix, subject to the maximum fees fixed for different purposes by the Central Government and different fees may be fixed for different purposes or for different classes of dealers or for different types of mixtures of fertilizers or special mixture. Any fee paid under sub-clause (1) shall not be refundable unless the grant or renewal of any certificate of registration or certificate of manufacture or duplicate copy of such certificate or renewal under this Order has been refused.

The fees payable for grant, amendment, renewal or duplicate copy of certificate of registration for industrial dealer and the authority to whom and the manner in which such fee shall be paid, shall be such as may be specified by the Controller from time to time by notification in the Official Gazette*

01. Manures – types, composition and value – sources

There are many ways of classifying the fertilizers and manures, the classification being based on one or two properties of the materials.

Nature of source

1. Natural manures
2. Artificial manures
3. Mineral manures

Nutrient content

1. Single manures
2. Compound manures

Nutrient element present

1. Complete manures
2. Incomplete manures

Nature of the materials

1. Organic manures
2. Inorganic manures
3. Indirect manures

Nature of action

1. General manures
2. Special manures
3. Stimulative substances
4. Soil amendments or soil conditioners

Critical consideration of the above-mentioned classification reveals that none of the classification is satisfactory. Each of the classification is based on only one property and may not be suitable to cover wide range of materials.

They are generally classified into Bulky organic manure and concentrated organic manures

ORGANIC MANURES

The word manure derived from the French "Manoeuvrer", means to manipulate, to work, to produce crop. In general manure means excreta of animals. The term bulky organic manure generally includes those materials of natural origin, organic in composition having greater volume per unit content of nutrients and being used to

increase the nutrient status of the soils as well as organic matter content of soils. They are obtained mainly as natural products. The materials included in this group are farmyard manure, compost, sewage sludge and green manure. Of these FYM, compost and green manure are the most important and widely used bulky organic manures.

Farm Yard Manure (FYM)

The FYM refers to the refuse from farm animals, mainly sheep, cattle and poultry. This is one of the oldest manure known and is highly valued for its many of the beneficial properties that are said to be produced when this manure is added to the soil. It not only adds the constituents to the soil but also adds organic matter to the soil.

Composition of farm manure

Several factors influence the composition of farm manure and they are the following

1. Source of manure
2. Feed of the animals
3. Age of the animals
4. Condition of the animals
5. Manner of storage and handling
6. Litter use etc.,

On an average the composition of FYM is usually 0.5 % N, .25 % P_2O_5 and 0.5 % K_2O .

Methods of collection

Many methods of collecting the cattle manure are in vogue and this include,

1. Use of ordinary cattle shed with kacha floor
2. Use of cattle shed with impermeable floor and provision for collecting urine in separate urine pit
3. Dry earth system
4. Loose box system
5. Other special methods

The method of collection and storage is the most important factor which decides the final composition of the manure. The following are recognized methods of storing FYM

1. The heap method

2. The pit method

Various losses during collection and storage of FYM can be prevented or atleast minimized by adopting the following procedures

1. Better methods of collection
2. Better methods of storage
3. Use of cow dung gas plant
4. Use of chemical preservatives like gypsum, superphosphate etc

Organic Wastes :

Organic wastes are the wastes of biological / animal / agro-industry origin and can be converted to valuable manure by composting. The various organic wastes can be classified as follows,

Sources of Organic Wastes			
<i>Agriculture</i>	<i>Animal Husbandry</i>	<i>Agro-industries</i>	<i>Municipal Activities</i>
* Crop residues (paddy straw, sugacane trash etc) * Weeds	* Dairy * Goat / Sheep * Poultry * Piggery	* Sugar Industry (Pressmud) * Coir Industry (Ciorpith) * Fruits / vegetables processing industries * Sago Industry	* Household / municipal solid waste * Market waste (Vegetable/ fruit / flower market)

02. Green manures-Oilcakes-Sewage sludge-Biogas plant slurry-Plant and animal refuges

GREEN MANURES

Green manure:

Growing the plants *in-situ* and incorporation in the field.

Green leaf manure

Addition of green or plant tissues obtained from elsewhere *viz.*, trees, herbs, shrubs pruning and unwanted weeds.

Benefit of Green manure or Green leaf manures

- a. Addition of organic matter.
- b. Adds Nutrient – Macro, Secondary and micro nutrients.
- c. It improves physical condition of soil.
- d. Act as a soil amendment to reclamation of problem soils.
- e. It act as a cover or catch crop to prevent soil erosion, conserve moisture, prevent nutrient leaching.
- f. Leguminous crops fix the atmospheric – N by the roots and improves N status of the soil.

Characteristics of Green manure

1. It should have rapid growth and shorter duration so that can be fitted in a crop rotation
2. It should yield abundant biomass and should be succulent to have rapid decomposition
3. It should have the ability to grow on poor soils.

Nutrient content of agricultural wastes

Agricultural wastes	N	P ₂ O ₅	K ₂ O
Sugarcane Begasse	0.25	0.12	0.20
Sugarcane Begasse compost	1.40	0.45	0.60
Sugarcane Begasse Press mud	1 – 1.5	2.0	-

Press mud – compost	1.5	1.5	-
Saw dust	Traces	0.2 0.25	-
Tobacco waste	0.5 – 1.0	0.8	1.0
Tobacco seed cake	4 – 4.5	7 – 15	5 – 5.5
Tea waste	2.8 – 3.6	0.3 – 0.4	1 – 2
Cotton dust	1 – 1.5	-	-
Textile waste	1 – 1.5	-	-

Nutrient content of Commonly used Concentrated manures

Oil cake	N	P2O5	K2O
Groundnut cake (Decordicated)	7.8	1.5 – 1.9	1.4
Lin seed cake	5.5	1.4	1.2
Mustard cake	4.5	1.5	1.0
Neem cake	5.2	1.0	1.4
Niger cake	4.8	1.8	1.0
Pungam cake	2.5	1.0	1.0
Safflower (decordicated)	7.8	2.2	2.0
Sesamum	6.2	2.0	1.2
Castor	5.8	1.8	1.0
Coconut	3.2	1.8	1.7

Slaughter House wastes

Wastes	N	P2O5	K2O
Blood meal	10 – 12	1.2	1.0
Meat meal	10.5	2.5	0.5
Fish meal	4 -10	3 – 9	0.3 – 1.5
Horn – Hoff meal	13	-	-

Leather - waste	7	0.1	0.2
Hair and wool waste	12.3	0.1	0.3
Sewage water	25ppm	5 ppm	15 ppm
Sludge	1.5 – 3.5	0.75 – 4	0.3 – 0.6

Nutrients content of Commonly used Green manures

Green manure	N %	P2O5%	K2O %
Sunhemp	0.5	0.1	0.4
Danicha	1.1	0.2	0.4
Sesbania	0.7	0.1	0.6
Pelli pesera	0.7	0.2	0.4
Cluster bean	0.3	0.1	0.3
Cow pea	0.7	0.2	0.6
Green leaf manure			
Kolungi	0.7	0.1	0.4
Calotropis	0.3	0.1	0.6
Pungam	1.2	0.2	0.8
Glyricidia	0.8	0.1	0.7
Puvarasu	0.8	0.2	0.9

Guano - Birds Excreta or bat Dung

Guano	2.6	4.2	0.6
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03. Composting of organic wastes – composting technologies

COMPOSTING OF ORGANIC WASTES

Composting is a process of allowing organic materials to decompose more or less controlled conditions to produce stabilized product that can be used as a manure or soil amendment. Composting is basically a microbial process, which change the property of the organic material or mixtures.

Compost is the material resulting from the decomposition of plant residues under the action of bacteria and fungi. Composting is simply an acceleration of natural process or organic matter mineralization. The final product is dark brown in colour and resembles FYM in its properties and appearance.

Essential requirements for composting

- A bulky organic manure
- A suitable starter
- Addition of enough water
- Aeration

Main systems of composting

- ADCO process (Hutchinson and Richards of England)
- Activated compost process (Fowler and Rege)
- The Indore process (Howard and Wad)
- The Bangalore process (C.N.Acharya)
- The coimbatore method

Benefits of composting:

- * Enables clean environment
- * Absorbs odors, degrade toxic substances and heavy metals
- * Avoids un-necessary dumping of wastes
- * Supply valuable organic manure

Composting technologies

1. Crop residue composting

- Collect the available crop residues and weeds
- Shred them to a size of 2 to 2.5 cm length
- Mix these wastes with green residues (freshly collected), if available
- Form the compost heap (4 feet height)
- Add the bio-inoculants (2 kg of bio-mineralizer or 40 kg of cowdung for 1 tonne of waste)

- Properly aerate the compost either by providing perforated PVC pipes or by mechanical turning
- Maintain the moisture at 60 % by regular watering
- The compost will mature in 60 days

2. Vermi-composting

Vermicomposting is a process of degradation of organic wastes by earthworms. The species like *Eisenia foetida* and *Eudrilus eugeniae* are effective in converting the agricultural wastes into compost. The various steps involved in making vermicompost are as follows

Methods followed:

Heap method

Pit method – aboveground and belowground

Belowground method pit size : 10 X 1 X 0.3 m

Each layer : 6-7cm thick

Sprinkle water once in 8-10 days

Release : 2-2.5 kg worms / pit

Steps:

Collect the predigested wastes and mix cattle dung @ 30 %.

Place it in the pit/container layer by layer

Moist the residues at 60 % moisture

Allow the verms in to the feed material / residues @ 1 kg/ tonne of residue

Protect the pit or container from ants and rats (which are the enemies of verms)

The residue will be composted in 30 to 40 days

Remove the composted materials layer by layer at a weekly interval so as

To avoid any damage /disturbance to the feeding verms.

Nutritive value of vermicompost

The nutrients content in vermicompost vary depending on the waste materials that is being used for compost preparation. If the waste materials are heterogeneous one, there will be wide range of nutrients available in the compost. If the waste materials are homogenous one, there will be only certain nutrients are available. The common available nutrients in vermicompost is as follows

Organic carbon = 9.5 – 17.98%

Nitrogen = 0.5 – 1.50%

Phosphorous = 0.1 – 0.30%

Potassium = 0.15 – 0.56%

Sodium = 0.06 – 0.30%

Calcium and Magnesium = 22.67 to 47.60 meq/100g

Copper = 2 – 9.50 mg kg⁻¹

Iron = 2 – 9.30 mg kg⁻¹

Zinc = 5.70 – 11.50 mg kg⁻¹

Sulphur = 128 – 548 mg kg⁻¹

3. Coirpith composting

Coirpith is an agricultural waste produced from the coir industry. Approximately 180 grams of coirpith is obtained from the husk of one coconut. Coirpith contains Carbon : Nitrogen in the ratio of 112:1 and contains 75 per cent lignin which does not permit natural composting as in other agricultural wastes.

Mushroom *Pleurotus* has the capacity to degrade part of the lignin present in coirpith by production of enzymes like cellulases and lactases. The carbon: nitrogen ratio of coirpith is reduced from 112:1 to 24:1 as a result of composting.

Composting method

Select a shaded place of 5 x 3 m dimension and level it after removing weeds. Spread 100 kg of coirpith uniformly. Spread 100 g of *Pleurotus* spawn on this and cover with a second layer of 100 kg of coirpith. On the surface of the second layer, spread one kg of urea uniformly.

Repeat this sandwiching of one layer of coirpith with spawn followed by another layer of coirpith with urea up to one metre height.

Sprinkle water to keep the heap moist. Allow the heap to decompose for one month.

Manure conversion

The coirpith is converted into good manure after 30 to 40 days and the lignin content is reduced from 40 per cent to 30 per cent. The nitrogen content is increased from 0.20 per cent to 1.06 per cent. Coirpith compost contains macronutrients and micronutrients. It can absorb water up to eight times its weight. Coirpith, when added to sandy soil at 2 per cent increases the water holding capacity up to 40 per cent. It can be applied to a wide variety of crops and can be used to prepare potting mixture and can be applied as organic manure in kitchen gardens.

4. Composting of crop residues and weeds:

Composting is one of the useful ways for utilizing the some of the weeds and noncommercial plants like *Parthenium*, Water hyacinth, *Ipomoea* etc. instead of their eradication. The plants can be composted using *Trichoderma viridi* and *Pleurotus sajor-caju* as a microbial consortium with supplementation of urea. Select an elevated shady area of a thatched shed and mark an area of 5x1.5 meter. Cut the composting materials into 10 – 15 cm size. Spread 100 kg of these materials over the marked area. Sprinkle 1 bottle of microbial consortia over this layer. Again spread another 100 kg of composting materials over this layer. Spread 1 kg of urea uniformly over this layer. Likewise repeat these processes of spreading composting materials, then microbial consortia, again composting materials followed by urea application until a minimum of 1-meter height is reached. Sprinkle water to attain a moisture level of 50% to 60%. The surface of the heap is covered with a thin layer of soil. Water should be sprinkled depending upon the necessity to maintain the moisture around 50%. A turning is given at the end 20 days to give a thorough mixing of outside material with that of the inside ones. The bio-converted compost will be ready in about 40 days time.

5. Method of composting the Municipal Solid Wastes

Biodegradable municipal solid waste should be separated and collected for composting. Five hundred kg of material should be heaped in the compost yard. In that heaped waste, 1 kg of TNAU microbial consortium should be applied in the form of slurry to cover the full waste material. This 1 kg microbial consortium can be mixed with 5 litres of water to make slurry. This slurry is sufficient to cover 0.5 tonne of material. Then, 50 kg of cowdung should be mixed with 30 litre of water to form cowdung slurry. This cowdung slurry should be sprayed over the heap of municipal solid waste. Then, 1 kg of urea should be mixed with solid waste. 60% moisture should be maintained through out the period of composting. Compost should be turned up once in 15 days to create good aeration, and for thorough mixing. Because of this practice, a uniform composted material will be obtained. Solid waste can be composted with in 90 days by this method with the indication of reduction in the volume, appearance of dark coloured materials and a small of earthy odour. After the completion of composting, compost should be sieved through normal mesh to separate unwanted and partially composted material.

6. Value addition of poultry waste compost

A known quantity of poultry droppings and coir pith @ 4:5 ratio should be mixed well to attain a C/N ratio of 25:1 to 30:1 which is considered to be the optimum C/N ratio

for composting. *Pleurotus sajor-caju*, a lignocellulolytic organism, should be inoculated into the mix @ 2 packets per tonne of waste in order to speed up the composting process. The mix should be heaped under the shade. The moisture content of the mix should be maintained within 40 – 50%. Periodical turning should be given on 21st, 28th and 35th day of composting. Another two packets of *Pleurotus sajor – caju* is to be added when turning is given on the 28th day of composting. A good quality compost will be obtained in 45 days, which contains 2.08% N, 1.93 % P and 1.41 % K with C/N ratio of 10-16

7. Enriched Farm Yard Manure (EFYM)/ Reinforced FYM

Phosphorus content in FYM is relatively low and complete utilization of nitrogen and potassium in the manure is seldom realized. Hence, heavy quantities intended to supply the needed quantity of phosphorus will result in wastage of nitrogen in most soils. To overcome this P insufficiency, addition of superphosphate to the manure is recommended and the process is called reinforcing / enriching and the resultant material is called “enriched farmyard manure”. The Single Super Phosphate (SSP) can be sprinkled either in the cattle shed or on the manure heap. Rock phosphate can also be recommended for this purpose.

Factors affecting the Composting Process

- I. The Type and Composition of the Organic Waste
- II. The Availability Of Microorganism
- III. Aeration
- IV. The C, N and P Ratios
- V. Moisture Content
- VI. Temperature
- VII. pH
- VIII. Time

Preparation of Coir Waste Compost Using Yeast Sludge:

Yeast sludge is a waste product by alcohol distilleries @ 2t/day. This waste contain 6% N, 0.3% P and 0.9% K with other micronutrients, vitamins and growth promoting substances. The coir waste should be sieved so as to remove all the fibrous materials. For one tone of coir waste 200 kg of yeast sludge and 10 kg of rock phosphate should be added and mixed thoroughly. Moisture should be maintained at 60%. After mixing the material should be formed as heap. Within 4-5 days the temperature of the heap will be raised to 50-60° C. Within 40 to 50 days the coir waste and yeast sludge will become as mature compost. The matured compost will turn from

brown to black. There will not be any odor. The volume of the compost heap will be reduced to 1/3. The temperature of the heap will be 25-30°C and it should be constant. The compost will be very light and fine textured. The compost prepared by this means of above method contains N-1.09%, P-1.35%, K-1.95% besides copper, manganese, iron and zinc. This compost doesn't have any phytotoxicity and used for all agricultural crops.

C. Preparation of sugarcane trash compost using yeast sludge:

sugarcane trash collected from sugarcane field has to be cut into small bits using chaff cutter or shredder to a size of 1-2cm. for every tone of sugarcane trash 200 kg of yeast sludge and 10kg of rock phosphate are added and mixed thoroughly. Moisture is maintained at 60%. the heap is formed to a height of 1-1½ m. within 45-50 days sugarcane trash compost will be ready for application to crops. The sugarcane trash compost consists of N-1.2%, P-0.7%, K-1.5% and considerable quantities of micronutrients. This compost can be applied at the rate of 5t/ha.

d. Japanese method of composting:

Instead of pits in conventional composting system, vats of 18-30' in length, 3-4' in width and 2.5-3.0' height are made of bamboo stakes of 2.5-3.0' width. For growth a non-leaky surface is prepared with broken stone stable or brick and plastered with cement. About 2 feet space is kept free on one side of the vat to facilitate turning the residues regularly. Sliced and broken pieces of coconut, shells, leaves, fibrous materials, tender tree barks or pieces form the bottom 10-15 cm layer. Second layer of dry leaves, grass residues, groundnut haulms are of 10-15 cm height. Cow dung, urine, biogas slurry are sprinkled over and this layer of soil and ash is spread over. Nitrogen rich green leaves of pongamia, albizzia, daincha, sesbania and crop residues forms third layer of 10-15 cm. Fourth layer of 10-15cm contains organic wastes rich in phosphorous and potash. Over these 2-3 buckets of cow dung and biogas slurry are sprinkled. Fifth layer contains paddy or ragi straw that is rich in carbon and provides energy for microorganisms. Sixth layer contains exclusively of dried and powdered cow dung of 20-30cm. Over these small quantities of old compost, tank silt and ash are sprinkled. For rapid degradation *Aspergillus*, *Penicillium*, *Trichoderma* should be inoculated. *Pleurotus* and *Polyporus* should be inoculated for degradation of high lignin contained residues. *Azotobacter* and Phosphobacteria can be mixed for enriching the composts.

General Properties Of Commercially Accepted Compost.:

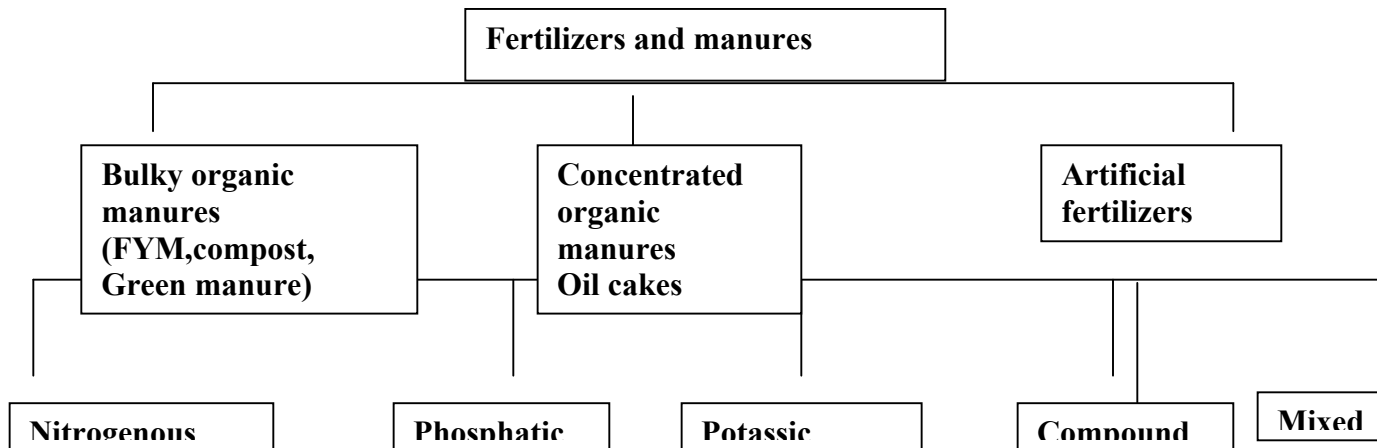
N %	>2	Color	Brown Black
C: N	<20	Odor	Earthy
Ash %	10-20	Water Holding Capacity (%)	150-200

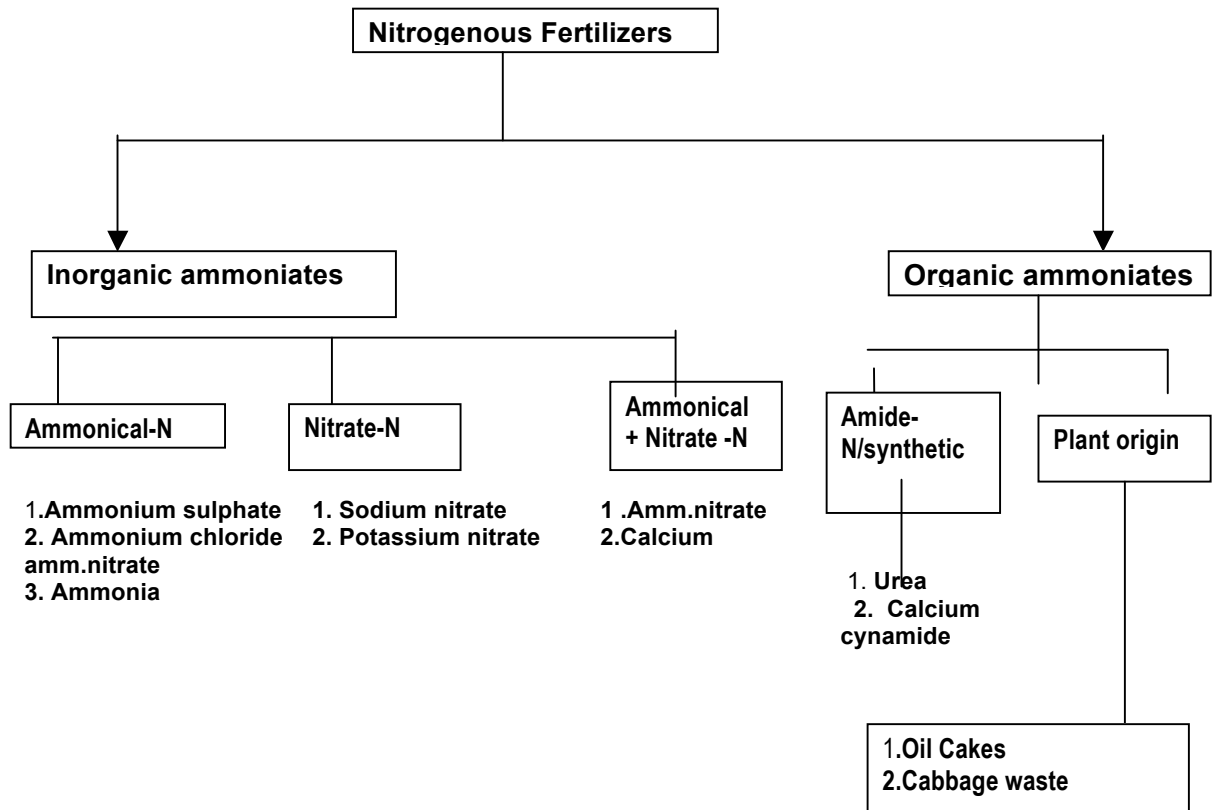
Moisture %	10-20	CEC (Meq 100 g ⁻¹)	75-100
P %	0.15-1.5	Reducing Sugar (%)	<35%

04. Classification of fertilizers – N, P and K fertilizers

Classification of fertilizers

Commercial N, both organic and inorganic is desired from a wide variety of materials which are found to differ very widely in their sources, properties, method of preparation and their reactions in the soil. Classification based on chemical form seems to be more satisfactory as indicated below.

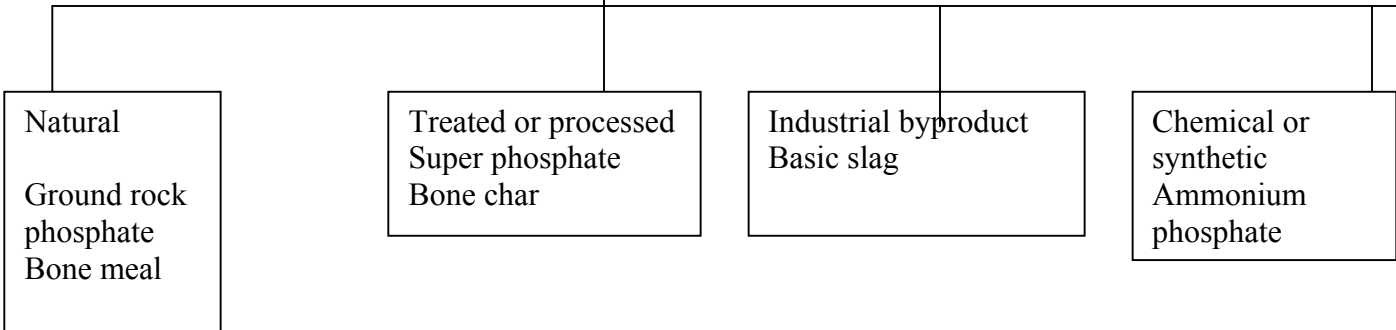




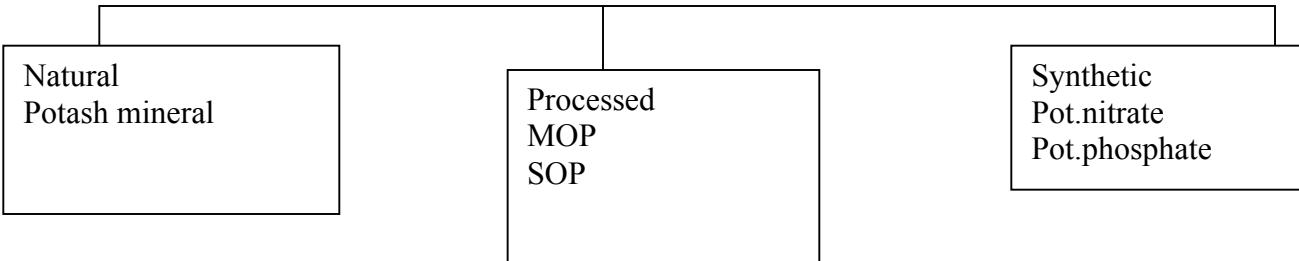
The nitrogen content of different nitrogenous fertilizers is given below

Sl.No	Name of the fertilizer	N content (%)	Form of N
1	Sodium nitrate (NaNO_3)	16.0	Nitrate (NO_3)
2	Potassium nitrate (KNO_3)	12.5-13.5	Nitrate
3.	Ammonium sulphate (NH_4) ₂ SO_4	20.6	NH_4 (Ammonia)
4.	Ammonium chloride (NH_4 Cl)	26.0	NH_4
5.	Ammophos - A	11.0	NH_4
6.	Ammophos – B	16.0	NH_4
7.	Ammonium Nitrate (NH_4)	33.0	NH_4 – 16.5 NO_3 – 16.5
8.	Ammonium sulphate nitrate	25.6	NH_4 – 19.5 NO_3 – 6.6
9.	Urea ($\text{CO}(\text{NH}_2)_2$)	46.0	Amide
10.	Calcium cyan amide (CaCN_2)	20.6	Amide
11.	Dried blood	3-14	Protein(organic)
12.	Groundnut cake	8.0	Protein(organic)
13.	Meat meal	09.0-11.	Protein (organic)
14.	Guano	10.0	Protein (organic)

PHOSPHATIC FERTILIZERS



POTASSIC



13. SECONDARY AND MICRONUTRIENT FERTILIZERS-Manufacturing of Zinc sulphate and Ferrous sulphate

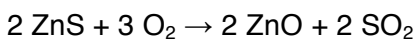
Zinc

Zinc is the fourth most common metal in use, trailing only iron, aluminium, and copper with an annual production of about 12 million tonnes.[14] The world's largest zinc producer is [Nyrstar](#), a merger of the Australian [OZ Minerals](#) and the Belgian [Umicore](#). [74] About 70% of the world's zinc originates from mining, while the remaining 30% comes from recycling secondary zinc. [] Commercially pure zinc is known as Special High Grade, often abbreviated *SHG*, and is 99.995% pure.

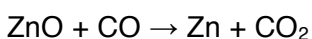
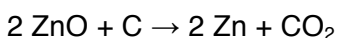
Worldwide, 95% of the zinc is mined from [sulfidic](#) ore deposits, in which sphalerite ZnS is nearly always mixed with the sulfides of copper, lead and iron. [77] There are zinc mines throughout the world, with the main mining areas being China, Australia and Peru. China produced 29% of the global zinc output in 2010.

Zinc metal is produced using [extractive metallurgy](#). [78] After grinding the ore, [froth flotation](#), which selectively separates minerals from [gangue](#) by taking advantage of differences in their [hydrophobicity](#), is used to get an ore concentrate. [78] A final concentration of zinc of about 50% is reached by this process with the remainder of the concentrate being sulfur (32%), iron (13%), and SiO₂ (5%). [78]

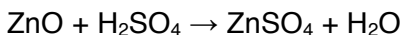
[Roasting](#) converts the zinc sulfide concentrate produced during processing to zinc oxide: [77]



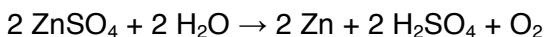
The sulfur dioxide is used for the production of sulfuric acid, which is necessary for the leaching process. If deposits of zinc carbonate, zinc silicate or zinc spinel, like the [Skorpion Deposit](#) in Namibia are used for zinc production the roasting can be omitted. For further processing two basic methods are used: [pyrometallurgy](#) or [electrowinning](#). Pyrometallurgy processing reduces zinc oxide with [carbon](#) or [carbon monoxide](#) at 950 °C (1,740 °F) into the metal, which is distilled as zinc vapor. [80] The zinc vapor is collected in a condenser. [77] The below set of equations demonstrate this process



Electrowinning processing leaches zinc from the ore concentrate by [sulfuric acid](#)



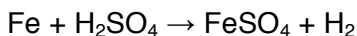
After this step [electrolysis](#) is used to produce zinc metal.[77]



The sulfuric acid regenerated is recycled to the leaching step.

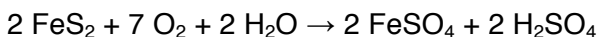
Ferrous Sulfate

In the finishing of [steel](#) prior to plating or coating, the steel sheet or rod is passed through [pickling baths](#) of sulfuric acid. This treatment produces large quantities of iron(II) sulfate as a by-product.[2]



Another source of large amounts results from the production of [titanium dioxide](#) from [ilmenite](#) via the sulfate process.

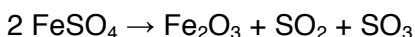
Ferrous sulfate is also prepared commercially by oxidation of pyrite:



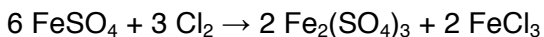
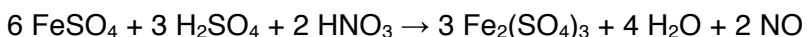
[\[edit\]](#)

Reactions

On heating, iron(II) sulfate first loses its [water of crystallization](#) and the original green crystals are converted into a dirty-yellow anhydrous solid. When further heated, the anhydrous material releases [sulfur dioxide](#) and white fumes of [sulfur trioxide](#), leaving a reddish-brown iron(III) oxide. Decomposition of iron(II) sulfate begins at about 480 °C.

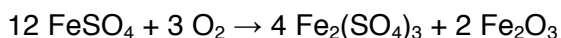


Like all iron(II) salts, iron(II) sulfate is a reducing agent. For example, it reduces nitric acid to nitrogen oxide and chlorine to chloride:



Ferrous sulfate outside [titanium dioxide](#) factory in Kaanaa, [Pori](#).

Upon exposure to air, it oxidizes to form a corrosive brown-yellow coating of basic ferric sulfate, which is an adduct of [ferric oxide](#) and [ferric sulfate](#):



15. Mixed fertilizers – sources – preparations- their compatibility – advantages

Mixed fertilizers

For over hundred years the mixed fertilizers are in use besides straight fertilizers. Many fertilizer mixtures are made available now and this account for a major portion of the consumption of N, P and K. Present day statistics show that numerous grades of fertilizers mixtures are manufactured and the fertilizer mixing industry is being considered as one of the major agro- industry.

The following are some of the common term frequently used in the mixed fertilizer industry.

Fertilizer : The substance which is used for the supply of plant nutrients

Mixed fertilizer : A mixture of more than one straight fertilizer which can supply more than one plant nutrient element

Complete fertilizer : A single fertilizer material containing the entire three major plant nutrients viz, N, P and K

Fertilizer grade : This refers to the minimum guarantee with regard to the nutrient content of the fertilizer mixture in terms of N, P and K.

Fertilizer formula : This related to the quantitative expression of the analysis of the different ingredients included in the mixed fertilizer in terms of N, P and K.

Fertilizer ratio : This indicates the relative percentage of N, P_2O_5 and K_2O in the manure mixture.

Acidic fertilizer : Fertilizer capable of increasing the acidity of the soil by continued applications.

Basic fertilizer : Fertilizers which increase the pH and the soil on continued use by leaving a basic residue in the soil.

Neutral fertilizer : Materials which are neither increasing nor decreasing the pH of the soil

Filler : It is called as the 'make-weight' material added to the fertilizer mixtures. Filler materials are inert materials like sand, saw dust etc, are added to make up the difference between weight of ingredients added to supply the plant nutrients in a tonne and the final weight viz., 1,000 kg.

Advantages

All the three major plant nutrients are made available in one and the same material. There is saving of time and labour. The residual effects will not be there. The fertilizer mixtures are usually prepared taking into account the acidic or alkaline nature of the ingredients, and other chemical reactions. Hence, some of the residual effects like acidity

will not be there. Usually mixed fertilizer are prepared to suit a group of crops and soils.

Disadvantages

- Specific needs of crops and deficiency of individual nutrient elements cannot be satisfied by using mixed fertilizers as efficiently as in the case of straight fertilizers.
- The use of mixed fertilizer in such cases of specific needs will be a waste as other nutrients are also added to the soil.
- Unit cost of the various nutrients contained in the mixed fertilizer will always be higher when compared to the unity cost of nutrients contained in the straight fertilizers.

Improper mixing and storage of fertilizers can result in large nutrient losses. Some important aspects to consider in fertilizer mixing and storage include the following:

- Urea should not be mixed with ammonium calcium nitrate (CAN), KCl, SSP or TSP.
- Urea can be mixed with most other fertilizers but fertilizer mixtures containing urea should be applied immediately after mixing. Do not store fertilizer mixtures containing urea.
- Ammonium phosphates and super phosphates should not be mixed with lime, slag, rock phosphate or CAN.
- Potassium chloride and sulfate of potash can be mixed with most fertilizers, but mixtures of these fertilizers with urea and calcium ammonium nitrate should not be stored.
- CAN should not be mixed with basic slag but can be mixed with urea, single superphosphate, and ammonium phosphates immediately prior to application.

Do not store fertilizers in damp or dirty places. Make sure that bags of fertilizer in the store do not absorb moisture from leaky roofs or water seepage through walls and floors.

Preparation of mixed fertilizers

Many kinds of materials are used in the manufacture of fertilizer mixtures. The materials are found to be highly varying in their properties. However, only a limited number of materials are being used like $(\text{NH}_4)_2\text{SO}_4$, $\text{CO}(\text{NH}_2)_2$, Super phosphate, ammonium phosphate, muriate of potash, limestone, gypsum and some fillers.

The manufacture of fertilizer mixtures usually involves the weighing and proportioning of ingredients that are used, sieving and sizing of the various ingredients, mixing the different materials and packing. All the above operations are done both mechanically and by hand operation. Different kinds of machineries are being used.

Guide for mixing

To determine the amount of individual fertilizer in a mixture, the quantity is calculated as follows.

$$\frac{\text{(Percentage of plant nutrient desired x (Weight of final mixture))}}{\text{in the mixture}}$$

Quantity =

$\frac{\text{(The Percentage of the plant nutrient in the straight fertilizer)}}{\text{P}}$

$$A = \frac{R \times T}{P}$$

R = Percentage in the mixture

T = Final weight of the mixture

P = Percentage in the straight fertilizer.

To prepare a mixture of 10: 5: 10 using $(\text{NH}_4)_2\text{SO}_4$, (20% N), Super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), the following quantities will be required per tonne (1,000 kg).

$$1. \text{ Ammonium sulphate} = \frac{10 \times 1000}{20} = 500 \text{ Kg.}$$

$$5 \times 1000$$

$$\begin{array}{rcl}
 2. \text{ Super phosphate} & = & \frac{\quad}{16} = 312.5 \text{ Kg.} \\
 & & \\
 & & 10 \times 1000 \\
 3. \text{ Muriate of potash} & = & \frac{\quad}{60} = 166.5 \text{ Kg.} \\
 & & \hline
 \text{Total} & & = \underline{979.0 \text{ Kg.}}
 \end{array}$$

$$\text{Filler} = 1000 - 979 = 21 \text{ Kg.}$$

If the total calculated weight exceeds the final weight, a mixture of that ratio can not be prepared.

Changes that occur while manufacturing mixed fertilizer

The ingredients used in fertilizer mixtures vary widely in their physical and chemical characteristics. When such widely varying materials in physical and chemical properties are mixed together, naturally many changes are expected to take place during or after the mixing. Some changes will be of physical nature and some will be of chemical nature. The following are the most important physical changes that will take place during or after the mixing of fertilizers.

Hygroscopicity

It is a property of any substance which absorbs from air and gets converted to semi- solid or liquid condition. Fertilizer like $\text{Ca}(\text{NO}_3)_2$, NH_4NO_3 , NaNO_3 and $\text{CO}(\text{NH}_2)_2$ are capable of absorbing moisture from air and become hygroscopic. In such cases handling will be very difficult for such mixtures.

Caking up

Moisture present in some of the ingredients is responsible for caking up. Moisture dissolves some of the easily soluble ingredients and forms a saturated solution. This saturated solution on evaporation gives out crystals which knit together forming larger lumps.

The caking up can be prevented by the use of certain kind of materials called as 'conditioners'. The commonly used conditioners are groundnut hulls, lime, clay etc. Another way of preventing the caking up is manufacture of granulated fertilizer mixture.

The granulation aims at preparation of uniform sized particles with reasonable stability, which presents caking up.

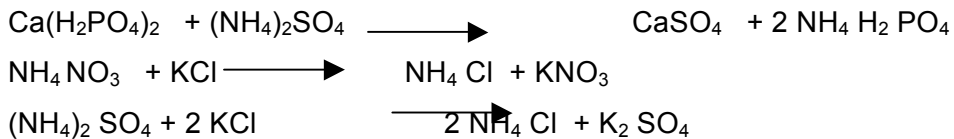
Segregation

This relates to separation of different sized particles individually. When ingredients of different sizes and densities are included there will be the tendency for the segregation (sorting out to different sizes) to take place. To prevent this bad effect, granulation is conveniently followed.

The following are some of the most important chemical changes that take place either during or after the manufacture of fertilizers mixtures. These changes are found to be influenced by temperature, moisture content and particle size of the ingredients.

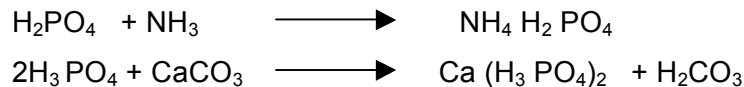
(a) Double decomposition

The reaction is between two compounds without a common ion in the presence of moisture. New compounds are formed which may have different physical and chemical properties.



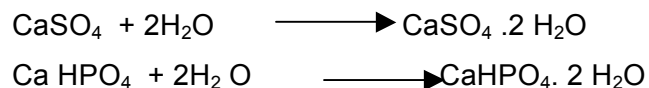
(b) Neutralization

This reaction takes place when free acids present in some of the fertilizers are neutralized by alkalis or Ca containing salts included in the mixture.



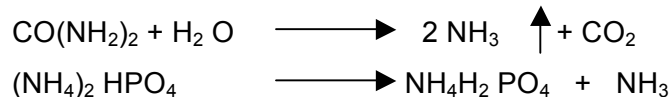
(c) Hydration

The process of tying up of water by the anhydrous form of salts is called hydration. Some of the fertilizers are found to have this property.



(d) Decomposition

Under certain conditions of moisture and temperature, there will be break down in the composition of molecules forming new compounds.



However, the following important principles must be taken into consideration while preparing mixed fertilizers.

1. All fertilizers containing ammonia are not mixed directly with the basic fertilizers (e.g. RP, limestone, basic slag, CaCN_2) as reaction will take place resulting in the loss of gaseous NH_3 .
2. The water – soluble phosphates are not mixed with those materials which contain free lime (e.g) lime stone, CaCN_2) as there will be reaction towards the reversing of water – soluble phosphate to water – insoluble phosphates.
3. Hygroscopic fertilizers are not included as they will facilitate caking up.
4. The acidic fertilizers are likely to produce some free acids which may damage the container or packing materials.

Manufacturing process

The principal steps in the manufacture of solid mixed fertilizers are calculating, weighing, sieving, sizing, mixing the materials and packing the product.

Calculating and weighing

With a good weighing device the calculated quantities of the various ingredients are weighed accurately for preparing mixtures.

(1) Sieving and sizing

If the raw materials have undergone too much of caking in the storage piles, it may be necessary to subject them to preliminary grinding, sieving and sizing. The raw materials must be converted into uniform sized particles to have effective making and to avoid segregation during subsequent handling.

(2) Mixing

Many kinds of fertilizer mixing machines have been proposed and used at present. Rotary drum type is found to be more common than the vertical cylinder type. Weighed quantities of different materials are introduced into the mixer and mixed thoroughly.

(3) Packing

Equipments for packing fertilizer mixture range from the simplest types of hand operated facilities to highly sophisticated automatic machines.

Granular mixtures

Compared to pulverized or powdered mixture, the advantages of granular mixtures are reduced caking up tendency, less dusting loss and easy handling. Of late, attention is found in the manufacture of only granular mixtures.

19.FERTILIZERS CONTROL ORDER (FCO) 1985

ORDER

Under the Essential Commodities Act, 1955 (10 of 1955), the Central Government makes the Fertilizers (Control) Order, 1985. It shall come into force on the date of its publication in the Official Gazette. In this Order, some of the definitions are used

Act means the Essential Commodities Act, 1955 (10 of 1955).

"certificate of source" means a certificate given by a State Government, Commodity Board, manufacturer, + importer, pool handling agency

Commodity Board means the Coffee Board constituted under section 4 of the Coffee Act, 1942 (7 of 1942) or the Rubber Board constituted under section 4 of the Rubber Act, 1947 (24 of 1947)

compound or complex fertilizers means a fertilizers containing two or more nutrients during the production of which chemical reaction takes place

controller means the person appointed as Controller of Fertilizers by the Central Government and includes any other person empowered by the Central Government to exercise or perform all or any of the powers, of the Controller under this Order.

"dealer" means a person carrying on the business of selling fertilizers whether wholesale or retail or industrial use* and includes a manufacturer, +Importer, and a pool handling agency carrying on such business and the agents of such person, manufacturer, +importer or pool handling agency.

fertilizer means any substance used or intended to be used as a fertilizer of the soil and/or crop and specified in Part A of Schedule I and includes a mixture of fertilizers and special mixture of fertilizers.

"grade" means the nutrient element contents in the fertilizer expressed in percentage

"granulated mixture" means a mixture of fertilizers made by intimately mixing two or more fertilizers with or without inert material, and granulating them together, without involving any chemical reaction.

"importer" means a person who imports fertilizers in accordance with the Export and Import Policy of the Central Government, as amended from time to time.

inspector" means an Inspector of Fertilizers appointed under clause 27.

"manufacturer" means a person who produces fertilizers or mixtures of fertilizers and the expression "manufacture" with its grammatical variations shall be construed accordingly.

"mixture of fertilizers" ***means a mixture of fertilizers made by physical mixing two or more fertilizers with or without inert material in physical or granular form and includes a mixture of NPK fertilizers, a mixture of micronutrient fertilizers and a mixture of NPK with micronutrient fertilizers.

"physical mixture" means a mixture of fertilizers made by physically mixing two or more fertilizers with or without inert material necessary to make a required grade, without involving any chemical reaction.

"prescribed standard" means-in relation to a fertilizers included in column 1 of Part A of Schedule-I, the standard set out in the corresponding entry in column 2, subject to the limits of permissible variation as specified in Part B of that Schedule

PRICE CONTROL-Fixation of prices of fertilizers

The Central Government may, with a view to regulate equitable distribution of fertilizers and making fertilizers available at fair prices, by notification in the Official Gazette, fix the maximum prices or rates at which any fertilizers may be sold by a dealer, manufacturer, +importer or a pool handling agency. The Central Government may consider the local conditions of any area, the period of storage of fertilizers and other relevant circumstances, fix different prices or rates for fertilizers having different periods of storage or for different areas or for different classes of consumers. No dealer, manufacturer +importer or pool handling agency shall sell or offer for sale any fertilizers at a price exceeding the maximum price or rate fixed under this clause.

Display of stock position and price list of fertilizers

Every dealer, who makes or offers to make a retail sale of any fertilizers, shall prominently display in his place of business:-**the quantities of opening stock of different fertilizers** held by him on each day & a list of prices or rates of such fertilizers fixed under clause 3 and for the time being in force.

Issue of cash/credit memorandum

Every dealer shall issue a cash or credit memorandum to a purchaser of a fertilizers in FormM*

CONTROL ON DISTRIBUTION OF FERTILIZERS BY MANUFACTURER/ IMPORTER

Allocation of fertilizers to various States

The Central Government may, with a view to secure equitable distribution and availability of fertilizers to the farmers in time, by notification in the Official Gazette, direct any manufacturer/importer to sell the fertilizers produced by him in such quantities and in such State or States and within such period as may be specified in the said notification.

AUTHORISATION OR REGISTRATION OF DEALERS”

Registration of Industrial dealers and authorization of other dealers

No person shall sell, offer for sale or carry on the business of selling of fertilizer at any place as wholesale dealer or retail dealer except under and in accordance with clause 8:

Application for intimation or registration

Every person intending to sell or offer for sale or carrying on the business of selling of fertilizer as Industrial Dealer shall obtain a certificate of registration from the controller by making an application in Form A together with the fee prescribed While, a manufacturer, an importer, a pool handling agency, wholesaler and a retail dealer intending to sell or offer for sale shall make a Memorandum of Intimation to the Notified Authority, in Form A1 duly filled in, in duplicate, together with the fee prescribed under clause 36 and certificate of source in Form O. On receipt of a Memorandum of Intimation, complete in all respects, the Notified Authority shall issue an acknowledgement of receipt in Form A2 and it shall be deemed to be an authorization letter granted and the concerned person as authorised dealer for the purposes of this Order.

A certificate of registration granted before the commencement of the Fertilizers (Control) Amendment Order, 2003, shall be deemed to be an authorization letter granted under the provisions of this Order: when the applicant is a State Government, a manufacturer or an importer or a pool-handling agency, it shall not be necessary for it or him to submit Form O.

Grant or refusal of certificate of registration

The Controller, shall grant a certificate of registration in Form 'B' within thirty days of the receipt of application to any person who applies for it under clause 8; no certificate of registration shall be granted to a person: -if his previous certificate of registration is under suspension; or it has been cancelled within a period of one year immediately preceding the date of application; or if he has been convicted of an offence under the Act, or if he fails to enclose with the application a certificate of source ; or if the application is incomplete in any respect;

Period of validity of certificate of registration and letter of authorization

Every certificate of registration granted, **be valid for a period of three years from the date of its issue.**

Renewal of certificates of registration and authorization letters

Every holder of a certificate of registration granted make an application for renewal to the Controller, in Form C, or to the Notified Authority in Form A1, respectively, in duplicate, together with the fee prescribed under clause 36 for such renewal and a certificate of source as required under clause 8.

Manufacture of Mixtures of Fertilizers - Restriction on preparation of mixtures of fertilizer

No person shall carry on the business of preparing any mixture of fertilizers. or special mixture of fertilizers except under and in accordance with the terms and conditions of a certificate of manufacture granted to him under clauses 15 or 16.

Standards of mixtures of Fertilizers

Subject to the other provisions of the order, no person shall manufacture any *mixture of fertilizers whether of solid or liquid fertilizers unless such mixture conforms to the standards set out in the notification to be issued by the Central Government in the Official Gazette;

Application for certificate of manufacture of mixtures of fertilizers

Every person desiring to obtain a certificate of manufacture for preparation of any mixture of fertilizers or special mixture of fertilizers shall possess such mixture, *and possess the minimum laboratory facility as specified in clause 21A of this Order. An applicant shall make an application to the registering authority if he is an applicant for a certificate of **manufacture for any mixture of fertilizers** in Form D, in duplicate, together with the fee prescribed there for under clause 36; or, if he is an applicant for a certificate of manufacture for any **special mixture, in Form E, in duplicate**, together with the fee prescribed there for under the said clause 36 and an attested copy of the requisition of the purchaser.

Grant or refusal of certificate of manufacture for preparation of mixtures of fertilizers

On receipt of an application under clause 14, the registering authority shall, by order in writing, grant or refuse **within forty-five days from the date of receipt of the application, furnish to the applicant a copy of the order so passed;** to the applicant in Form G

Period of validity of a certificate of manufacture for preparation of mixtures of fertilizers

Every certificate of manufacture granted under clause 15 for preparation of a mixture of fertilizers shall, unless suspended or cancelled, be valid for a period of three years from the date of issue.

Renewal of certificate of manufacture for preparation of mixtures of fertilizers

Every holder of a certificate of manufacture for preparation of a mixture of fertilizers desiring to renew the certificate, shall, before the date of expiry of the said certificate of manufacture make an application to the registering authority in Form D in duplicate, together with the fee prescribed for this purpose under clause 36.

Manufacturers/Importers pool handling agencies to comply with certain requirements in regard to packing and marking, etc.2

Every manufacturer/importer and pool handling agency shall, in regard to packing and marking of containers of fertilizers, comply with the following requirements, namely:-Every container in which any fertilizers is packed shall conspicuously be Superscribed with the word "FERTILIZERS" and shall bear only such particulars in case of containers the gross weight of which is 5 kg or less, no such printing of superscription and other particular shall be necessary

if such super superscription and other particulars are printed on a separate label which is securely affixed to such container. in case fertilizer bags are in cut, torn or damaged condition during transportation or is handling during loading or unloading operation, the manufacturer of such fertilizer may, under intimation to the State Government and the Central Government, repack the fertilizer in new bags or restandardise the quantity in terms of declared weight. Every fertilizers bag in which any fertilizers is packed for sale shall be of such weight and size as may be specified by the Central Government from time to time in this behalf

Manufacturers to comply with certain requirements for laboratory facilities:-

Every manufacturer shall, in order to ensure quality of their product, possess minimum laboratory facility, as may be specified from time to time by the Controller.

Disposal of non-standard fertilizers

Notwithstanding anything contained In this Order, a person may sell, offer for sale, stock or exhibit for sale or distribute, [any fertillser except any fertillser imported by the Central Government] which, not being an adulterated fertilizers, does not conform to the prescribed standard (hereinafter in this Order referred to as non-standard fertilizers) subject to the conditions that:- the container of such non-standard fertilizers is conspicuously super scribed in red colour with the words "non-standard" and also with the sign "X"; and an application for the disposal of non-standard fertilizers in Form H is submitted to the [Notified authority] to grant a certificate of authorization for sale of such fertilizers and a certificate of authorization with regard to their disposal and price is obtained in Form such non-standard fertilizers shall be sold only to the manufacturers of mixtures of fertilizers or special mixtures of fertilizers or research farms of Government or Universities or such bodies. The price per unit of the non-standard fertilizers shall be fixed by the notified authority If a manufacture or importer detects or as reasonable doubt about the standard of the fertilizer manufactured or imported by him, and dispatched for sale as deteriorated in quality during transit due to natural calamity and is not of the prescribed standards, he may, within fifteen days from the date of dispatch from factory or port, apply with detailed justifications to the Central Government for obtaining permission for reprocessing the same in a factory to meet the prescribed standards and the Central Government may, after considering the facts, permit the re-processing of such fertilizer on the terms and conditions as may be notified by the Central Government in this behalf.

ENFORCEMENT AUTHORITIES

Appointment of registering authority The State Government may, appoint such number of persons, as it thinks necessary, to be registering authorities for the purpose of this Order for industrial dealers, and may, define the limits of local area within which each such registering authority shall exercise his jurisdiction.

Notified Authority- The State Government may, appoint such number of persons, to be Notified Authorities for the purpose of this Order and define the local limits within which each such Notified Authority shall exercise his jurisdiction.

Appointment of inspectors-The State Government, or the Central Government may, by notification in the Official Gazette appoint such number of persons, to be inspectors of fertilizers for the purpose of this Order, and may, in any such notification, define the limits of local area within which each such inspector shall exercise his jurisdictions.

Qualifications for appointment of fertilizers Inspectors

No person shall be eligible for appointment as Fertilizers Inspector under this Order unless he possesses the following qualifications, namely:-Graduate In agriculture or science with chemistry as one of the subjects, from a recognized university; and Training or experience in the quality control of fertilizers and working in the State or Central Government Department of Agriculture.

Powers of Inspectors

An inspector may, with a view to securing compliance with this Order:- require any manufacturer, +importer, pool handling agency, wholesale dealer or retail dealer to give any information in his possession with respect to the manufacture, storage and disposal of any fertilizer manufactured or, in any manner handled by him draw samples of any fertilizers in accordance with the procedure of drawal of samples laid down in Schedule II. Provided that the inspector shall prepare the sampling details in duplicate In Form J, and hand over one copy of the same to the dealer or his representative from whom the sample has been drawn; enter upon and search any premises where any fertilizers is manufactured/ Imported or stored or exhibited for sale,; seize any books of accounts or documents relating to manufacture, storage or sale of fertilizers, etc. in respect of which he has reason to believe that any contravention of this

Order has been or is being or is about to be committed; Where any fertilizers is seized by an inspector under this clause, he shall forthwith report the fact of such seizure to the collector whereupon the provisions of sections 6A, 6B, 6C, 6D and 6E of the Act, shall apply to the custody, disposal and confiscation of such fertilizers. Every person, if so required by an inspector, shall be bound to afford all necessary facilities to him for the purpose of enabling him to exercise his powers under sub-clause (1).

ANALYSIS OF SAMPLES

Laboratory for analysis

A fertilizer sample, drawn by an inspector, shall be analyzed in accordance with the instructions contained in Schedule II in the **-Central Fertilizers Quality Control and Training Institute, **Faridabad or Regional Fertilizers Control Laboratories at Bombay, Madras or Kalyani (Calcutta)** or in any other laboratory notified for this purpose by the State Government [with the prior approval of the Central Government. Every laboratory in order to ensure accurate analysis, of fertilizers samples, possess minimum equipment and other laboratory facilities, as may be specified from time to time by the Controller in this behalf

Qualifications for appointment of fertilizers analyst in the fertilizer control laboratories

No person shall be eligible for appointment as fertilizers analyst for analysis of fertilizers samples in the laboratories notified under clause 29 of the Order, unless he possesses the following qualifications, namely:-graduate in Agriculture or Science with chemistry as one of the subjects from a recognized university; and training In fertilizers quality control and analysis at **Central Fertilizer Quality Control and Training Institute, Faridabad.** Provided that the fertilizers analysts appointed before the commencement of this Order, who do not possess the requisite training, shall undergo prescribed training, within a period of three years, in the Central Fertilizers Quality Control " and Training Institute, Faridabad from the date of commencement of this Order.

Laboratories for referee analysis

Every laboratory referred to in sub-clause (1) of clause 29 shall be designated as referee laboratory for the purpose of analysis of any sample of fertilizers : Provided that no such laboratory which carried out the first analysis of the fertilizers sample shall be so designated in respect of that sample: Further in respect of any sample the analysis of which has been challenged, may be sent for referee analysis to any one of the other laboratories except those which are located in the State or where the first analysis has been done. Central Fertilizers Quality Control and Training Institute and Regional laboratories shall be considered as one group of laboratories and a sample first analysed by any one of them, shall not be sent for referee analysis to any other in that group, but only to any other laboratory notified by a State Government.

Time limit for analysis, and communication of result

Where sample of a fertilizer has been drawn, the same shall be dispatched along with a memorandum in Form K to the laboratory for analysis within a period of seven days from the date of its drawl. The laboratory shall analyze the sample and forward the analysis report in Form L within [30 days] from the date of receipt of the sample in the laboratory to the authority specified in the said memorandum.

The authority to whom the analysis report is sent under sub-clause (2) shall communicate the result of the analysis to the dealer/manufacturer/Importer/pool handling agency from whom the sample was drawn within [15 days] from the date of receipt of the analysis report of the laboratory.

Maintenance of records and submission of returns, etc.

The controller may by an order made in writing direct the dealers. manufacturers/ importers, and pool handling agencies:- to maintain such books of accounts, records, etc. relating to their business in Form 'N'. and to submit to such authority, returns and statements in such form and containing such information relating to their business and within such time as may be specified in that order. Where a person holds certificates of registration for retail sale and wholesale sale of fertilizers, he shall maintain separate books of accounts for these two types of sales made by him.

Fees

The fees payable for grant, amendment or renewal of an authorization letter or certificate of registration or certificate of manufacture a duplicate of such certificates or, renewal thereof

under this Order shall be such as the State Government may, from time to time fix, subject to the maximum fees fixed for different purposes by the Central Government and different fees may be fixed for different purposes or for different classes of dealers or for different types of mixtures of fertilizers or special mixture. Any fee paid under sub-clause (1) shall not be refundable unless the grant or renewal of any certificate of registration or certificate of manufacture or duplicate copy of such certificate or renewal under this Order has been refused.

The fees payable for grant, amendment, renewal or duplicate copy of certificate of registration for industrial dealer and the authority to whom and the manner in which such fee shall be paid, shall be such as may be specified by the Controller from time to time by notification in the Official Gazette*

Learning objective :

To understand the importance of soil fertility

To study the essential nutrients in plant growth

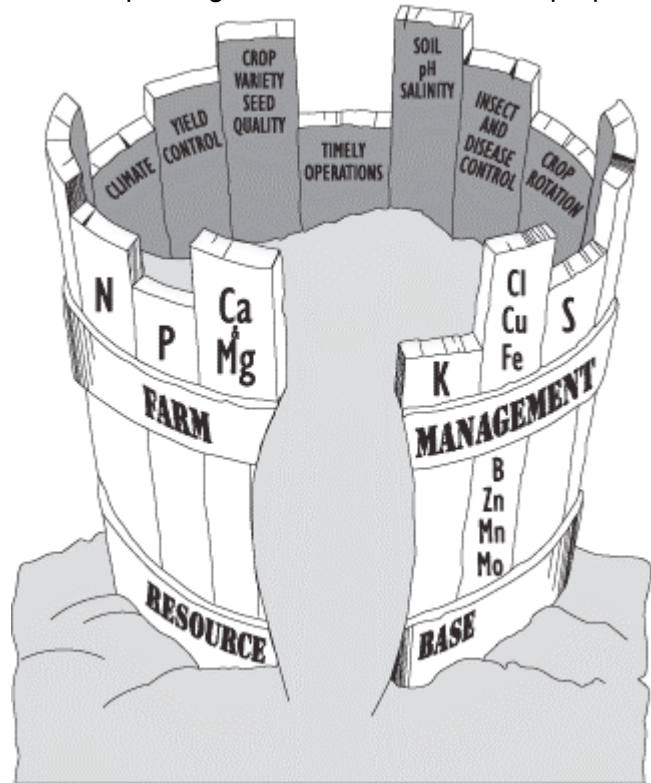
Crops depend on extrinsic and intrinsic factors for their growth and environment to provide them with basic necessities for photosynthesis. These essential plant growth factors include:

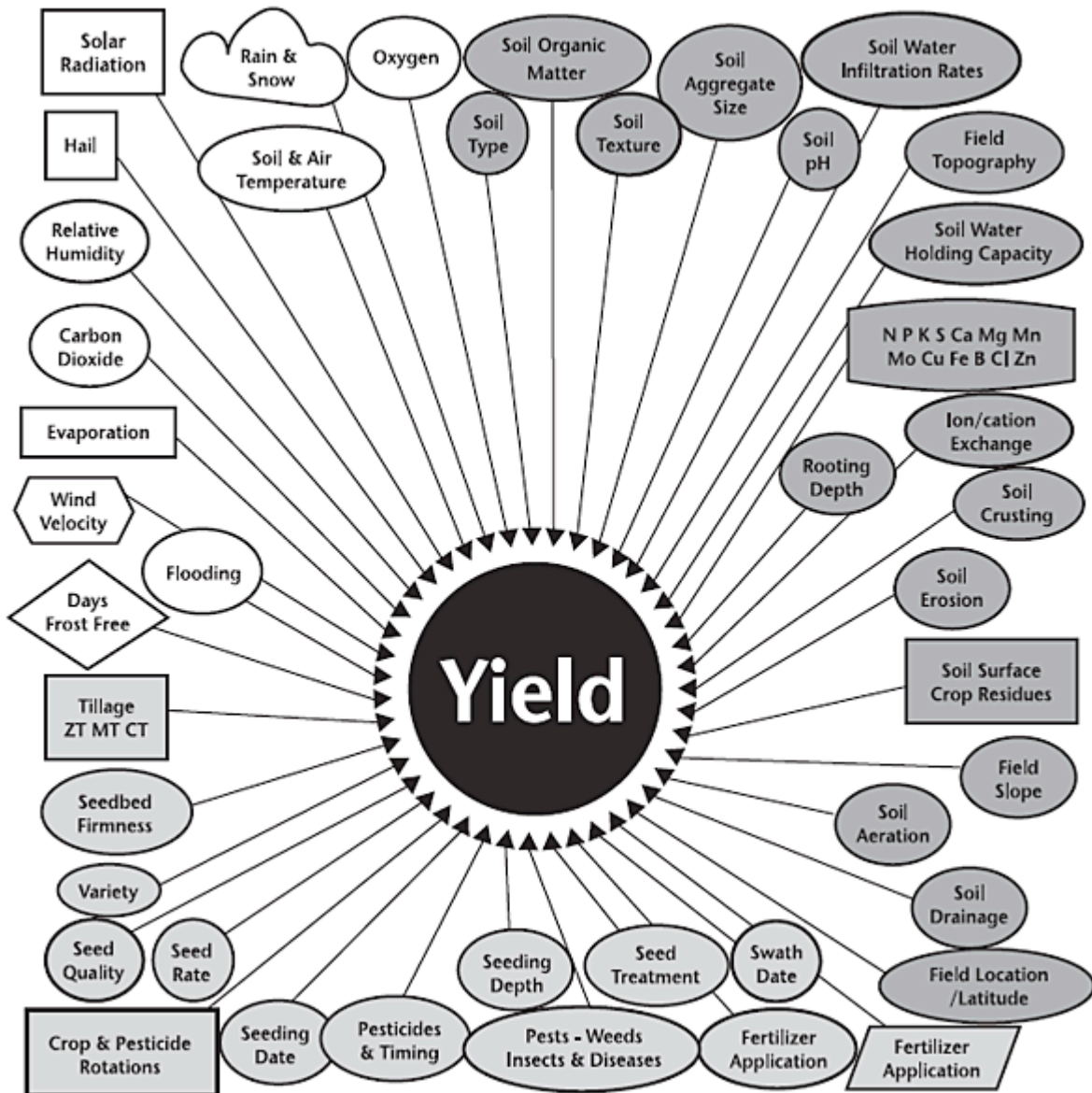
- light
- heat
- air
- water
- nutrients
- physical support

If any one factor, or combination of factors, is in limited supply, plant growth will be adversely affected. The importance of each of the plant growth factors and the proper combination of these factors for normal plant growth is best described by the principle of limiting factors. This principle states: "The level of crop production can be no greater than that allowed by the most limiting of the essential plant growth factors." The principle of limiting factors can be compared to that of a barrel having staves of different lengths with each stave representing a plant growth factor.

Crop yield and quality depends upon the essential growth factors and the many interrelated soil, plant, environmental and agronomic factors or variables. Within this system, some of these factors cannot be controlled; others can be controlled and are manageable.

Soil is one of the key factors affecting plant growth as observed in the figure. The major functions of the soil are to provide plants with nutrients, water and oxygen.





Crop Production Factors

FAO has listed seven important soil qualities which affect crop growth as given below.

Soil Qualities	Soil Characteristics
SQ1 Nutrient availability	Soil texture, soil organic carbon, soil pH, total exchangeable bases
SQ2 Nutrient retention capacity	Soil Organic carbon, Soil texture, base saturation, cation exchange capacity of soil and of clay fraction
SQ3 Rooting conditions	Soil textures, bulk density, coarse fragments, vertic soil properties and soil phases affecting root penetration and soil

		depth and soil volume
SQ4	Oxygen availability to roots	Soil drainage and soil phases affecting soil drainage
SQ5	Excess salts.	Soil salinity, soil sodicity and soil phases influencing salt conditions
SQ6	Toxicity	Calcium carbonate and gypsum
SQ7	Workability (constraining field management)	Soil texture, effective soil depth/volume, and soil phases constraining soil management (soil depth, rock outcrop, stoniness, gravel/concretions and hardpans)

Soil fertility is the key to sustainable agriculture. Soil fertility is defined in several ways.

Soil fertility

“Soil fertility is the ability of the soil to supply essential plant nutrients during growth period of the plants, without toxic concentration of any nutrients”. i.e “**the capacity of soil to supply nutrient in available to crop**”.

Soil productivity

“Soil productivity is ability of soil to produce a particular crop or sequence of crops under a specified mgt system” i.e **the crop producing capacity of soil**”.

All the productive soils are fertile but all the fertile soils may not be productive

Sometimes even if the soil is fertile, they are subjected to drought or other unsatisfactory growth factors or management practices.

History of development of soil fertility

Francis Bacon (1591- 1624) suggested that the principle nourishment of plants was water and the main purpose of the soil was to keep plants erect and to protect from heat and cold.

Jan Baptiste **Van Helmont** (1577 – 1644) was reported that water was sole nutrient of plants.

Robert Boyle (1627 – 1691) an England scientist confirmed the findings of Van Helmont and proved that plant synthesis salts, spirits and oil etc from H₂O.

Anthur Young (1741 – 1820) an English agriculturist conducted pot experiment using Barley as a test crop under sand culture condition. He added charcoal, train oil, poultry dung, spirits of wine, oster shells and numerous other materials and he conducted that some of the materials were produced higher plant growth.

Priestly (1800) established the essentiality of O₂ for the plant growth.

J.B. Boussingault (1802-1882) French chemist conducted field experiment and maintained balance sheet. He was first scientist to conduct field experiment. He is considered as **father of field experiments**.

Justus Von Liebig (1835) suggested that

- a. Most of the carbon in plants comes from the CO_2 of the atmosphere.
- b. Hydrogen and O_2 comes from H_2O .
- c. Alkaline metals are needed for neutralization of acids formed by plants as a result of their metabolic activities.
- d. Phosphorus is necessary for seed formation.
- e. Plant absorb every thing from the soil but excrete from their roots those materials that are not essential.

The field may contain some nutrient in excess, some in optimum and some in least, but the limiting factor for growth is the least available nutrient. **The law of Mn**, stated by **Liebig in 1862**, is a simple but logical guide for predicting crop response to fertilization. This law states that, "the level of plant production cannot be greater than that allowed by the most limiting of the essential plant growth factors". The contributions made by Liebig to the advancement of agriculture were monumental and he is recognized as the **father of Agricultural chemistry**.

J.B. Lawes and J. H. Gilbert (1843) established **permanent manurial experiment** at Rothemsted Agricultural experiment station at England. They conducted field experiments for twelve years and their findings were

- a. Crop requires both P and K, but the composition of the plant ash is no measure of the amounts of these constituents required by the plant.
- b. No legume crop require N. without this element, no growth will be obtained regardless of the quantities of P and K present. The amount of ammonium contributed by the atmosphere is insufficient for the needs of the crop.
- c. Soil fertility can be maintained for some years by chemical fertilizers.
- d. The beneficial effect of fallow lies in the increases in the available N compounds in the soil.

Robert Warrington England showed that the nitrification could be supported by carbon disulphide and chloroform and that it would be stopped by adding a small amount of unsterilized soil. He demonstrated that the reaction was two step phenomenon. First NH_3 being converted to nitrites and the nitrites to nitrates.

Essential and Beneficial elements

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

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

The following is the essentiality criteria described by Arnon and Stout (1939)

1. A plant must be unable to complete its life cycle in the absence of the mineral element.
2. The function of the element must not be replaceable by another mineral element.
3. The element must be directly involved in plant metabolism.

Beneficial Nutrients/Elements: Beneficial elements are the mineral elements that stimulate the growth and exhibit beneficial effects at very low concentration or which are essential only for certain plant species or under specific conditions are called as “beneficial elements”.Eg.Na,Va,Co,Si

D.J.Nicholas coined the term “functional or metabolic nutrient”

Any mineral element that functions in plant metabolism, whether or not its action is specific. (Cl, Si, Na, Va, Co, Se)

The following table gives the essentiality of elements established by different scientists

Essentiality of the elements established by

Carbon	:	Priestly (1800)
Nitrogen	:	Theodore De saussure (1804)
Ca, Mg, K, S	:	Carl sprengel (1839)
Phosphorus	:	Von Liebig (1844)
Iron (Fe)	:	E. Greiss (1844)
Manganese (Mn)	:	J.S. Hargue (1922)
Zinc(Zn)	:	Sommer and Lipman (1926)
Copper (Cu)	:	Sommer, Lipman and Mc Kenny (1931)
Molybdenum (Mo)	:	Arnon and Stout (1939)
Sodium (Na)	:	Brownell and wood (1957)
Cobalt(Co)	:	Ahamed and Evans (1959)
Boron(B)	:	Warring ton (1923)
Chlorine (Cl)	:	Broyer (1954)
Nickel	:	Brown et.al.(1987)

Classification of Essential Elements

- 1) Based on the amount required by the plant
 - i) Major nutrients – required in large quantities eg. N,P,K
 - ii) Secondary nutrients – required in lesser quantities compared to Major nutrients eg. Ca,Mg,S
 - iii) Micronutrients- required in trace quantities eg. Fe, Mn, Zn, Cu, B, Mo

Classification based on the role of element in plant system

(According to TRUOG, 1954)

- | | |
|------------------------------------|-----------------------------|
| Structural Elements | : C, H, O |
| ii). Accessory structural elements | : N. P. S |
| iii). Regulator & Carriers | : K, Ca, Mg |
| iv). Catalyst & Activators | : Fe, Mn, Zn, Cu, Mo, Cl, B |

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Questions to ponder

- 1) How are the essential elements essential to crops?
- 2) Which elements are considered to be essential for crop growth?
- 3) Why is some nutrient deficiencies exhibited in older leaves, while other nutrient deficiencies show up first on newer leaves?
- 4) What are beneficial elements?
- 5) What is the difference between major and micronutrient?

05.

Forms of nutrients in soil and their functions in plants

Learning objective :

To know the functions of each nutrient in plant

Primary or major nutrients: are those nutrients required relatively in large quantities by the plants for its growth and development. Ex: N, P and K.

Secondary nutrients: are those nutrients which are required by plants in moderate amounts and given secondary importance in its supply and management.

Ex: Ca, Mg and S.

Micronutrients: The nutrients which are utilized by plants in relatively smaller quantities for their growth and development, but these are equally important & essential to plants as macronutrients.

Ex: Fe, Mn, Zn, Cu, B, Mo, Cl and Ni.

Plant Nutrients

Sixteen elements are considered essential for plants. They are grouped based on their relative abundance in plants.

Many non-essential elements are also found in plants that account for over 60 elements. Al is absorbed when soil solution is rich in Al ions. When plant materials is burned, the remaining plant ash contains all the essential and non-essential elements except C, H, O, N, S. Macro nutrients are absorbed in 30-100 times in proportion to that of micronutrients.

1 (3/4)

Essential Nutrients

Non-mineral Nutrients	Macronutrients		Micronutrients	
	Primary	Secondary	By all plants	Some

C	N	Ca	Fe	B	Na
H	P	Mg	Mn	Cl	Co
O	K	S	Zn	Mo	Va
			Cu		Ni
					Si

Chemical nature

Metals	K, Ca, Mg, Fe, Mn, Zn, Cu,
Non-metals	C, H, O, N, P, S, Cl

The plant content of mineral elements is affected by many factors and their concentration in crops varies considerably.

Nutrient		Relative concentration (Times)	Concentration (%)
Primary	N, K	400-1000	1-1.5
	P	30	0.1-0.3
Secondary	Ca, Mg	100-200	0.2-0.5
	S	30	0.1
Micro	Fe, Mn, B	1-2	0.002-0.01
	Others	<1	<0.002

Plant Nutrients

Concentration, Mobility, forms, functions

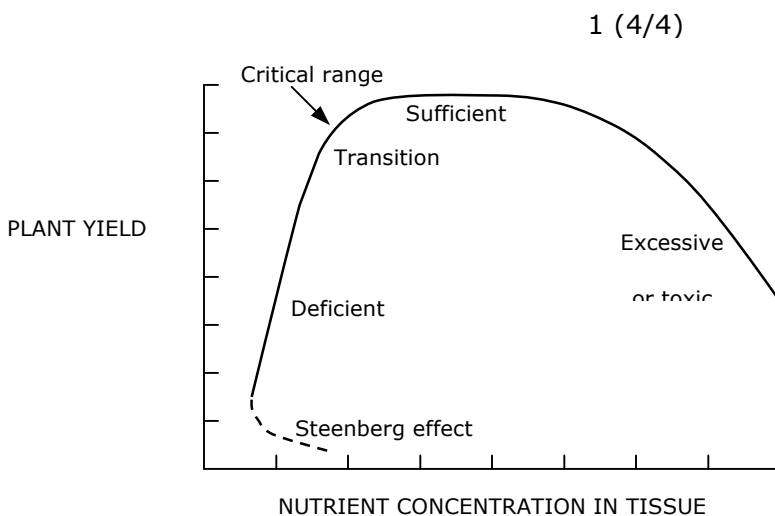
A mineral element is considered essential to plant growth and development if the element is involved in plant metabolic functions and the plant cannot complete its life cycle without the element. Terms commonly used to describe level of nutrients in plants are

Deficient

When the concentration of an essential element is low enough to limit yield severely and distinct deficiency symptoms are visible then that element is said to be deficient. Extreme deficiencies can result in plant death. With moderate or slight deficiencies, symptoms may not be visible, but yields will still be reduced.

Critical range

The nutrient concentration in the plant below which a yield response to added nutrient occurs. Critical level or ranges vary among plants and nutrients but occur somewhere in the transition between nutrient deficiency and sufficiency.



Sufficient

Concentration range in which added nutrients will not increase yield but can increase nutrient concentration. The term luxury consumption is used to describe nutrient absorption by the plant that does not influence yield.

Excessive or toxic

When the concentration of essential or other elements is high enough to reduce plant growth and yield then it is said to be toxic. Excessive nutrient concentration can cause an imbalance in other essential nutrients, which also can reduce yield

Forms of nutrients for Plant absorption	
N	NH_4^+ , NO_3^- , organic N
P	H_2PO_4^- (Primary) and HPO_4^{2-} (Secondary) Orthophosphates
K	K^+
Ca	Ca^{++}
Mg	Mg^{++}
S	SO_3^- (Sulphite) and SO_4^-
Fe	Fe^{++} (Ferrous), Fe^{+++} (Ferric)
Mn	Mn^{++} (Manganous) and Mn^{+++} (Manganic)
Zn	Zn^{++}
Cu	Cu^+ (Cuprous) and Cu^{++} (Cupric)
B	BO_3^- and other forms
Mo	MoO_4^{--} (Molybdate)
Cl	Cl^-

Concentration and plants yield

Yield is severely affected when a nutrient is deficient. When deficiency is corrected, growth increases more rapidly. Under severe deficiency, rapid increase in growth with added nutrient can cause a small decrease in nutrient concentration due to dilution effect. This is called the **Steenberg effect**

1 (2/8)

Luxury consumption

Nutrient sufficiency occurs over a wide concentration range, wherein yield is unaffected. Increase in nutrient concentration above the critical range indicates that the plant is absorbing nutrient above that needed for maximum yield.

This **luxury consumption** is common in most plants. Elements absorbed in excessive quantities

can reduce plant yield directly through toxicity or indirectly by reducing concentration of other nutrient below critical ranges.

Functions of nutrients in plants:

Nutrient		Functions
Major nutrients		
Nitrogen		Basic component of proteins and chlorophyll (the pigment that gives plants their green colour). Plays an essential role in plant growth. Also feeds microorganisms in the soil
Phosphorus		Plays an important role in root growth and promotes the establishment of young plants, flowering, fruiting and ripening, photosynthesis, respiration and overall plant growth.
Potassium		Moves through the plant. Promotes the movement of sugars, turgor and stem rigidity. Also increases the plant's overall resistance to cold, diseases, insect pests, etc. Promotes the formation of flower buds, the hardening-off of woody plants and fruiting.
Secondary nutrients		
Calcium		Plays a vital role in plant structure, because it is part of cell walls and holds them together. Promotes the development of the root system and the ripening of fruit and seeds. Found in the growing parts of plants (apex and buds).
Magnesium		An important part of chlorophyll. Helps fruit ripen and seeds germinate. Reinforces cell walls and promotes the absorption of phosphorous, nitrogen and sulphur by plants
Sulphur		A component of several proteins, enzymes and vitamins. Contributes to chlorophyll production. Helps plants absorb potassium, calcium and magnesium.
Micronutrients		

Iron		Essential to chlorophyll production. Also contributes to the formation of some enzymes and amino acids.
Boron		Essential to overall plant health and tissue growth. Promotes the formation of fruit and the absorption of water.
Manganese		Promotes seed germination and speeds plant maturity. Plays an important role in photosynthesis by contributing to chlorophyll production. Essential for nitrogen assimilation and protein formation.
Molybdenum		Essential for nitrogen assimilation by plants and nitrogen fixation by bacteria. This means that it is needed for the production of nitrogen-based proteins.
Chlorine		Stimulates photosynthesis.
Copper		Activates various enzymes. Also plays a role in chlorophyll production
Zinc		Plays an important role in the synthesis of proteins, enzymes and growth hormones.
Nickel		Key component of selected enzymes involved in N metabolism and biological N fixation.
Beneficial elements		
Silicon		Strengthens cell walls, energy transfer & drought resistance Reduces water loss & prevents fungal infection.
Cobalt		Essential in N fixation
Sodium		Na replaces K in certain functions in halophytes plants For C4 plants having dicarboxylic photosynthetic pathway
Vanadium		Essential for green algae

Forms of elements in Mineral soil

Macro elements are available in (1) Solid (2) Cations (3) Cations in soil solution

Nutrients	Mineral / solid	Cations	Soil solution as ions
N	Organic compounds and Amino acids	NH_4^+	NH_4^+ , NO_2^- , NO_3^-
P	Organic compounds, nucleic acid and inorganic compounds. Ca, Fe, Al, PO_4 's	-	H_2PO_4^- , HPO_4^-
K	Feldspar, mica, silicate clays	K^+	K^+
Ca	Feldspar, hornblende, lime stone	Ca^{2+}	Ca^{2+}
Mg	Mica, Hornblende, lime stone	Mg^{2+}	Mg^{2+}
S	Organic sources – protein, amino acids inorganic sources – Gypsum, pyrites .	- -	HSO_4^- , SO_3^{2-} SO_4^{2-}

Forms of nutrient element absorbed by plants

Nutrient element	Forms absorbed
C	Mainly through leaves - CO_2
H	HOH (Hydrogen from H_2O) – H^+
O	CO_2 mainly through leaves – O_4^{2-} , OH^- , CO_3^{2-}
N	NH_4^+ , NO_3
K	K^+
Ca	Ca^{2+}
Mg	Mg^{2+}
S	SO_4^{2-}
Fe	Fe^{2+} (Ferrous), Fe^{3+} (ferric)
Mn	Mn^{2+} (Manganous), Mn^{4+} (Manganic)

Zn	Zn^{2+}
Cu	Cu^+ (cuprous), Cu^{2+} (Cupric)
Co	CO^{2+}
Na	Na^+
Si	$\text{Si}(\text{OH})_4$
Cl	Cl^-
B	H_3BO_3 (Boric acid) H_2BO_3^- (Borate)
Mo	MoO_4^{2-}

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Tisdale, S.L., Nelson, W.L., Beaton, J.D., Havlin, J.L. 1997. Soil fertility and Fertilizers. Fifth edition, Prentice hall of India Pvt.Ltd, New Delhi.

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<http://edis.ifas.ufl.edu/hs1191>

Questions to ponder

- 1) How will you differentiate between N and K deficiencies of corn visually?
- 2) What is luxury consumption?
- 3) Which element is absorbed both in anionic and cationic forms?
- 4) Which element is specifically involved in nitrate reduction in plants?
- 5) Name the nutrients whose deficiencies are first exhibited in the apical region of the growing plant?

06.

Mechanism of nutrient transport in plants

Learning objectives

- a. Understand ways in which nutrients in the soil reach plant roots
- b. To know how plant roots absorb nutrients and move inside plants

Nutrients must reach the surface of a root for plant uptake of essential elements to occur. There are three major mechanism of movement of ions from soil to roots. They are

Root interception

Root interception occurs when a nutrient comes into physical contact with the root surface. As a general rule, the occurrence of root interception increases as the root surface area and mass increases, thus enabling the plant to explore a greater amount of soil. Root interception may be enhanced by mycorrhizal fungi, which colonize roots and increase root exploration into the soil. Root interception is responsible for an appreciable amount of **calcium** uptake, and some amounts of **magnesium, zinc** and **manganese**. The CEC of roots for monocots is 10 - 30 meq/100 g and takes up monovalent cations more readily and that of Dicots is 40 - 100 meq/100 g and takes up divalent cations more readily. The quantity of nutrients intercepted by roots depends on the soil concentration of nutrients and volume of soil displaced by root system

Factors affecting root interception

- a. Anything that restricts root growth
 - i. Dry soil
 - ii. Compaction
 - iii. Low soil pH
 - iv. Poor aeration
 - v. Root disease, insects, nematodes
 - vi. High or low soil temperature
- b. Root growth is necessary for all three mechanisms of nutrient supply, but absolutely essential for root interception to occur

Mass flow:

Mass flow occurs when nutrients are transported to the surface of roots by the movement of water in the soil (i.e. percolation, transpiration, or evaporation). The rate of water flow governs the amount of nutrients that are transported to the root surface. Therefore, mass flow decreases as soil water decreases. Most of the **nitrogen, calcium, magnesium, sulfur, copper, boron, manganese** and **molybdenum** move to the root by mass flow. Quantity of nutrients transported is proportional to:

- i. Rate of flow (volume of water transpired)
- ii. Solution concentration of nutrient

Nutrients supplied primarily by mass flow are considered mobile nutrients. e.g. N, S, B

Factors affecting mass flow

- a. Soil water content
 - i. Dry soil where there is no nutrient movement
- b. Temperature
 - i. Low temperature reduces transpiration and evaporation
- c. Size of root system
 - i. Affects water uptake and therefore movement
 - ii. Root density much less critical for nutrient supply by mass flow than for root interception and diffusion

Diffusion:

Diffusion is the movement of a particular nutrient along a concentration gradient. When there is a difference in concentration of a particular nutrient within the soil solution, the nutrient will move from an area of higher concentration to an area of lower concentration. This phenomenon is observed when adding sugar to water. As the sugar dissolves, it moves through parts of the water with lower sugar concentration until it is evenly distributed, or uniformly concentrated. Diffusion delivers appreciable amounts of **phosphorus, potassium, zinc, and iron** to the root surface. Diffusion is a relatively slow process compared to the mass flow of nutrients with water movement toward the root. Nutrients supplied primarily by diffusion are considered immobile nutrients e.g. P, K

Factors affecting diffusion

- a. Fick's law is given as $dC/dt = De * A * dC/dX$

dC/dt = diffusion rate (change in concentration over time)

De = effective diffusion coefficient

A = cross sectional area for diffusion

dC/dX = concentration gradient (change in concentration over distance)

Diffusion rate is directly proportional to concentration gradient, diffusion coefficient, and the area available for diffusion to occur

b. Effective diffusion coefficient

Effective diffusion coefficient $De = Dw * q * (1/T) * (1/b)$ where

Dw = diffusion coefficient in water

q = volumetric soil water content

T = tortuosity factor

b = soil buffering capacity

- a. Diffusion coefficient in water (Dw)
 - i. Includes a temperature factor

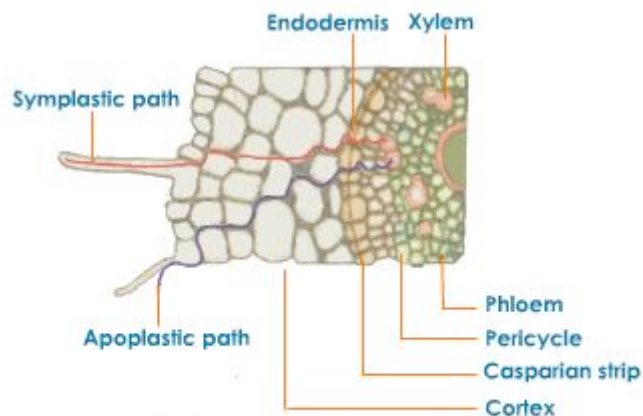
- ii. Colder = slower diffusion
 - b. Soil water content
 - i. Drier soil = slower diffusion
 - ii. Less water = less area to diffuse through
 - c. Tortuosity
 - i. Pathways through soil are not direct
 - ii. Around soil particles, through thin water films
 - iii. Affected by texture and water content
 - 1. More clay = longer diffusion pathway
 - 2. Thinner water films = longer path
 - d. Buffering capacity
 - i. Nutrients can be removed by adsorption as they move through soil, reducing diffusion rate
- c. How far can nutrients diffuse in a growing season?**
 - a. Diffusion distances are very short
 - i. K ~ 0.2 cm
 - ii. P ~ 0.02 cm
 - b. Size and density of plant root systems is very important for nutrients supplied by diffusion
 - c. Has implications for fertilizer placement

Ion traffic into the root

Mineral nutrients absorbed from the root has to be carried to the xylem. This transport follows two pathways namely apoplastic pathway and symplastic pathway.

In apoplastic pathway, mineral nutrients along with water moves from cell to cell through spaces between cell wall by diffusion. The ions, which enter the cell wall of the epidermis move across cell wall of cortex, cytoplasm of endodermis, cell walls of pericycle and finally reach the xylem.

In symplastic pathway, mineral nutrients entering the cytoplasm of the epidermis move across the cytoplasm of the cortex, endodermis of pericycle through plasmodesmata and finally reach the xylem.



Anatomical aspect of symplastic and apoplastic pathways of ion absorption in the root hair region

Translocation of solutes

P.R. Stout and Dr. Hoagland have proved that mineral nutrients absorbed by the roots are translocated through the xylem vessel. Mineral salts dissolved in water moves up along the xylem vessel to be transported to all the parts of the plant body. Translocation is aided, by transpiration. As water is continuously lost by transpiration on the upper surfaces of the plant, it creates a transpirational pull, by which water along with mineral salts is pulled up along the xylem vessel.

Active absorption of energy can be achieved only by an input of energy. Following evidences show the involvement of metabolic energy in the absorption of mineral salts.

- Higher rate of respiration increases the salt accumulation inside the cell.
- Respiratory inhibitors check the process of salt uptake.
- By decreasing oxygen content in the medium, the salt absorption is also decreased.

These evidences indicate that salt absorption is directly connected with respiratory rate and energy level in the plant body, as active absorption requires utilization of energy.

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http://www.ctahr.hawaii.edu/mauisoil/c_relationship.aspx

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Questions to ponder

- 1) What is contact exchange?
- 2) What soil factors influence diffusion of nutrients to roots?
- 3) What is diffusion?
- 4) Why is anion adsorption little important in agricultural soils?
- 5) What is the mechanism of active absorption of iron by roots?

Nitrogen – Transformation, factors affecting nitrogen availability ,deficiency and toxicity symptoms

Learning objectives

- a. To understand the transformation of nitrogen
- b. To know the factors affecting the availability of nitrogen
- c. To understand the deficiency symptoms of Nitrogen and corrective measures

Nitrogen

The cheap source of N is the crop residues in temperate region. In tropical soils, the total N content is 0.03 - 0.1 %. Rainfall is also source of N at 4.6 kg of N / ha is received $\text{ha}^{-1} \text{yr}^{-1}$. It is converted to NO_3 during lightning addition of organic matter and fertilizer is other major sources. Nitrogen is an essential constituent of protein and also other non protein compounds of great physiological importance in plant metabolism. It is an integral part of chlorophyll, which is primary observer of light energy needed for photosynthesis. Nitrogen also imparts vigorous vegetative growth and governs the utilization of P,K and other elements

Forms of soil nitrogen

Inorganic forms N

1. Ammonium NH_4^+
2. Nitrite NO_2^-
3. Nitrate NO_3^-
4. Elemental N (No)

Organic forms of soil

- Amide form (NH_2)
- Plant absorbs N as both
- NH_4^+ , NO_3^- .

Losses of Nitrogen

1. Crop removal
2. Leaching (or) drainage (11-18% loss)
3. Gaseous losses as NH_4 or elemental N_2
4. Volatilization.
5. Erosion ($8 - 15 \text{ kg ha}^{-1} \text{yr}^{-1}$).
6. Ammonia fixation by clays
7. Immobilization in organic materials.

N transformations in soils

- a. N - Mineralisation
- b. Aminisation
- c. Conversation of urea

- d. N Immobilization.
- e. N factor
- f. Ammonification.
- g. Nitrification
- h. Denitrification
- i. Organic fixation
- j. Elemental N loss.
- k. Nitrogen cycle.

N transformations in soils

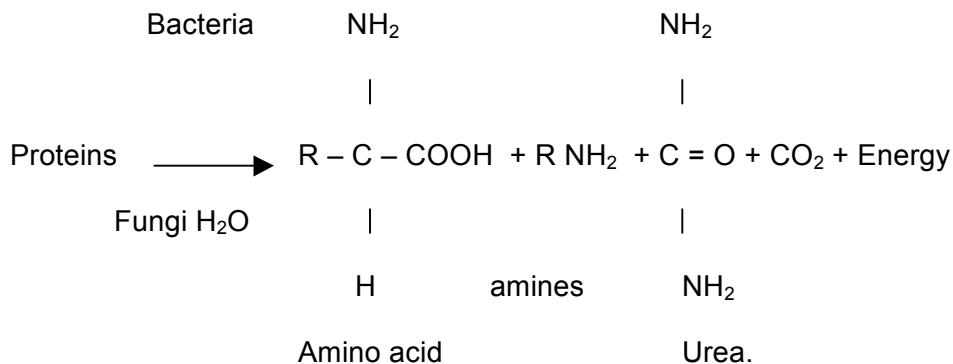
Nitrogen mineralization

Mineralization is the conversion of organic N to NH_4^+ as a result of microbial decomposition. Mineralization increases with a rise in temperature and is enhanced by adequate, although not excessive, soil moisture and a good supply of O_2 . Mineralization of organic N involves in two reactions.

i.e 1) Aminization 2) Ammonification.

Aminisation

Aminisation is the decomposition of proteins and the release of amines, amino acids and urea is called aminisation.



The initial step in the decomposition of organic matter by the enzymatic digestion of proteins into amino acids like, peptones and amino acid. **Under aerobic** protolysis the major end products are CO_2 $(\text{NH}_4)_2 \text{SO}_4$ and H_2O . Under anaerobic conditions the end products are ammonia, amides, CO_2 and H_2S .

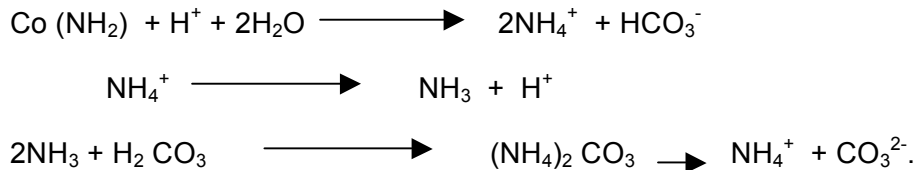
The organic compounds and proteins are mainly decomposed by various species of Pseudomonas,

Bacilli, clostridium, serrotia, Micrococcus

Generally in the neutral and sodic soils, bacteria are active and in acidic soils fungi are active.

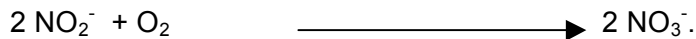
Conversion of urea

Urea is a product of ammonification. The hydrolysis of urea by the action of urease enzyme is effected by Bacilli, micrococcus, Pseudomonas, clostridium, Aeromonas and corynebacterium.



The optimum H₂O holding capacity for these reactions is 50 – 75 and optimum temperature is 30 – 50°C.

The NH₄⁺ can be utilized by microorganisms and root of higher plants. Some of the released NH₃ is fixed by clay especially illite. A major portion is oxidized to nitrate form. In the second reaction NO₂⁻ is further oxidized to NO₃⁻ by nitrobacter.



Nitrogen immobilization

“Immobilisation is the process of conversion of inorganic N (NH₄⁺ or NO₃⁻) to organic N and it is basically the reverse of N mineralization”.

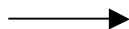
The Microorganisms accumulate NH₄⁺ N and NO₃⁻ N in the form of protein, nucleic acid and other complexes. If C:N ratio is wider than 30, it favours immobilization and lesser C:N ratio encourage mineralization.

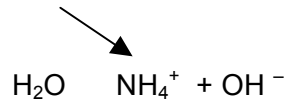
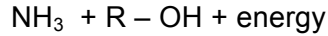
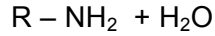
N factor

N factor is the No of units of inorganic nitrogen immobilized for each 100 units of materials under going decomposition”. The average values for the nitrogen factor vary from 0.1 or < to 1.3.

Ammonification

“Amines and Aminoacids produced during aminification of organic N are decomposed by other heterotrophs with release of NH₄⁺ is termed Ammonification”





Nitrification

Nitrification is the process of biological oxidation by which the NH_4 - Cal form of N converts to nitrate form of N. There are two steps. (a) NH_4 is converted first to NO_2^- and then to NO_3^- .

Nitrosomonas



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

Others autotrophic bacteria *Nitrosolobus*, *Nitrospira* and *nitroso vibrio* and to some extend heterotrophic bacteria also can oxidize NH_4^+ and other N reduces, compounds to NO_3^- .

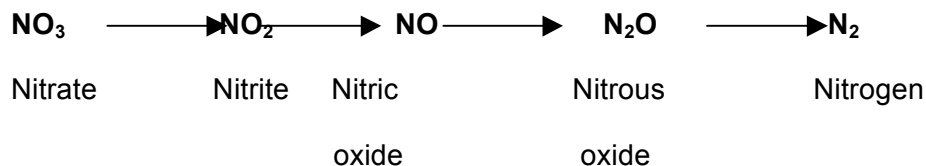
Losses of Nitrogen

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.

Denitrification

Denitrification is the biochemical reduction of NO_3N or NO_2N to gaseous N, either as molecular Nitrogen or an oxide of Nitrogen. The most probable bio chemical pathway is



Nitrogen fixation

The conversation of elemental nitrogen to organic forms readily use able in biological process. Vermicullite and illite are capable of fixing NH_4^+ by a replacement of K^+ or Na^+ for interlayer cations in the expended lattice of clay minerals. The radius of NH_4 ion $0.143^\circ A$. K^+ ion $0.133^\circ A$.

Because of NH_4 and K have more or less same charge, they easily replace each other in the exchange sites.

Organic fixation

If the soil has more organic matter the NH_4 will lockup as a complex. These complexes are called **Chelates**. It releases the nutrients only after its molecular breakdown. The facultative aerobic bacteria like pseudomonas, bacillus, paracoccus are responsible for denitrification. It also depends upon the texture of soil. In heavy clay soils loss is up to 50% of added fertilizer.

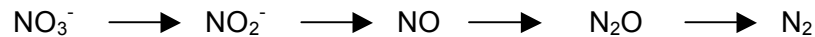
Elemental N loss

It is due to chemical reduction. If chemical fertilizer containing amide (or) NH_4 form of N, it may be oxidized to elemental N and lost.

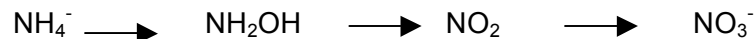


Sources of N leading to N and NO_2 gaseous loss

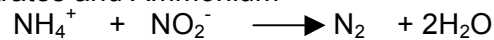
1. Denitrification



2. Nitrification



3. Nitrates and Ammonium



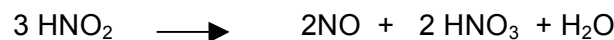
4. Nitrites and aminoacids.



5. Lignin : $\text{HNO}_2 + \text{lignin} \xrightarrow{\text{N}_2 + \text{N}_2\text{O} + \text{CH}_3\text{O NO}}$

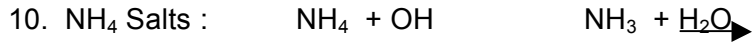
6. Phenols : Phenol $\longrightarrow \text{N}_2 + \text{N}_2\text{O} + \text{Organic residue}$

7. Decomposition of nitrous acid / reaction with metal cations.



8. NH_3 Gas

9. Urea : $(\text{NH}_4)_2\text{CO} + \text{H}_2\text{O} \xrightarrow{2\text{NH}_3} \text{CO}_2$



11. Decomposition of residues and manures

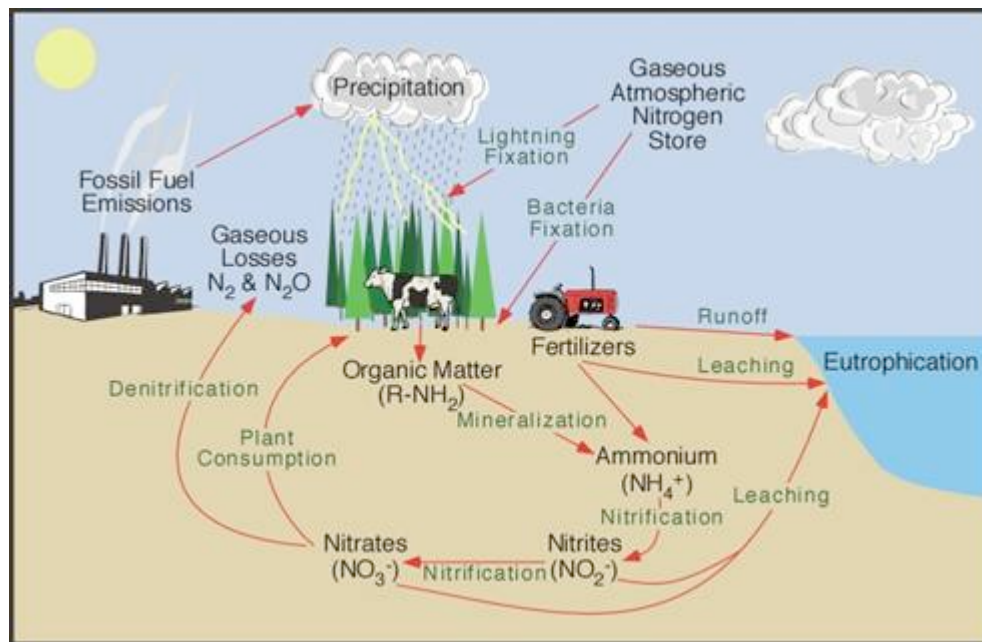
Release and volatilization of NH_3

Nitrogen cycle

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

The N cycle can be divided into

1. N inputs or gains.
 2. N outputs or losses
 3. N cycling with in the soil.
1. N in plant and animal residues and N derived from the atmosphere through electrical, combustion, biological and industrial process is added to the soil.
 2. N in the residues is mobilized as NH_4 by soil organisms as an end product of residue decomposition, plant roots absorb a portion of the NH_4 .
 3. Much of the NH_4 is converted to NO_3^- by nitrifying bacteria in a process called nitrifications.
 4. NO_3 is taken up by the plant roots and is used to produce the protein in crops that are eaten by humans or fed to live stocks.
 5. Some NO_3 is lost to ground H_2O or drainage systems as a results of downward movement through the soil in perculating H_2O .
 6. Some NO_3 is consorted by denitrifying bacteria in to N_2 and N_2O that escape into the atmosphere, completely the cycle.



The nitrogen cycle

Source: <http://www.physicalgeography.net>

Important microorganisms in BNF

Organisms	Properties	Active location
Azotobacter	Aerobic, free living	Soil, water, rhizosphere, leaf surface
Azospirillum	Micro aerobic rhizobacteria; free fixers	Free living in Rhizosphere; Colonize roots of cereals and also gives phytotonic effect
Rhizobium	Symbiotic	Root nodules of legumes
Actinomyces, Frankia, Beijerinckia	Symbiotic	Non leguminous forest tree roots, leaf surfaces
Cyanobacteria	Photo autotrophic Anabaena - symbiotic	In wetland flood water; Anabaena associate with Azolla

Symbiotic N fixation

The symbiosis is the mutually beneficial relationship between host plant and bacteria. The location of association is in root or stem nodules, inside cavities, or by colonizing and penetrating plant tissue.

Legume (nodule forming)

Legumes and bacteria of the genera **Rhizobium** and **Bradyrhizobium** provide the major biological source of fixed N (40-60%) in agricultural soils. These organisms infect the root hairs and the cortical cells, ultimately inducing the formation of root nodules that serve as the site of N fixation. The host plant supplies the bacteria with carbohydrates for energy and the bacteria reciprocate by supplying the plant with fixed N compound.

Effective nodules cluster on primary roots and have pink to red centers. The red colour of the nodule is attributed to the occurrence of **leghemoglobin**. The quantity of N fixed by properly nodulated legume averages about 75% of the total N used for the plant growth. The amount of BNF varies with Rhizobium strain, host plant, and environment.

Yield of non-legume crops often increases when they are grown following legumes (e.g. maize after soybean). Maximum N fixation occurs only when available soil N is at a minimum. When optimum conditions for N fixation are not prevailing, a legume crop can deplete soil N greatly, more than a cereal, if the legume grown is not incorporated into the same soil.

Fixer	Host plant
Rhizobium	Alfalfa, clover, peas, bean, soybean
	Gliricidia, Leuceana, Sesbania, Mimosa, Acacia 3 (3/4)
Bradyrhizobium	Cowpea, groundnut, red gram

Non-legume (nodule forming)

Roots of many species of angiosperm trees like casuarina in forests and wetlands form distinct nodules when infected with Actinomycetes of the genus **Frankia**.

Non-legume (non-nodule forming)

Azospirillum, **Azotobacter**, and **Azorhizobium**, dominant N fixers in cereals like rice, wheat, corn, sorghum, millets can grow on root surfaces and penetrate root tissues. The organisms use carbohydrates of root exudates as source of energy. They also induce crop growth by hormonal action. The organism **Beijerinckia** fixes N on leaf surfaces of tropical plants.

The **Anabaena** blue green algae (Cyanobacteria) inhabit cavities in the leaves of the floating water fern **Azolla** and fix quantities of N comparable to those of the better Rhizobium-legume complex. It could fix about 30-105 kg N/ season taking care of 75% N requirement of rice.

Nonsymbiotic N fixation

In wetland floodwater photoautotrophic **Cyanobacteria** independently do photosynthesis and fix N up to 20–30 kg N/ ha/ year. The excess ammonia is excreted in floodwater, which is beneficially absorbed by rice plants.

Free-living heterotroph bacteria like **Azotobacter** and **Beijerinckia** in aerobic upland soils and **Clostridium** in anaerobic wetland soils effectively fix N in pockets where O₂ supply is limited. Fixation depends upon the pH, soil N level, and source of organic matter.

Industrial fixation of N

Commercially produced N is the most important source of plant nutrient in agriculture. Industrial N fixation is by Haber-Bosch process, in which H₂ and N₂ gases react to form NH₃ under high temperature (1200^o C) and pressure (500 atm). Anhydrous NH₃ can directly be used as fertilizer or combined to other ions as solid forms.

N additions from atmosphere

Ammonia escapes in to atmosphere from soils, manures, and industries because of volatilization. Organic N compounds remain in fine dust of air lifted from earth surface. Rainfall brings down to soil NH₃, NO₃⁻, NO₂⁻, N₂O, and organic N. About 10 to 20% of the NO₃⁻ in the rainfall is due to fixation of N₂ by energy of lightning.

Deficiency and toxicity symptoms of Nitrogen in plants

Deficiency of N:

1. Plants are stunted and yellow in appearance.
2. The loss of protein N from chloroplasts. In older leaves produces the yellowing or chlorosis. It appears first on the lower leaves, the upper leaves remain green, while under severe N deficiency lower leaves will turn brown and die.
3. The necrosis begins at the leaf tip and progress along the midrib until the leaf is dead.
In cauliflower - young leaves turn pale yellow and old leaves become orange.

In coffee - Veins becomes yellow and new leaves are very small.

Tomato - Stem become purple and hard. Flower buds become yellow and flower dropping rate also increases

Excess of Nitrogen (Toxicity of nitrogen)

- a. Causes excess vegetative growth, dark green leaves, lodging, maturity is delayed with increases susceptibility to pest and disease.
- b. In cotton, weak fibre are resulted. In rice, lodging is common.
- c. Lengthening of crop duration and narrow leaf.
- d. Slender shoot, profuse vegetation, thick peel and skin will be rough and leathery in the case of citrus.
- e. Excess N in coffee plant, interferes the K uptake causing imbalance between N and K.

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Questions to ponder

- 1) How does the soil pH affect the nitrogen availability?
- 2) What climatic factors influence nitrogen availability to crops?
- 3) What is nitrogen fixation?
- 4) What is C: N ratio?
- 5) How does salinity affect nitrogen availability?

Phosphorus – Transformation, factors affecting Phosphorus availability, deficiency and toxicity symptoms

Learning objectives

- a. To understand the transformation of phosphorus
- b. To know the factors affecting the fixation of phosphorus
- c. To understand the deficiency symptoms of Phosphorus

Phosphorus

Phosphorus is taken up by the plant in the form of H_2PO_4^- , HPO_4^{2-} , PO_4^{3-} through **diffusion** and **mass flow** action.

The P availability mainly depends on pH. In acid soils (**Al & Fe**) the presence of Al, Fe, Mn, P gets fixed as AlPO_4 , FePO_4 and not available to the plants. Some times as CaPO_4 . these are insoluble in H_2O .

Under hilly areas (or) high rainfall areas, all the cations will be leached leaving Fe, Al and Mn. The P availability will be reduced.

Ideal pH for available P = 6.5 - 7.5. If pH > 8.5 the fixation will be more. < 6.5 the fixation will be more.

Forms of P

Organic P : Nucleic acid and Phospho lipids

Rock Phosphate - acid soluble. If the organic matter content is high the availability of P is more since it is soluble in acid. It is highly suited to **plantation crops**. Rock Phosphates is black in colour. Roots also exudates acids, which will solublises the P.

Fixation is high so the P_2O_5 deficiency is 15 – 35%.

P is present as Apatities

1. Chlor - $\text{Ca}_{10}(\text{PO}_4)_6 \text{Cl}_2$.
2. Fluor - $\text{Ca}_{10}(\text{PO}_4)_6 \text{F}_2$.
3. Carbonate - $\text{Ca}_{10}(\text{PO}_4)_6 \text{CO}_3$.
4. Hydroxy - $\text{Ca}_{10}(\text{PO}_4)_6 (\text{OH})_2$.

Based on solubility the P fertilizers can be grouped into 4 groups.

1. H₂O soluble : (i) SSP 16% P as H₂O soluble
P : (ii) TSP 45% P as H₂O soluble
2. Citrate soluble : Dicalcium PO₄ 34% P₂O₅.
P : Tricalcium PO₄ 24%
3. Acid soluble P : Anhydrous Rock phosphate 16 - 18 %
4. Both H₂O and citrate soluble P: Kotka PO₄ 25% P₂O₅.

Rock phosphate is obtained in Bihar: Singlahe

Rajaithan: Udaipur

Uttar Pradesh: Mussoorri

Andhra Pradesh: Kasi pattinam

Phosphorus occurs in most plants in concentrations between 0.1 and 0.4%. Plants absorb either H₂PO₄⁻ or H + PO₄²⁻ ortho PO₄ ions Absorption of H₂PO₄⁻ is greatest at low pH values, where as uptake of HPO₄²⁻ is greater at higher values of soil pH, plant uptake of HPO₄⁻ is much slower than H₂PO₄⁻.

Functions of P

1. It has a greater role in energy storage and transfer.
2. It is a constituent of nucleic acid, phytin and phospholipids
3. It is essential for cell division and development
4. P compounds act as energy currency within plants. The most common P energy currency is that found in ADP and ATP. Transfer of the energy rich PO₄ molecules from ATP to energy requiring substances in the plant is known as **“Phosphorylation”**
5. It stimulates early root development and growth and there by helps to establish seedlings quickly.
6. It gives rapid and vigorous start to plants strengthen's straw and decreases lodging tendency.
7. It is essential for seed formation because larger quantities of P is found in seed and fruit-phytic acid is the principle storage form of phosphorus in seeds.
8. It increases the activity of Rhizobia and increases the formation of root nodules.

Soil P its origin and Nature

Soil P exists in many primary and secondary compounds. The **apatite** group of primary mineral is the original source i.e. 55% of soil P.

a) Aluminium and Iron Phosphates

In the initial stages of acid weathering PO_4 becomes increasingly bound to Fe^{3+} and Al^{3+} ions released from silicate minerals by replacing OH^- from **hydroxyl minerals** or oxygen from **oxide minerals**. FePO_4 and ZnPO_4 has been found in H_2O logged or poorly drained soils, sand and silt fraction of some soils.

Calcium phosphates

The group of compounds form an important category in the young soils and the matured soils of **neutral** to **alkaline** pH ranges. The CaPO_4 found either in **stable** or **metastable** state in the soil fertilizer reaction zones.

Eg. Fluorapatite	-	$\text{Ca}_{10}(\text{PO}_4)_3 \text{Fe}$
Carbonate apatite	-	$\text{Ca}_{10}(\text{PO}_4)_3 \text{CO}_3$
Dicalcium PO_4	-	$\text{Ca HPO}_4 \cdot 2\text{H}_2\text{O}$
Monocalcium PO_4	-	$\text{CaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$.

Organic phosphates

It is derived secondarily by the addition of organic matter to the soil through the growth of plants and the deposition of plant residues. The soil micro organic synthesize organic PO_4 compounds and accumulate in the soil mixed with derived from plant tissues. It constitute 20 – 30% of total soil P. The major classes of organic compounds in soils are

- Phospholipids (0.6 – 0.9%)
- Phospho proteins of nucleic acid (0.6 – 2.4%)
- Phosphorylated sugar
- Phytin and Inositol PO_4

The ideal C : N : P : S ratio in soils are

- Calcarious 113 : 10 : 1.3 : 1.3
- Non calcarious 147 : 10 : 2.5 : 1.4
- Indian soils 144 : 10 : 1.4 : 1.8

Chemistry of solid phosphorus compounds and their equilibrium

The PO_4 concentration in soil solution is governed by the heterogenous equilibrium.

P adsorbed in soil $\text{PO}_4 \longrightarrow$ P in soil solution \longrightarrow P' precipitated in soil solution.

The reactions involved in soil PO_4 equilibrium are **dissolution, precipitation, solubility product principle.**

By using radio active p^{32} Larsen (1952) characterized the total soil PO_4 into **Labile** and **Non labile** fractions and found the size of the labile pool primarily depended on soil properties and not a function of the total content of inorganic P. he correlated and equilibrium of

Non labile soil P \rightleftharpoons Labile soil P \rightleftharpoons P in soil solution.

Fixation of phosphorus in soil

"It is the way of removal of PO_4 from solution by soil which reduces the amount that plant roots can absorb".

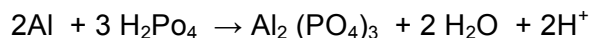
The factors affecting P fixation are.

1. clay minerals

The PO_4 is fixed by clay minerals by reacting with soluble aluminum which originates from the exchanges sites or from lattice dissociation to form a highly **insoluble AlPO_4** .

2. Iron and Aluminum (fixation in acid soils)

The formation of Iron and aluminium PO_4 in the soil results from the combination of P with these metals in solution and their oxides hydroxides in acid soil.



3. Exchange cations and calcium carbonate (Fixation alkaline soils)

In calcareous soils, free Ca CO_3 is a potent sources for 'P' fixation. P fixation in calcareous soil involved a rapid monolayer sorption of P in dilute concentration In CaCO_3 surfaces and form less soluble compounds of di and tricalcium PO_4 .



4. Organic matter

Organic Po_4 can be fixed by soil organic matter also influences in Organic Po_4 fixation. The acids produced during the transformations of Organic matter could decrease the pH and increase fixation by the solubilization of Fe and Al.

P Fixation in soil is affected by

1. Nature and Amount of soil minerals

Soils have high amount of Fe and Al oxides, crystalline hydrous metal oxides are usually capable of retaining more P than amorphous forms. P adsorbed to a greater extent by 1 : 1 than 2 : 1 clays. The greater amount of P fixed by 1 : 1 clays is probably due to the higher amounts of Fe and Al oxides, associated with kaolinite clays that are predominant in highly weathered soils. Soils containing large quantities of clay will fix more P than soils with low clay content.

2. Soil pH

- a. Fixation of P by Fe and Al oxides decreases with increasing pH.
- b. P availability is more in soils at a max in the pH range of 5.5 to 6.5
- c. At low pH values, Fe and Al ions react with to form AlPO_4 and FePO_4 oxides.
- d. As the pH increases, the activity of Fe and Al decreases and the results of higher amount of P liberates into soil solution.

Above pH 7.0, Ca^{2+} can precipitate with P as $\text{Ca}_3(\text{PO}_4)_2$ mineral and P availability again decreases.

3. Cation effects

Divalent cations enhance the P fixation than monovalent cations.

4. Anion effects

Both organic and inorganic anions can compete with P for adsorption sites, resulting in decrease the fixation of P.

5. Organic matter

Addition of organic matter to soils increased P availability by

- a. Formation of organo PO_4 complexes that are more easily assimilate by plants.
- b. Anion replacement of H_2PO_4^- on adsorption sites.
- c. Coating of Fe and Al particles by humus to form a productive cover and thus reduce the P fixation.

6. Temperature

The rate of most chemical and biological reactions increases with increasing temperature. Mineralization of P from soil organic matter is dependent on soil biological activity and increases in temperature.

7. Flooding

In most soils there is an increase in available P after flooding largely due to conversion of $\text{Fe}^{3+} \text{PO}_4$ to soluble $\text{Fe}^{2+} \text{PO}_4$ and hydrolysis of Al PO_4 and thereby prevent the fixation of P in soils.

8. $\text{R}_2\text{O}_3 : \text{P}_2\text{O}_5$ (Ratio)

" $\text{R}_2\text{O}_3 : \text{P}_2\text{O}_5$ (Ratio) is a measure of amount of P present in the soil". A wide ratio indicates a small P fixation and vice versa. When the ratio is narrow P fixation is more.

9. Addition of ZnSO_4

It may also cause P deficiency since it forms insoluble complex with P. This can be averted by addition of ZnSO_4 more and more.

P Cycle

"Process by which P moves from solid and liquid phase and transformation is called P cycle". P is taken mostly by diffusion in plants.

I. The decrease in soil solution P concentration with absorption by plants roots is buffered by both inorganic and organic fractions in soils.

Primary and secondary P minerals dissolve to re supply $\text{H}_2\text{PO}_4^- / \text{HPO}_4^{2-}$ in solution.

Inorganic P adsorbed on mineral and clay surfaces as H_2PO_4^- or HPO_4^{2-} (labile inorganic P) also can desorb to buffer decreases in soil solution P. Numerous soil micro organic digest plant residues containing P and produce many organic plant compounds in soil and it can be mineralized through microbial activity to supply solution P.

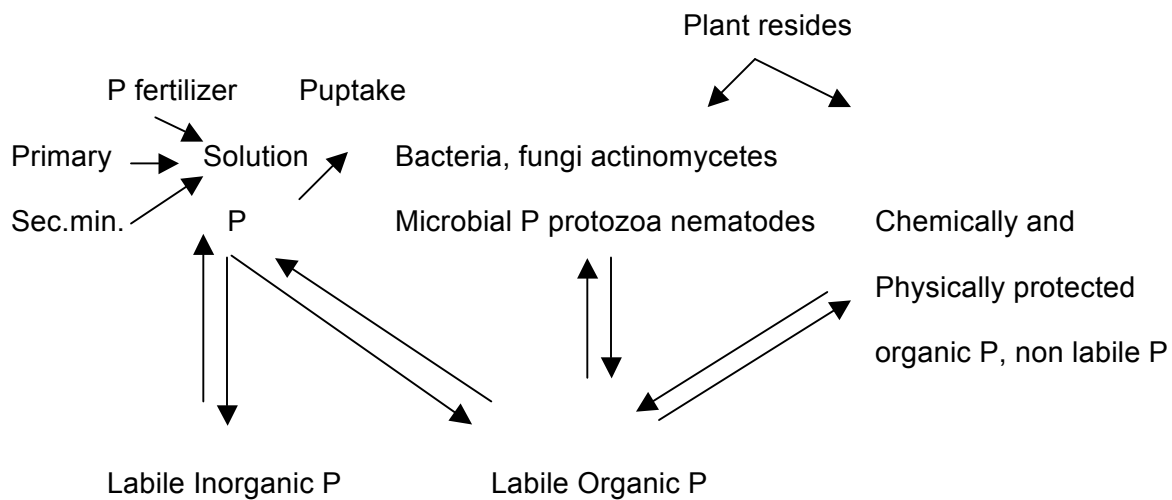
H_2O soluble fertilizer P applied to soil readily dissolves and increases the concentration of soil solution.

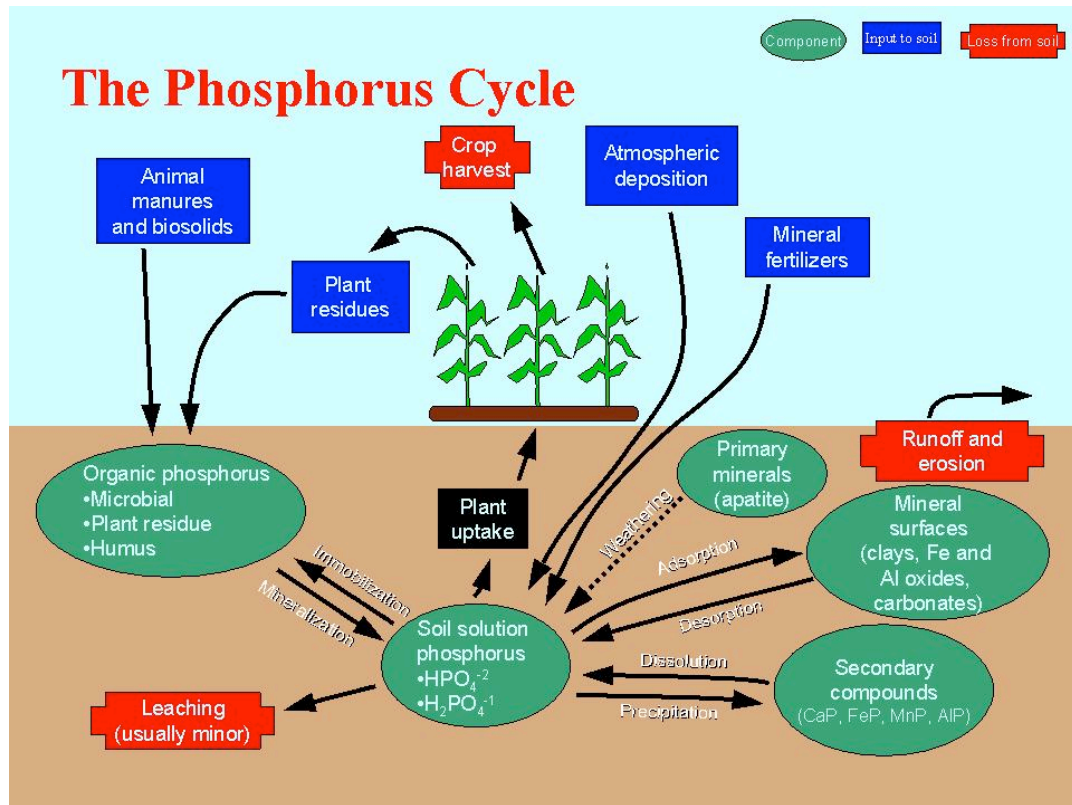
II. In addition to uptake of P by roots, solution P can be adsorbed on minerals surfaces and precipitated as organic P and these organic P compounds are more resistant to microbial degradation.

Soil solution P is called **Intensity factor**, while organic and inorganic labile P fractions are collectively **Quantity factor**.

Maintenance of solution P concentration for adequate P nutrition in the plant depends on the ability of labile P to replace soil solution P. “The ratio of quantity to intensity factor in called the **capacity factor**, “which express the relative ability of the soil to buffer changes in soil solution”.

P cycle can be simplified to Soil solution \longrightarrow labile P \longrightarrow Non labile P
 (Inorganic) (Organic)





Source: <http://phsgirard.org/Biology/Ecology/PhosphorusCycle.jpg>

Y value / L value (Larsens Value)

Larsen measured the quantity of soil P involved in the isotopic dilution of applied radio active P during a growing season. It is used to calculate P supply of the soil.

$$L \text{ (or) } Y = K \times \frac{(C_o - C)}{C}$$

Where, L = Avail P in soil

C_o = K x total P in the Plant

C = K x P taken by the plant

K = Proportionality constant.

Deficiency symptoms

P is mobile in plants and when a deficiency occurs it is translocated from older tissues to the active meristematic regions.

1. It arrests metabolism resulting in reduction of total N of Plants.

2. Reduced sugar content.
3. Premature leaf fall.
4. Develops necrotic area on the leaf petiole and in the fruit
5. Leaves will show characteristic bluish green colour.

Toxicity of phosphorus

- a. Profuse root growth i.e. lateral and fibrous root lets.
- b. It develops normal growth having green leaf colour.
- c. It may cause in some cases trace elements deficiencies i.e. **Zinc and Iron.**

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Singh, S.S. 1995. Soil fertility and Nutrient Management. Kalyani Publishers, Ludhiana.

<http://phsgirard.org/Biology/Ecology/PhosphorusCycle.jpg>

Questions to ponder

- 1) What is the role of soil pH in P availability?
- 2) P fixation is a blessing in disguise. How?
- 3) What are the natural sources of P?
- 4) What is C: P ratio?
- 5) How does calcareousness affect P availability?

9.

Potassium – Transformation, factors affecting Potassium availability, deficiency and toxicity symptoms

Learning objectives

- To understand the transformation of Potassium
- To study the forms of K and factors affecting K availability
- To understand the deficiency symptoms of Potassium

Potassium

The potassium ion (K^+) is actively taken up soil solution by plant roots. The concentration of K^+ in vegetative tissue ranges from 1 to 4% on dry matter basis.

Functions of potassium

- Essential for photosynthesis, development of chlorophyll.
- It improves vigour of the plants to enable to with stand adverse climatic conditions.
- Reduces lodging in cereal crops.
- It regulates stomata opening and closing.
- It regulates the movement of ions with in the plants and hence it is called **traffic policeman** of the plant.
- Activation of enzymes, enzyme synthesis, peptide bonds synthesis.
- Regulates H_2O imbalance within the plant.

Sources of K

The micas and feldspars constitute the major K bearing minerals which on weathering slowly release K to the soil.

(Muscovite and biotite)

(Orthoclase and microcline)



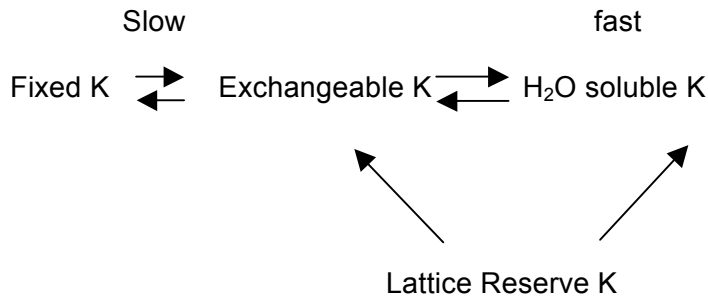
K-Feldspar: $KAlSi_3O_{10}$.

Courtesy: <http://ocw.mit.edu/ans7870/12/12.108/f04/imagegallery/lab3/lab3-32.html>

Forms of potassium in soils

- Water soluble K.
- Exchangeable K.
- Fixed or Non exchangeable K.
- Lattice or Mineral K.

The different forms are in **dynamic equilibrium** with one another and represented as follows.



Water soluble K

The Concentration of H₂O soluble K in soil depends on (a) type of day (b) H₂O content (c) Intensity of leaching (d) Amount of exchange K (e) Kind and concentration of other ions.

The dilution of the soil, increases the concentration of H₂O soluble K and drying decreases it. The uptake of K is influenced by the presence of other cations, ie Ca²⁺ and Mg²⁺, Al³⁺ (acidic soils) and Na⁺ in salt affected soils.

$$\begin{aligned} \text{The activity ratio } (AR_e^K) &= \frac{\text{Activity of } K^+}{\sqrt{\text{activity of } Ca^{2+} \text{ and } Mg^{2+}}} \\ & \text{(or)} \\ &= \frac{a_k}{\sqrt{a_{Ca-Mg}}} \end{aligned}$$

2. Exchangeable K

The K adsorbed on soil clay complex and replaceable with neutral salts in relatively short time. The Cl reacts with soil Ca and form Ca Cl₂ which is leached by high rainfall. Hence **K is called as Decalcifier**

3. Non exchangeable or Fixed K

Added K which is firmly bound by the soil and not immediately replaceable with neutral salts.

4. Lattice K or Mineral K

Muscovite, biotite and K feldspar. The capacity of soils to release lattice K by weathering depends on the content of K minerals and soil texture.

Potassium fixation

The important of K fixation is to regulate the supply of the soil a for the plants and protects it against loss through leaching.

In the dynamics of soil Potassium, the phenomenon of fixation of exchange K and the liberation of non-exchange K play an important role. K ions are relatively small to enter the silica sheets where they are held firmly by **electrostatic forces**. The presence of K^+ ions can block the release of fixed NH_4^+ and vice visa.

Factors affecting K fixation.

1. **Soil texture** : Increases the texture grater will be fixation and vice visa.
2. **Wetting and drying**: Fixation is more under dry condition than wet condition.
3. **Type of day min**: Fixation is more in 2:1 type than 1: 1 type
4. **Freezing and thawing** : Enhances the fixation of K depends their clay mineralogy and degree of weathering
5. **Soil pH** : A decreases in pH reduces the K fixation either as result of competition of H_3O^+ for the inter layer exchange position. Liming also favors for the fixation of K.

Factors affecting K availability in plants

- a. *Kind of clay minerals*: Soils containing vermiculite or montmorilonite will have more K than kaolinite clay soils.
 - b. *Cation exchange capacity*: Increases texture soils having higher CEC and can hold more exchange K.
 - c. *Amount of exchangeable K*: More K in soil solution leads to
Higher fixation.
 - d. *Subsoil K and rooting depth*: Low soil temperature may exhibit K release and diffusion, thus increasing crop response to K
 - e. *Soil moisture*: fertilization increasing K levels or moisture contain will accelerate K diffusion.
6. **Soil temperature** : The reduced temperature slow down plant process plant growth and rate of K uptake.
 7. **Soil aeration** : Under high moisture levels or incompact soils root growth is restricted, O_2 supply is lowered and absorptions of K is slowed.
 8. **Soil pH** : In very acid soils, toxic amount of exchange Al^{3+} and Mn^{2+} create unfavorable root environment for uptake of K and other nutrients.
 9. **Ca and Mg** : K uptake would be reduced as Ca^{2+} and Mg^{2+} are increased or uptake of these two cations would be reduced as the available supply of K is increased.
 10. **Tillage**: Tillage is increased that K availability is reduced because of increases compaction, less aeration and lower temperature.

Plant factors affecting K availability

1. CEC of Roots :Important for determining the ability of plants to absorb like more slowly available forms of soil K.
2. Root system and crop :Higher root density, higher the removal of exchange K and soil solution K. Fibrous root system absorbs more K than tap root system.
3. Variety or Hybrid :Hybrid absorbs more K than variety.
4. Plant population :Higher plant population and closer spacing increased the K removal.

Deficiency symptoms

1. Plant becomes stunted in growth with shortening of internodes and bushy in appearance.
2. K deficiency in plants show reduced rate of photosynthesis.
3. Chlorosis, yellowing of leaves and leaf scorch in case of fruit trees.

Rice : The leaf tips will turn dark brown in colour and blades will be blueish green, chlorotic and necrotic are seen.

Banana : Deficiency is seen in the margin and bottom of leaves.

Grapes : Leaves are yellow with brown spots which are necrotic, brittle with uneven ripening.

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Tisdale, S.L., Nelson, W.L., Beaton, J.D., Havlin, J.L. 1997. Soil fertility and Fertilizers. Fifth edition, Prentice hall of India Pvt.Ltd, New Delhi.

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<http://ocw.mit.edu>

Questions to ponder

- 1) What is luxury consumption?
- 2) What is activity ratio and what does it measure?
- 3) How does CEC affect the amount of K in solution?
- 4) What is the effect of K: Ca ratio in K availability?
- 5) Does fixed K tend to become available to plants?

10.

Secondary nutrients – Transformation, factors affecting nutrient availability, deficiency and toxicity symptoms

Learning objectives

- a. To understand the transformation of secondary elements
- b. To study the forms of secondary nutrients and factors affecting the availability
- c. To understand the deficiency symptoms of secondary nutrients

Calcium

Calcium is absorbed by plants as Ca^{2+} and its concentration ranges from 0.2 to 1.0% and it is supplied through mass flow method.

Functions of calcium

1. It is immobile in plants and hence the deficiency is observed in younger leaves.
2. It is a constituent of cell wall and increases in stiffness of plants.
3. Promotes root development and growth of plants, root elongation and cell division.
4. Helps to translocate the sugar in the plants.
5. It involves chromosome stability and that it is a constituent of chromosome structure.
6. Affects translocation of CHO in plants.
7. Encourages seed production.
8. Activates enzyme phosphate and kinase.
9. Accumulated protein during respiration by mitochondria and it increases their protein content.
10. It binds DNA to protein molecules.

Deficiency of calcium

- a. Young leaves of terminal buds dieback at the tip and margins.
- b. Normal growth in affected.
- c. Root may become short, stubby and brown.
- d. Causes acidity of soil.
- e. Cell may become rigid and brittle.
- f. Young leaves of cereals remain folded.

Sources of soil calcium

Earth crust contains about 3.64%. The important source of calcium is **anorthite** ($\text{Ca Al}_2\text{Si}_2\text{O}_3$). Generally arid region soils contain high amount of Ca regard less of texture, low rainfall and little leaching.

In arid and semiarid regions Calcite (CaCO_3)

Dolomite ($\text{Ca, Mg, (CO}_3)_2$)

Gypsum ($\text{CaSO}_4, 2\text{H}_2\text{O}$)

In humid regions, even the soils formed from limestone are frequently acid in the surface layers because of the removal of Ca and other cations by leaching.

Calcium transformations in soils

In acid and humid region soils Ca occurs largely in exchange form and as primary minerals. In most of these soils Ca^{2+} , Al^{3+} and H^+ dominates the exchange complex.

The forms of Ca are

1)Solution Ca^{2+} / Mg^{2+}

2)Exchangeable Ca/Mg

3)Mineral Ca/Mg.

The activity of solution Ca is decreased by leaching or plant removal. If solution Ca is increased, the equilibrium shifts in the opposite direction with subsequent desorption of some of the Ca^{2+} by the exchange complex. The rate of solution Ca is less complex than of K^+ . It may be (a) Lost in drainage H_2O 's. (b) absorbed by organisms (c) adsorbed on the CEC (d) Reprecipitated as secondary calcium compound.

Factors affecting Ca^{2+} availability

1. Total Ca supply :Sandy acidic soils with low CEC having less Ca.
2. Soil pH:In acid soils Ca is not readily available to plants at low concentration.
3. CEC:Soils having low CEC might will supply more Ca^{2+} .
4. % Ca saturation:High Ca^{2+} saturation indicates favourable pH for plant growth and microbial activity.
5. Type of soil colloid: 2 : 1 type require higher Ca saturation than 1: 1 type.
6. Ratio of Ca^{2+} to other cations : Increasing the Al^{3+} conc. in soil solution reduces Ca uptake in plant.

Magnesium

Magnesium is absorbed as Mg^{2+} and the concentration in crop varies between 0.1 and 0.6%. It was taken by plant by *Mass flow and diffusion*.

Functions of Mg in plants

1. Primary constituent of chlorophyll
2. Imports dark green Colour in leaves.
3. Serves as a structural components in ribosomes and stabilizing the ribosome configuration for protein synthesis.
4. Involves numbers of physiological and biochemical function.
5. Activates phosphorylating enzymes in CHO metabolism.
6. Act as a cofactor for certain enzymes other than PO_4 transfer enzyme.
7. Increases in the oil content of oil seed crops.
8. Regulates the uptake of other nutrients.

Deficiency of Magnesium

1. Interveinal chlorosis of the leaf in which only the leaf veins remain green.
2. Stiff brittle, twisted leaves, wrinkled and distortion of leaves.
3. cotton –lower leaves may develop a reddish purple finally necrotic (Redding of leaves)
4. In brassica, Chlorosis with interveinal mottling uniformly distributed in older leaves while the other vascular tissues remain green. This condition is called “**Puckering**”.

Sources of soil Magnesium

It constitutes 1.93% of earth crust

Primarily minerals (a) Biotite (b) Dolomite (c) Hornblende (d) olivine (e) serpentine.

Secondary minerals (a) Chlorite (b) Illite (c) Montmorillonite.

In arid region substantial amount of Mg present as **Epsomite** ($Mg\ SO_4\ 7H_2O$)

Forms of Mg in the soil

1. It occurs predominately as exchange and solution mg.
2. Coarse text soil exhibits the greatest potential for Mg deficiencies.
3. Competition bet NH_4^+ and Mg^{2+} also lower the Mg^{2+} availability to crops.

Losses of Mg

It is leached by soils and it depends on the Mg content, rate of weathering, intensity of weathering and uptake of plants.

Sulphur

Sulphur is absorbed by plant roots as SO_4^{2-} ions. Concentration of S in plants range between 0.1 and 0.4%.

Functions of sulphur

1. Essential for synthesis of sulphur containing amino acids cystine, cysteine and methionine.

2. Essential for synthesis of other metabolites including Co-enzyme A., Biotin, Thiamin of vitamin B and Glutathione.
3. Synthesis of chlorophyll.
4. It is a vital part of ferredoxins i.e Fe – S – protein occurring in the chloroplasts.
5. Responsible for the characteristic smell or odor and taste of mustard, onion and Garlic. (Puncy smell)
6. Enhances the oil formation in crops (Soya bean)
7. Increasing root growth.
8. Stimulate seed formation.
9. Promote nodule formation – Leguminous species.

Deficiency of sulphur

- a. Stunted growth pale green to yellow colour.
- b. Immobile in plants and plants symptoms start first at younger leaves.
- c. Poor seed set in rapeseed.
- d. Tea –Tea yellows.

Sources of sulphur

1. Amount has <0.05 ppm in the form of SO_2 .
2. Earth crust contains 0.06 to 0.10%.
3. Sulphur bearing minerals

Gypsum	- $\text{CaSO}_4 \cdot 2 \text{H}_2\text{O}$.
Epsomite	- $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
Mirabilite	- $\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$.
Pyrite	- FeS_2 .
4. Silicate min contains <0.01 % S.
5. Igneous rocks 0.02 to 0.07%
Sedimentary rocks 0.02 to 0.22%

Forms of sulphur in soil

Present both organic (90%) and Inorganic forms.

The inorganic forms are

1. Solution SO_4^{2-} .
2. Adsorbed $\text{SO}_4^{=}$ Readily available fraction.
3. Insoluble $\text{SO}_4^{=}$
4. Reduced inorganic compounds.

Factors affecting S oxidation in soils

- a. Microbial population in soil.
- b. Characteristics of the 'S' source
- c. Soil environmental condition.
- d. **Soil micro flora** Chemolithotropic S bacteria Thiobacilli utilized energy from oxide of Inorganic S for the fixation of CO_2 in Organic matter.
- e. **Soil temperature**

An increase in temperature increases the S oxidation rate in soil. Ideal temperature 25 – 40°C.

f. Soil moisture and aeration

S oxidizing bacteria are mostly aerobic and their activity will decline if O_2 is lacking due to H_2O logging. Favourable moisture is field capacity moisture.

g. **Soil pH:** Optimum pH 4.0 or lower.

S transformation in soils

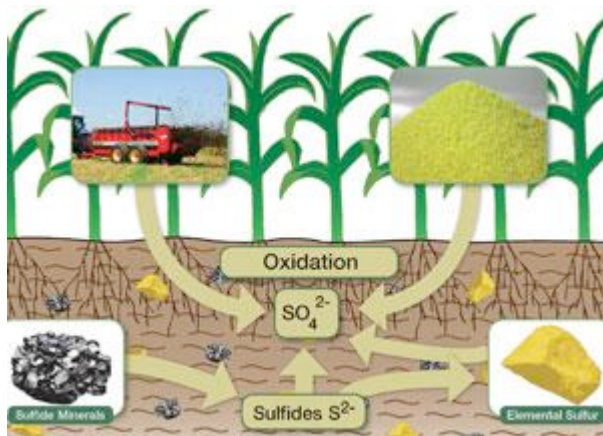
Numerous transformations of S in soil occur from inorganic to organic forms due to the presence of hetero tropic micro organic viz., Thiobacillus, chlorabium, Desulfotomaculam and Desulfovibrio.

When plant and animal residues are returned to the soil they are digested by microorganism releasing of the S as SO_4^{2-} . Most of the S remains in organic form and becomes part of soil humus. The S supply to plants in largely depend on the SO_4^{2-} released from the organic soil fractions and from the plant and animal residues.

S Mineralization and immobilization

Mineralization of "S" is the conversion of organic S to inorganic SO_4^{2-} .

Immobilisation is the conversion of SO_4^{2-} to organic S.



Sulphur cycle

http://www.agweb.com/assets/1/9/NewsMainImage/sulfur_cycle2.jpg

Factors affecting S mineralization and Immobilization.

1. S content of organic matter

Mineralization of S depends on the S content of the decomposing material, smaller amounts of SO_4^{2-} are liberated from low S containing residue.

2. Source of mineralizable sulphur :

Most of the available S removed by plants from the SO_4^{2-} fraction of labile S in soil Organic matter.

3. Soil Temperature

Mineralization of S is impeded @ 10°C increases with increasing temperature from 20°C to 40°C and decreases of temperature >40°C.

4. Soil moisture

Mineralization occurs in optimum moisture conditions.

5. Soil pH

S released is directly proportional to pH up to pH 7.5. Above 7.5 mineralization increases more rapidly.

6. Absence or presence of plants.

Soils mineralization more S in the presence of growing plants than in their absence.

7. Time and cultivation

8. S Volatilization

Volatile S compounds are produced through microbial transformations under both aerobic and anaerobic conditions. The volatile compounds are **dimethyl sulfide (CH₃ SCH₃) (CS₂) Carbandi sulphide and mercaptans (CH₃SH).**

In low organic matter soils, S volatilization is negligible and increases with increasing organic matter content.

Practical aspects of S transformations.

1. Crops grown on coarse texture soils are generally more susceptible to S deficiency because these soils having low organic matter content and So_4^- leaching.
2. Leaching losses of So_4^- can occur highly on coarse texture soils under high rainfall. Under such conditions, So_4^- containing fertilizers maybe applied more frequently
3. **Immobilization** of added S can occur in soils having a high. **C/S or N/S ratio.** S mineralisation is favored in soils with a low C/S or N/S ratio. S availability generally increases with organic matter content.
4. Actual amount of S needed will depend on the balance between all soil additions of S by precipitation, air, irrigation H₂O, crop residues fertilizers, Agriculture Chemicals and all losses through crop removal. Leaching and erosion.

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Questions to ponder

- 1) What is the importance of C:N:P:S ratio to the availability of soil sulphur?
- 2) Is Magnesium fixed in soils?
- 3) How is a low calcium soil condition usually corrected?
- 4) Which crops have high calcium requirement?
- 5) Can climate influence the availability and uptake of Calcium and Magnesium?

11.

Micro nutrients – Transformation, factors affecting nutrient availability, deficiency and toxicity symptoms

Learning objectives

- To understand the transformation of micronutrients
- To study the forms of micronutrients and factors affecting the availability
- To understand the deficiency symptoms of micro nutrients

Iron

Fe is absorbed by plants roots as Fe^{2+} , Fe^{3+} and chelated irons. Sufficiency range of Fe in plant tissue is 50-250 ppm.

Functions of Iron

- It helps in the synthesis of chlorophyll.
- Structural component of porphyrin molecules like cytochromes, hematin, hemes, ferrichrome and hemoglobin. These substance are involved in oxidation-reduction reactors in respiration and photosynthesis.
- Structural component of non heme compounds like ferredoxins.
- Constituent of enzyme systems E.g. cytochrome oxidase, catalase, nitrogenase reaction in plants.
- Component of flavoprotein like

FMN = Flavin mono nucleotides

FAD = Flavin Adenosine Dinucleotide.

Deficiency symptoms

- Deficiency symptoms occurs in younger leaves since Fe is immobile element within plant.
- It occurs in soils of calcareous or alkaline soils and poorly drained H_2O logged soils.
- Younger leaves develop interveinal chlorosis with progresses rapidly over the entire leaf. Severe cases entire leaf turns yellow colour.

Sources of iron

Earth crust contains about 5%

Primary and secondary minerals such as

- Olivine, 2. Pyrite, 3. Hematite, 4. Goethite, 5. Magnetite, 6. limestone

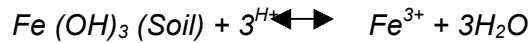
Forms of iron

Fe occurs in Four major forms in soil.

1. Primary and secondary minerals Fe
2. Adsorbed Fe
3. Organic Fe and
4. Solution Fe.

Soil solution Fe

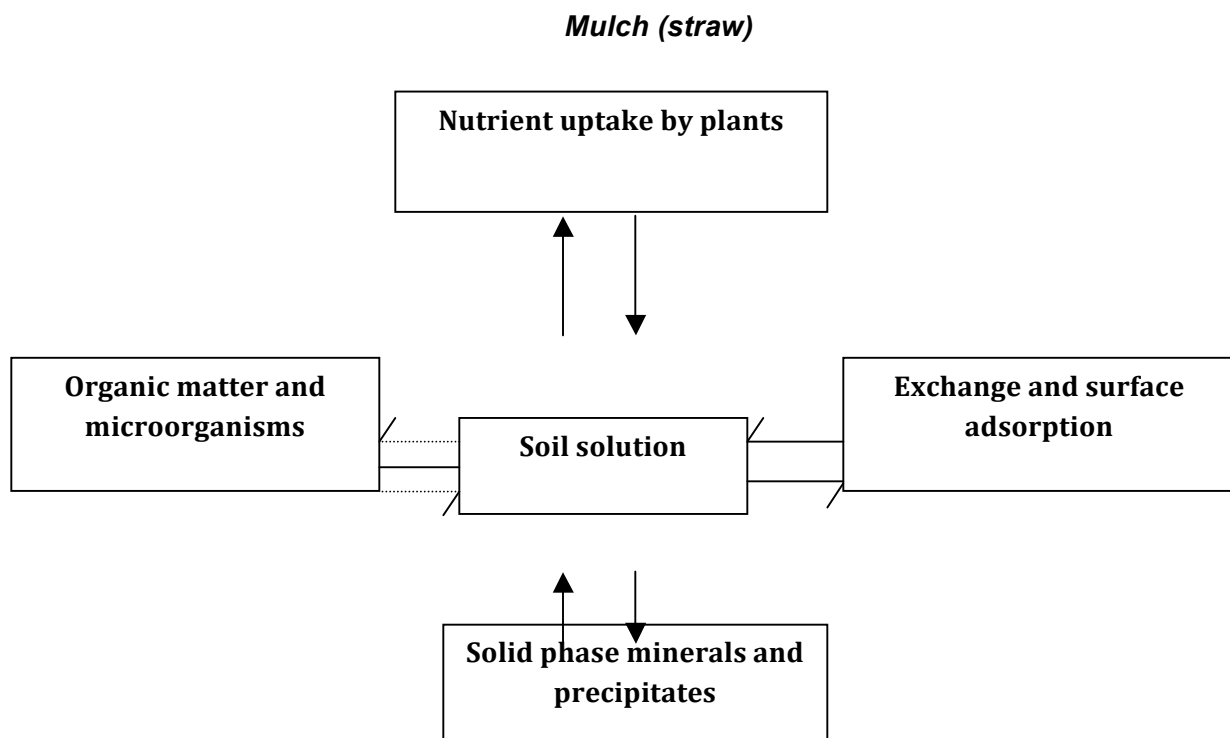
It occurs primarily as $Fe(OH)^+_2$, Fe^{3+} concentration In solution is very low. In well-drained, oxidized soils, the solution Fe^{2+} concentration is less than that of the dominant Fe^{3+} in solution. The pH dependent relationship for Fe^{3+} is described as



For every increases in pH, Fe^{3+} concentration decreases 1000 fold. Oxidation - redn reactions, the result of change in O_2 partial pressure, exert considerable influence on the amount of soluble Fe in the soil solution. The insoluble Fe^{3+} form predominates in well drained soils, while levels of soluble Fe^{2+} increases significantly when soils become H_2O logged. In general, lowering Redox increases Fe^{2+} solubility, 10 fold for each unit decreases. in pH.

Over the normal pH range in soils, total solution Fe is not sufficient to meet plant requirements for Fe even in acid soils, where Fe deficiency Occur less frequently than in high pH and calcanous soils.

Schematic representation of Fe, Zn, Cu and Mn cycle



Chelates

“Is a term derived from a Greek and meaning “Claw”.

Chelates are soluble organic compounds that bond with metals such as Fe, Zn, Cu and Mn increasing their solubility and their supply to plant roots.

“Natural organic chelates in soils are products of microbial activity and degradation of soil organic matter and plant residues. Root exudates are capable complexing nutrients substantial quantities of organic completed. Fe can be cycled through crop residue and compounds of citric acid and oxalic acids have chelating properties.

Dynamics of chelation

“The dynamics of chelation increasing solubility and transport of micronutrients”.

During active plant uptake, the concentration of chelated Fe or other micronutrient is greater in the bulk solution than at root surface the chelated Fe diffuses to the root surface in response to concentration gradient. After Fe^{3+} dissociates from the chelates and diffused due to concentration gradient. As the unchelated Fe^{3+} concentration decreases in solution because of chelation, additional Fe is desorbed from mineral surfaces or Fe minerals dissolved to resupply solution Fe.

Synthetic chelates

In soils synthetic chelates behave similarly to natural organic chelates. The choice of a chelate to use as chelate depends 1. specific micronutrient ii. Solubility of chelate in the soil. When synthetic or natural chelates are added to soils and they are readily complex with cations in soil solution.

Eg: Citric acid and Oxalic acids, two natural chelates complex Al^{3+} at low pH, but when pH increases above 5 or 6, Ca^{2+} and Mg^{2+} are more readily complexed.

Diethylene triamine penta acetic acid (DTPA) and EDTA (Ethylene diamine tetra acetic acid) readily chelate Fe at pH < 7 and pH < 6.5 respects. The chelate EDDHA (Ethylene Diamine dihydroxy phenyl acetic acid) will strongly complex Fe and is stable over the entire pH range. As a result Fe EDDHA is commonly used as an Fe fertilizer because it provides more plant available Fe than other chelates.

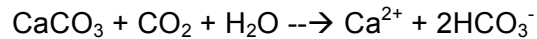
Factors affecting Fe availability

1. Soil pH, Bicarbonate and Carbonates

Fe deficiency is most often observed in high pH and calcareous soils in arid regions, but it may occur in acid soils that are very low in total Fe.

Irrigation waters and soil high in HCO_3^- may aggravate Fe deficiency because of high pH levels associated with HCO_3^- accumulation.

In calcareous soils having pH range of 7.3 to 8.5 have Fe deficiency due to the lowest solubility of soil Fe and the formation of bicarbonate ion.



2. Excessive H₂O and poor aeration

Flooding and submergence of soils can improve Fe availability by increasing Fe²⁺ conc. They actually build up of toxic conc. of Fe²⁺ organic matter removed from the eroded portions of semi arid region calcareous net soils lime induced Fe deficiency will occur.

3. Organic matter

Additions of organic matter to well drained soils can improve Fe avail. Due to increases the Fe²⁺ solubility.

4. Interactions with other nutrients

Fe deficiency occur due to the accumulation of Cu, Mn, Zn, Mo and P. Fe availability decreases when the soils are having more NO₃⁻ than NH₄⁺ deficiency of K or Zn can reduce Fe translocation with in plants.

MANGANESE

Mn concentration in plant ranges from 20 to 500 ppm

Functions of Mn

1. Helps in chlorophyll formation
2. Involves in photosynthesis, particularly in evolution of O₂.
3. Involves in oxidation - reduction - process in decarboxylation and hydrolysis reactions.
4. Involves in enzyme systems and various enzyme reactions in the citric acid cycle.
5. It is a substitute for Mg²⁺ in many of the phosphorylating and group transfer reactions.

Deficiency of Mn

1. Immobile in plant and def. starts in the younger leaves.
2. Interveinal chlorosis occur

Oats - Gray specks / streaks

Peas - Marsh spot

Sugarbeet - speckled yellow

Sugar cane - Pahala blight - midrib pale green and white.

3. Deficiency increases aspartic acid and decreases glutamine
4. Increases respiration
5. Accumulation N compounds mainly as amines.

Sources of Mn

Earth crust contains 1000 ppm. Various oxides and hydroxides.

Manganite $\text{MnO}(\text{OH})$

Braunite Mn_2O_3

Factors affecting Mn availability

1. Soil pH and carbonates

Liming to acid soils decreases solution and exch. Mn^{2+} due to precipitation Mn^{2+} as MnO_2 .

2. Excessive H_2O and poor aeration

H_2O logging will reduce O_2 and lower redox potential will increase soluble Mn^{2+} . Poor aeration increases Mn availability.

3. Organic matter

Increases solution and exchangeable Mn.

4. Climatic factor

Increases soil temp during the growing season improves Mn uptake, because of greater plant growth and root activity.

5. Soil micro org

Deficiency caused by soil organisms oxidizing Mn^{2+} to Mn^{4+} .

Forms of Mn

- i. Solution Mn^{2+}
- ii. Exchange Mn^{2+}
- iii. Organic bound Mn
- iv. Mn Mineral

ZINC

Normal concentration in plant 25 to 150 ppm

Deficiency level is < 20 ppm

Toxic level is > 400 ppm

Zn is present in all parts of the plants. In general root contain more zinc than fruits.

Cereals : 27.8 ppm

Pulses : 34.8 ppm

Vegetables : 28.2 ppm

Fruits : 36.6 ppm

Functions of Zn

1. Essential to formation of growth hormones
2. Helps in reproduction of certain plants.
3. Stabilise ribosomal fractions
4. Influence the activity of dehydrogenase enzymes
5. Involves in auxin metabolism like tryptophan synthetase.

Deficiency of Zn

1. Light yellow or white areas bet the veins of leaves particularly older leaves.
2. Death of tissue, discolored
3. Mal formation of fruits
4. Reduced growth hormone production.

Cotton : White bud (or) little leaf

Citrus : Mottle leaf

Potato : Fern leaf

Fruit trees : Rosette (Upnormal growth)

Paddy : Khaira

Foliar spray : 0.2 to 0.5% ZnSO₄.

Sources of zinc

Soil : 10-300 ppm

Igneous rock : >10 ppm

Sedimentary : > 95 ppm

Forms of soil Zn

1. Solution Zn^{2+}
2. Adsorbed Zn^{2+}
3. Organically completed Zn^{2+}

Factors affecting Zn availability

1. Soil pH : Avail of Zn decrease with increase soil pH Zn def occur in neutral and calcareous soil. At soil pH, Zn precipitates as insoluble amorphous soil Zn, which reduces Zn^{2+} in soil.

Al and Fe oxides, OM and $CaCO_3$ increase with increasing pH.

2. Organic matter
3. Interaction with other nutrients

SO_4 and N can increase the Zn uptake in plants.

Higher the soil pH, poor aeration greater the Zn deficiency

COPPER

Copper is absorbed by plants as cupric ion Cu^{2+}

Normal concentration in plants 5-20 ppm.

Functions of copper

1. Essential for the synthesis of vitamin A
2. Act as a catalyst in respiration
3. Act as a "electron carrier" in enzyme which bring about oxidation reduction reactions in plants.
4. Constituent of chlorophyll.

Deficiency of copper

1. Chlorosis, withering and distortion of terminal buds.
 2. Dead tissue appears along the tips and edges of leaves.
 3. Multiple bud formation in the leaf axil and mal formation of leaves.
 4. Guava - cracking of fruits and terminal bud die back
1. Heavy liming, excessive application of N and P - induces Cu deficiency.

Sources of copper

1. Igneous rock 10-100 ppm of Cu.
2. Sedimentary rock 4-45 ppm
3. Primary minerals contains
 1. Chalcopyrite
 2. Chalcocite
 3. Bornite
4. Sedimentary minerals
 - Oxides, Carbonates, Silicates, Sulphates and Chlorides.

Forms of soil copper

1. Soil solution - ionic and completed
2. Cation exchange sites of clay and organic matter
3. Occluded and co-precipitated in soil oxide material.
4. Specific adsorption sites
5. Inorganic matter and living organisms

Factors affecting Cu availability

1. Soil texture
2. pH
3. CEE
4. Org matter content
5. Hydrous oxides

Soil texture

Sandy soils contain lower amounts of Cu than silt and clay soils.

pH

The concentration of Cu in soil solution decreases with increase in pH.

Interaction with other nutrients

Application of NPK fertilizer induce Cu deficiency

Increase N supply to crops reduce mobility of Cu in plants

High concentration of Zn, Fe and P in soil solution also can depress Cu absorption by plant roots.

BORON

B concentration in mono cotyledons and dicotyledons (20-60 ppm) varies between 6 and 18 ppm.

It is absorbed by plants as undissociated boric acid (H_3BO_3).

Functions of boron

1. New cell development in meristematic tissue.
2. Pollination, fruit / seed set.
3. Translocation of sugars, starches, N and P
4. Synthesis of proteins and amino acids.
5. Nodule formation in legumes
6. Regulation of CHO metabolism.

Deficiencies of Boron

1. Since it is immobile, deficiency Symptoms occurs in terminal bud growth.
2. Flowering and fruit development are restricted.
3. Sterility and mal formation of reproductive organs.
4. Thickened and curled leaves.
5. Discoloration, cracking or rotting of fruit, tubers or roots

Apple - Internal cracking.

Break down of internal tissue in root crops given rise to darkened areas referred to Brown heart / black heart : cotton - weeping disease.

Sources of boron

1. Non metal among the micronutrient
2. Low concentration in earth crust igneous rocks (<10 ppm)
3. Tourmaline and borosilicate contains B.

Forms of boron (Boron cycle)

B exists in 4 forms in soil.

1. Rocks and minerals.
2. Adsorbed on clay surface, Fe and Al oxides combined with O.M.
3. Boric acid (H_3BO_3) and $4 \text{ B}(\text{OH})_4^-$ in soil solution.

Boron cycling between the solid and solution phase is very important because of the narrow range in solution concentration that separates deficiency and toxicity in crops.

Soil solution B

H_3BO_3 is the predominant species in soil solution at pH values ranging from 5-9. At $\text{pH} > 9.2$ H_3BO_3^- can hydrolyse to H_4BO_4^- . It was taken by Massflow and Diffusion methods in plants.

Absorbed B

B adsorption and desorption can help to reduce B leaching losses. Main B adsorption sites are

1. Broken Si - O and Al-O- bonds at the edge of clay min.
2. Amorphous hydroxide structure
3. Al and Fe oxides and hydroxides.

Factors affecting B availability

1. Soil texture : Fine text soils added B for longer period than coarse text soil.

Plants can take up larger quantity of B from sandy soils than fine text soil at equal concentration of H_2O soluble B.

2. Type of clay : Mica > mont > kaolinite

3. Soil pH and liming : Less avail to plants with increase pH heavy liming lead to greater adsorption and reduced B uptake.

4. Organic matter : Avail of B in surface soil is high compared to subsurface soil.

5. Interactions with other cations

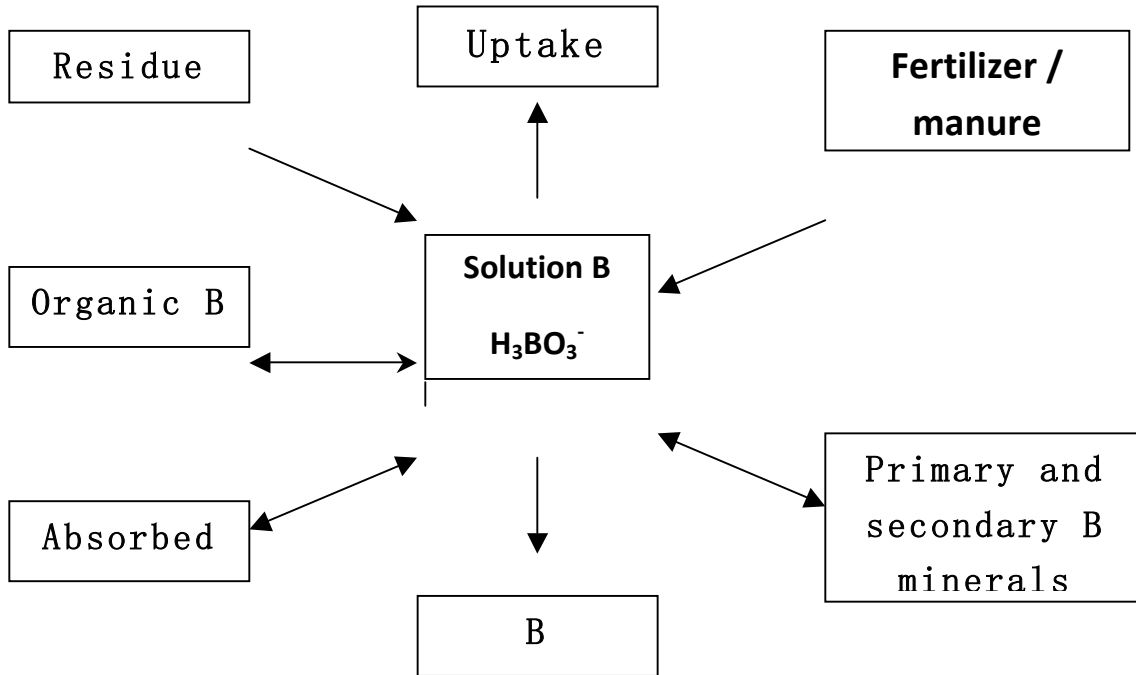
Occurrence of Ca in alkaline soil with restrict B availability. Increased K rates causes B toxicity.

6. Soil moisture

Restricted moist supply reduce the B availability in the root zone.

Boron cycle in soil

Mulch (straw)



MOLYBDENUM

Non metal anion absorbed as molybdate (MoO_4). It is weak acid and form complex poly anions such as phosphomolybdate. Plant contains <1 ppm Mo.

Functions of Mo

1. Essential component of enzyme NO_3 reductase, which catalyses NO_3^- to NO_2^- .
2. Structural component of nitrogenase enzyme - involved in N fixation.
3. Essential for absorption and translocation of Fe in plant.

Deficiency of Mo

1. Inhibits flower formation
2. Imbalances various Amino Acids in plants.

3. Reduce activity of symbiotic and non symbiotic N fixation.

Cauliflower - Whip tail.

Sources of Mo

Earth crust 2 ppm : and range from 0.2 to 5 ppm.

Forms of Mo

1. Non exchangeable Mo in primary and secondary minerals.
2. Exchangeable Mo held by Fe and Al oxides.
3. Mo in soil solution
4. Organically bound Mo.

Mo in solution occurs mainly as $\text{Mo}_4^{=}$, HMoO_4^- , H_2MoO_4^0 .

Factors affecting Mo availability

1. Soil pH and liming

Mo availability increases with increasing pH. Liming to correct acidity will increase Mo avail. Mo avail decrease with application of acid forming fertilizer $(\text{NH}_4)_2\text{SO}_4$.

2. Reaction with Fe and Al

Strongly absorbed by Fe and Al oxides.

3. Interaction with other nutrients

Mg and P enhances Mo absorption by plants.

High level SO_4 decrease Mo absorption by plants.

Cu and Mn decrease Mo uptake by plants.

NO_3^- N encourages Mo uptake

NH_4^+ N reduces Mo uptake

The beneficial effect of NO_3^- nutrition is related to the release of OH ions.

CHLORINE

Normal concentration in plant is about 0.2-2.0%. Absorbed by plants as Cl^- through roots and aerial parts.

Functions of chloride

1. Essential for biochemical reactions Osmotic cation neutralization reactors.
2. Act as a counter ion during rapid K fluxes.
3. Involves in the evaluation of O_2 in photosynthesis.
4. Creates disease resistant by increase osmotic pressure in cell sap.

Deficiency of Cl

1. Partial wilting and loss of turgidity.
2. Necrosis, leaf bronzing and reduction in growth.

Sources of Cl

- i. Igneous and metamorphic rocks
- ii. Soluble salts such as NaCl, $CaCl_2$ and $MgCl_2$.
- iii. Earth crust 0.02-0.05%.

It is mobile with in the plant it can be rapidly recycled through soil systems.

COBALT

Normal concentration of Co in dry matter - 0.02 - 0.5 ppm.

Functions of cobalt

1. Essential for M.O. fixing atmosphere. N. It forms vit. B12 during growth and development of symbiotic M.O.
2. Improves growth, transpiration and photosynthesis.
3. Take parts in leg hemoglobin metabolism and Rhibonucliotide reductase.

Deficiency

1. Acidic, highly leached, sandy soils with total Co low.
2. Calcareous and peaty soils.

Factors affecting : Co availability

1. Soil pH : Avail increase with increase in soil acidity, H_2O logging conditions.
2. Liming and drainage practices - reduce co availability.
3. Application $CoSO_4$ rectify the deficiency.

VANADIUM

Low concentration of Vanadium is beneficial for growth of Microorganisms.

Vanadium substitute for Mo in N fixation by Rhizobia.

Involves in Biological - oxidation-reduction reactions.

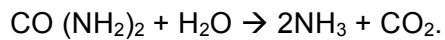
NICKEL

Nickel content in plant is 0.1 - 1.0 ppm dry matter basis.

Taken by plant as Ni²⁺

High levels of Ni may induce Zn or Fe deficiency

1. Ni - metal component of urease that catalyse reaction.



2. Essential for N metabolism.

3. Stimulates nodule weight and yield of crops.

SODIUM

Functions

1. Essential for maintaining turgor and growth of Plants.

2. Helps oxalic acid accumulation in Plants.

3. Helps in stomatal opening and regulate NO₃⁻ reductase activity.

Sources of Na

Earth crust 2.8% soils

Minerals.

Forms of Na in soil

Solution, exchangeable Na and in silicate minerals.

In arid and semi arid soils Na exist in silicates, NaCl, Na₂SO₄

Na salts accumulating in poorly drained soils of arid and semi arid regions and causes soil salinity and sodicity.

Effect of Na on soil properties

Dispersing action of Na^+ on clay and organic matter reduces soil aggregation, permeability to air and H_2O , germination and root growth.

Sodium fertilizers

Sodium NO_3 : 25% Na

Rhenania PO_4 12% NA

Abundant element. in lithosphere and absorbed as monosilicic acid.

Cereals and grass contain 0.2 - 2.0%.

Functions of silica

1. Contributes structure of cell wall.
2. Contributes drought tolerance to crops.
3. Regulates photosynthesis.
4. De activates invertase enzyme activity in sugarcane resulting grater sucrose production.

Larger amounts of Si are accumulated in intracellular deposits known as 'PLANT OPALS'.

5. Increased available P.
6. Responsible for plant disease resistance.

Sources of silicon

Earth crust : 27.6% Most abundant element in earth crust.

Soils 23-35%

Primary and secondary mineral and quartz - major source.

Quartz is the most common mineral in soil, comprising 90-95% of all sand and silt fractions.

Factors affecting Si availability

1. High H_2O content encourages Si uptake
2. Heavy application of N decreases Si concentration
3. Liming decreases Si uptake in plants.
4. Acidification increases Si uptake
5. Fe and Al oxides influence Uptake of Si by plants.

Si fertilizers

1. Calcium silicate slag ($\text{CaAl}_2\text{Si}_2\text{O}_4$) - 18.21% Si
2. Calcium silicate (CaSiO_3) - 31% Si.
3. Sodium metasilicate NaSiO_3 - 23% Si.

Chelates

Chelate is a term derived from a Greek word meaning, “claw”. Chelates are soluble organic compounds that bond with **metals ions** such as Fe^{3+} / Fe^{2+} , Zn^{2+} , Cu^{2+} , Mn^{2+} , and other, thereby *increasing their solubility and supply to plant roots*. It is important particularly in micronutrient availability.

Numerous natural organic compounds in soil, or synthetic compounds added to soils, are able to complex or chelate ions of micronutrients.

Natural organic chelates in soils are products of microbial activity and degradation of soil organic matter and plant residues. Root exudates also are capable of complexing micronutrients.

The concentration of metal ions in solution and the quantity transported to the root by mass flow and diffusion can be greatly increased through complexation with natural organic chelating compounds in soil.

Substantial quantities of organic-complexed metal ions can be cycled through crop residue, which remain available for the succeeding crop.

Many of the natural organic chelates have not been identified; however, compounds like citric and oxalic acids have chelating properties.

Common synthetic chelates are:

Ethylene diamine tetra acetic acid (EDTA)

Diethylene triamine pentaacetic acid (DTPA)

Ethylene diamine di-o-hydroxy phenyl acetic acid (EDDHA)

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Questions to ponder

- 1) What is the role of organic matter addition on micronutrient availability to plants?
- 2) How does Fe and Al oxides affect the micronutrient availability?
- 3) Why is copper deficiency often referred to as reclamation disease?
- 4) What are the ways to avert Fe chlorosis?
- 5) What are the common manganese fertilizer materials?

LECTURE 12

NUTRIENT DEFICIENCY AND TOXICITY

Causes and Symptoms

Nitrogen

When N supplies are more than sufficient, carbohydrates are converted to proteins. Hence, vegetative portion is less with carbohydrates and more with protein as protoplasm. As protoplasm are highly hydrated more succulence results.

Excessive succulence may have a harmful effect. With cotton, a weakening of the fiber; with grain crops, lodging particularly with a low K supply; more susceptibility to disease and insect attack occurs.

N deficient plants become stunted and yellow in appearance. The loss of protein N from chloroplasts in older leaves produces **yellowing or chlorosis** - indicative of N deficiency. Chlorosis appears first on lower leaves; upper leaves remain green. Under severe N deficiency, lower leaves turn brown and die. This necrosis begins at the leaf tip and progresses along the midrib until the entire leaf is dead. The tendency of the young upper leaves to remain green as the lower leaves yellow or die is an indication of the mobility of N in the plant.

Phosphorus

The marked effect of P deficiency is **retarding** overall **growth**; the striking foliar symptoms that are evident with N or K deficiency are seldom observed for P, In corn and some other grass species, purple discoloration of the leaves or leaf edges appears.

Potassium

When K is limiting, characteristic deficiency symptoms appear in the plant. Typical K deficiency symptoms in alfalfa are white spots on the leaf edges; in corn and banana **chlorosis** and **necrosis** of the leaf edges.

Since K is mobile in plant, visual deficiency symptoms appear first in the lower old leaves, progressing toward the top with severity. K deficiency also occurs in young leaves of high-yielding, fast maturing crops like cotton and wheat. Another symptom is weakening of straw in grain crops, causing lodging in small grains and stalk breakage in corn and sorghum, reducing crop yields.

In fact, serious yield reductions may occur without deficiency symptoms. This phenomenon is termed *hidden hunger* and is not restricted to K alone.

Calcium

In corn, Ca^{2+} deficiency prevents the emergence and unfolding of new leaves, the tips are almost colorless covered with a sticky gelatinous material that causes them to adhere to one another.

In fruits and vegetables, the most frequent indicator of Ca^{2+} deficiency is disorders in the storage tissues: **rot in tomato, bitter pit of apples**. Often Ca^{2+} is an immobile element in the plant; hence, there is very little translocation of Ca^{2+} to fruits and storage organs.

Magnesium

Deficiency symptoms often appear first on the lower leaves. In many species, shortage of Mg^{2+} results in interveinal chlorosis of the leaf, in which **only**

veins remain green. In more advanced stages the leaf tissue becomes uniformly pale yellow, then brown and necrotic. In cotton, the lower leaves may develop a reddish-purple cast, gradually turning brown and finally necrotic.

Sulphur

S deficiency has a pronounced retarding effect on plant growth, characterized by **uniformly chlorotic** plants - stunted, thin-stemmed, and spindly. In many plants, these symptoms resemble those of N deficiency. Unlike N, deficiency symptoms occur first in younger leaves.

S deficient cruciferous crops such as cabbage and rapeseed will initially develop a reddish color on the underside of the leaves. In rapeseed the leaves are also cupped inward. In **cabbage**, there is a reddening and purpling of both upper and lower leaf surfaces; the **cupped leaves** turn back on themselves, presenting flattened-to-concave surfaces on the upper side.

Boron

B deficiency symptoms appear as thickened, wilted, or curled leaves; a thickened, cracked, or water-soaked condition of petioles and stems; and a discoloration, cracking, or rotting of fruit, tubers, or roots.

22 (2/6)

Internal cork of apple is caused. In **citrus** fruits uneven thickness of the peel, lumpy fruit, and gummy deposits result. The breakdown of internal tissues in root crops appear as darkened areas and referred as ***brown heart or black heart.***

Iron

Fe deficiency is most frequently seen in crops growing on calcareous or alkaline soils. Fe chlorosis is exhibited by citrus and deciduous fruit crops, by sorghum, grown in neutral to alkaline soils. Other crops are soybeans, beans, corn, strawberries, avocado, vegetable crops, and many ornamentals.

Deficiency of Fe shows up first in young leaves, as a result, growth ceases. The young leaves develop an **interveinal chlorosis**, which progresses rapidly over the entire leaf. In severe cases, *the leaves turn entirely white*.

Fe **toxicity** causes nutritional disorders in rice grown on poorly drained, submerged soils. This condition known as **bronzing** is associated with Fe levels > 300 ppm in leaf blade of rice at tillering.

Manganese

In broad-leaved plants, interveinal chlorosis appears. Mn deficiency of several crops is described by terms: **gray speck** of oats, **marsh spot** of peas, **speckled yellows** of sugar beets. Wheat plants low in Mn are often more susceptible to root rot diseases.

Plants are injured by **excess** ^{22 (3/6)} of Mn. *Crinkle leaf of cotton* is an Mn toxicity observed in highly acid red yellow soils. Mn toxicity in tobacco, soybeans, tree fruits, and rapeseed is noted on extremely acid soils.

Copper

Deficiencies of Cu are reported in numerous plants, *although they are more prevalent among crops growing in peat and muck soils*. Crops most

susceptible to Cu deficiency include alfalfa, wheat, onions, carrots, clover, corn, and fruit trees.

Symptoms vary with crops. In corn, the youngest leaves become yellow and stunted, and if more severe, the young leaves turn pale and older leaves die back. In advanced stages, dead tissue appears along the tips and edges of the leaves *in a pattern similar to that of K deficiency*.

Cu-deficient small-grain plants lose color in young leaves, which break, and die. In many vegetable crops, the leaves lack turgor, developing a bluish-green cast, with chlorotic curl; flower production fails.

Zinc

Crops sensitive to Zn deficiency are corn, beans, citrus, flax, grapes, onions, rice, and soybeans. Mildly sensitive crops are alfalfa, clovers, sorghum, sudan grass, and tomatoes.

Deficiency symptoms appear frequently in leaves; sometimes in fruit or branches or affect in overall development of the plant. Symptoms include light green, yellow, or white areas between the veins of leaves particularly the older lower leaves resulting in: Chlorotic leaf areas. Shortening of the stem **rosette** appearance of the leaves; Malformation of the fruit, often with low or no yield.

White bud in corn and sorghum, **little leaf** in cotton, **mottle leaf or frenching** in citrus crops, **fern leaf** in potato are described terms of Zn deficiency.

Molybdenum

Mo is a structural component of nitrogenase enzyme that actively involves in N_2 fixation. Mo deficiency arrests biological N_2 fixation. Legumes exploit soil N supplies, turning soil to low N fertility, if the legume residues are not incorporated in soil.

Chloride

As Cl^- is the active osmotic agent, its deficiency results in partial wilting and loss of leaf turgor. Chlorosis in younger leaves and an overall wilting of the plants are the two most common symptoms of Cl^- deficiency. Necrosis in some plant parts, leaf bronzing, and reduction in root growth may be seen. Tissue concentrations below 70 to 700 ppm are usually indicative of deficiency.

Symptoms **high level of Cl^-** in wheat plants are increase total leaf water potential and cell sap osmotic potential. Excess of Cl^- can be harmful, and crops vary widely in their tolerance to this condition. Tobacco, legumes are among the most sensitive crops. Leaves of tobacco and potatoes thicken and tend to roll. The storage quality of potato tubers is adversely affected.

Cobalt

The essentiality of Co is for the growth of symbiotic microorganisms such as symbiotic rhizobium, free-living N_2 -fixing bacteria, and blue-green algae and in the formation of vitamin B12. Hence, lack of cobalt affects N_2 fixation in soil.

Silicon

Freckling, a necrotic leaf condition is a symptom of low Si in sugarcane receiving direct sunlight due to Ultraviolet radiation. Adequate Si in sugarcane plant filters out harmful ultraviolet radiation.

The oxidizing power of rice roots and accompanying tolerance to high levels of Fe and Mn were dependent of Si nutrition. Si application is necessary when Si concentration in rice straw falls below 11%. Many of the favorable effects of Si on plant growth, such as disease resistance, stalk strength, and reduction in lodging, have also been attributed to K.

Nickel

High levels of Ni may induce Zn or Fe deficiency because of cation competition. Application of some sewage sludge may result in elevated levels of Ni in crop plants.

LECTURE 13

SOIL FERTILITY EVALUATION

Calibration, Correlation of crop responses, yield prediction, fertilizer recommendation

SOIL TESTING RESEARCH IN INDIA

Farming is a business and, like all businesspersons, the farmer operates farming business for profit. Obviously, to reach a decision before planting a crop, a farmer needs all of the reliable information from the country's soil evaluation programme. In our country, system of fertility evaluation is being modified from time to time in various stages incorporating crop response data.

Some Important landmarks in soil testing research in India:

Year	Landmark
1953	Soil fertility and fertilizer use project
1955	Establishment of Soil Testing Laboratories
1956	All India Coordinated Agronomic Research Project
1960s	Establishment of Agricultural Universities 23 (1/16)
1967	All India Coordinated Research Project on Soil Test Crop Response (STCR) correlation
1967	All India Coordinated Research Project on Micronutrients in Soils and Plants
22 (6/6)	All India Coordinated Research Project on Long term Fertilizer Experiments
1980s	Emphasis on fertilizer prescription for whole

cropping system based on initial soil tests.

Since Liebig's time around 1840 many methods and approaches have been tried to get a precise or workable basis for predicting the fertilizer requirements of crops. The fertilizer use project initiated in 1953 following a study by Stewart (1947) was the first systematic attempt in the whole of the country to relate the knowledge of soils to the judicious use of fertilizers. The establishment of soil testing laboratories was initiated in 1955-56.

The project on Model Agronomic Experiments on Experimental Farms and Simple fertilizer trials on cultivators' Fields was started in 1957. The Soil Test Crop Response (STCR) correlation work carried out at Indian Agricultural Research Institute, New Delhi had resulted in the selection of soil test methods and categorizing the tests into low, medium, and high soil fertility classes.

Soil fertility evaluation

Soils are very heterogeneous in respect to forms of nutrients they contain, which greatly complicates the interpretation of Soil Test for assessing fertilizer needs. The total amount of a nutrient present in a soil offers little information relative to the amount of that nutrient which is available. Numerous extracting solutions and procedures have been used to remove nutrient elements from the soil, but none remove exactly the amount that plant roots obtain.

This means that, in order to interpret the data, the results from each analytical procedure must be correlated with the plant response obtained in field experiments by applying that fertilizer nutrient.

By this calibration, the requirement of fertilizer is calculated for achieving specific yield target. Soil fertility evaluation preferably employs a particular method of calibration as per the utility of the outcome.

Crop Response Data

In nutrient rating experiments, soil test data is correlated with the response of crop. The response is measured in terms of 'percent yield' or 'percent yield increase'. Both represent the ratio of the yield obtained in unfertilized soil (nutrient limiting deficient soil) to the yield in fertilizer nutrient applied soil (non-limiting or nutrient sufficient soil). The yield in non-limiting soil is otherwise known as maximum attainable yield or yield of standard treatment with all nutrients applied.

While comparing native fertility, in experiments that are conducted at different locations, *percent yield* is used.

$$\text{Percent yield} = \frac{\text{Yield without fertilizer nutrient}}{\text{Yield in standard treatment}} \times 100$$

While conducting multi location trials, or a pot experiment in a single location with soils brought from different locations, *percent yield increase* is worked out for every level of fertilizer application. The highest yield obtained in the experiment with all fertilizer nutrient applied, is taken as Maximum attainable yield

$$\text{Percent yield increase} = \frac{\text{Yield at fertilizer nutrient level} - \text{Yield without fertilizer nutrient}}{\text{Maximum attainable yield}} \times 100$$

The soils analyzed by standard nutrient extraction method are grouped. The soil tests are calibrated into different fertility groups by various procedures.

Present approaches in formulation of fertilizer recommendations extensively used in India:

Soil testing programme was initially started adopting the International soil fertility evaluation and improvement programme (Fitts, 1956). In this approach much stress is laid on laboratory characterization, followed by potted-plant studies ultimately leading to field - verification trials. These two initial steps help in eliminating arbitrariness of field trials. However, this approach had low adoption as it arrived one critical value below which economic responses are possible. Later, many improvements were suggested.

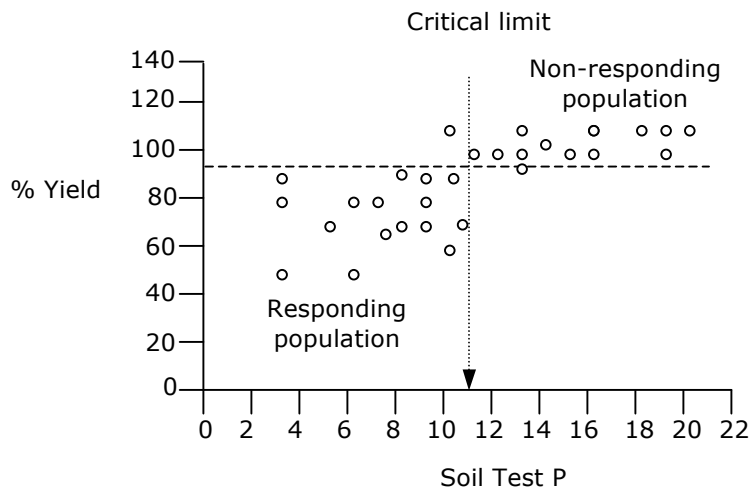
AGRONOMIC APPROACH

This is based on **fertilizer rate experiments** (recording yield at increasing nutrient levels) conducted at many locations. The level at which yields are high are recorded and averaged. From these results, the optimum dose of fertilizer is recommended for a crop at given agro-climatic region. Eg. A blanket dose of 120-50-50 kg/ha of N, P₂O₅, K₂O respectively is recommended for rice.

CRITICAL LIMIT APPROACH

Waugh and Fitts (1965) developed this technique which is largely meant for less mobile nutrients like P, K and micronutrients. Soils vary considerably in fixing capacities. Due to it a part of applied P, which is fixed in soil, is not readily available to plants.

The method includes incubation study. For P, Soil is incubated for 72 hours with graded doses of soluble P in the form of monocalcium phosphate. Then, the amount of phosphates released (extracted) with an extracting reagent (Olsen or Bray) will be determined. The extracted P versus the amount of P applied is plotted. If the relationship is unique, then for high P fixing soils a larger amount of fertilizer P application is needed. This amount of P fixed is estimated as X-value.



Then, in potted experiment fertilizer P is added at 0, 0.5X, X, 2X levels, and the test crop was grown to find out the soil critical value. The percentage yield obtained is plotted against the soil-test value for different soils. By using a plastic overlay, these data are grouped into two populations as described by Cate and Nelson (1965). The soil-test value where the vertical line crosses the x-axis is designated as the soil critical limit.

Critical limit for the soil test value is *the limit below which a positive or economic response to added fertilizer is possible and above which the response diminishes at a faster rate or vanishes.*

The validity of critical value is verified by conducting verification trials in the field locations where from the soil samples have been collected for pot studies.

14. PREDICTING YIELDS USING NUTRIENT FUNCTIONS

Nutrient function Crop yield is a function of 4 major factors:

Yield = f (crop, soil, climate, management).

Nutrient functions are fitted using data obtained in experiments conducted either in *deductive* or *inductive* approach.

Deductive approach

Deductive approach utilizes the natural variation in soil fertility for calibrating soil test values. Multilocation trials are carried out with same set of treatments. The responses are then fitted in the fertilizer prescription models.

Colwell (1967) developed this approach on the basis that some variables, which affect the response of crop to fertilizers, if omitted from the correlation between soil test and yield led to poor correlations. To prevent this difficulty, a calibration model was suggested based on the generalization of coefficients of an *orthogonal polynomial yield-response model*, which can include all the variables affecting the responses to fertilizers.

Inductive approach

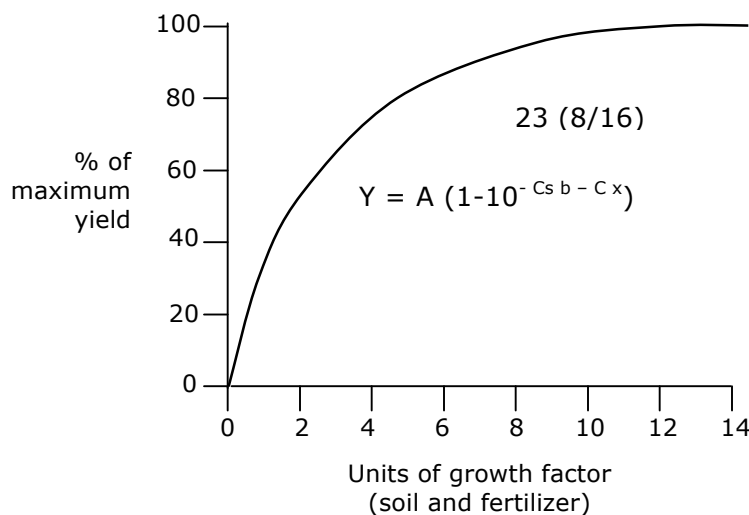
This approach is by creating fertility gradient artificially in a particular experimental location by addition of fertilizers. The approach of inducing fertility gradient (Ramamoorthy, 1970) aims at eliminating influence of the 3 out of 4 factors in the yield function, namely: crop, climate and management in the experimental location.

A large field having wide variation in fertility is chosen in a location. It is divided into 4 strips, which are treated with 4 doses of N, P and K fertilizers, viz., control ($N_0P_0K_0$), $\frac{1}{2}$ normal dose ($N_{\frac{1}{2}} P_{\frac{1}{2}} K_{\frac{1}{2}}$), normal dose ($N_1P_1K_1$) and double dose ($N_2P_2K_2$). The normal doses are fixed based on **nutrient fixing capacity** of the soil. Exhaustive crop like maize is grown. The calibration crop experiment is then laid out. For the purpose of correlation, 21 treatments having one untreated check plot are tested.

Quadratic Model:

Percentage of yield maximum concept (sufficiency concept)

This is commonly known as Mitscherlich and Bray approach. An empirical relationship is developed between percent yield, soil test, and fertilizer maximum yield (Bray, 1944).



Presently, this approach is modified and used by the Department of Agriculture, Tamil Nadu for giving site-specific fertilizer recommendations.

The modified Mitscherlich-Bray equation is:

$$\text{Log } (A-Y) = \text{Log } A - C_s b - Cx$$

Where,

A	=	calculated maximum yield
Y	=	percentage yield
C _s	=	proportionality factor for soil nutrient
b	=	soil test value
x	=	dose of fertilizer added.

The maximum yield (A) is calculated by extrapolation.

Quadratic Model:

Regression model for maximum profit

The amount of fertilizer that produces the greatest profit per hectare is called the optimum dressing (Cooke, 1972). Ramamoorthy (1974) established a significant relationship between soil tests, added fertilizers and crop yields by fitting a multiple regression of the quadratic form (*orthogonal polynomial yield-response model*):

$$Y = A + b_1SN + b_2SP + b_3SK + b_4SN^2 + b_5SP^2 + b_6SK^2 + b_7FN + b_8FP + b_9FK + b_{10}FN^2 + b_{11}FP^2 + b_{12}FK^2 + b_{13}SNFN + b_{14}SPFP + b_{15}SKFK$$

Where

Y	=	Crop yield (kg/ ha)
A	=	Intercept
b _i	=	Regression coefficient

SN, SP, SK = Available contents of soil N, soil P and Soil K

FN, FP, FK = Fertilizer N, Fertilizer P, Fertilizer K

Fertilizer calibrations for varying soil test value for obtaining maximum profit per hectare could be derived where the response to added nutrient follows the law of diminishing returns (Ramamoorthy, 1974)

Fertilizer adjustment equation is derived in the form:

$$FN = a - b SN - c R$$

$$FP_2O_5 = a - b SP - c R$$

$$FK_2O = a - b SK - c R$$

Where,

$$R = \frac{\text{Cost of fertilizer nutrient (Rs./kg)}}{\text{Value of produce (Rs./kg)}}$$

Linear model:

Targeted Yield approach

Fertilizer recommendation must aim at providing balanced nutrition to crops. Balanced nutrition should have nutrients to be present in available forms in adequate quantities and required proportion for the plant in order to produce maximum yield. The requirement of nutrient to produce the expected yield can be worked out based on **nutrient uptake**.

Nutrient requirement of crops

Crop	Nutrient Requirement (kg) to produce 100 kg of economic produce		
	N	P ₂ O ₅	K ₂ O
Rice	2.01	1.12	3.00
Wheat	2.45	0.86	3.28
Maize	2.63	1.39	3.58
Sorghum	2.24	1.33	3.40
Finger millet	2.98	1.13	3.90
Chick pea	4.63	0.84	4.96
Soya bean	6.68	1.77	4.44
Ground nut	5.81	1.96	3.01
Potato	0.39	0.14	0.49
Cotton	4.45	2.83	7.47

Liebig's law of minimum states that the growth of plants is limited by the plant nutrient element in the smallest quantity, when all others being present in adequate amounts. This forms the basis for fertilizer application for targeted yields, first advocated by Troug (1960) by significant **linear relationship** between the yield of grain and uptake of nutrients. Yield target can be projected within the linear region of the response function.

This approach, popularly known as **Soil Test Crop Response Function (STCR)**, implies that for a specific yield (grain or any other economic produce) a definite quantity of the nutrient must be taken up. This value can be determined by the magnitude of the expected yield (T in q/ha) and the nutrient requirement to produce unit quantity of that target (NR in kg/ha).

Once it is known for a target yield, the fertilizer dose (FD kg/ha) can be estimated.

It is done by taking into account the efficiency of soil contribution (CS in percent) from the soil available nutrients (STV in kg/ha), and the efficiency of fertilizer of fertilizer contribution (CF in percent) from the fertilizer nutrients (FD in kg/ha) towards the total uptake.

$$FD = \frac{NR}{CF} \times 100 T - \frac{CS}{CF} \times STV$$

Where F and S stand for fertilizer and soil nutrient in Kg/ha and T is yield target in q/ha.

LECTURE 15

FERTILITY EVALUATION BY PLANT ANALYSIS

Plant analysis is a useful diagnostic tool to ascertain if a nutrient has been or is being assimilated. Plant analysis is also important in ascertaining the nutrient requirements and nutrient status of plants during various stages of growth.

A reasonably simple laboratory test of plant sample provides a measure of nutrient availability in soil or nutrient status of plant at the time the sample was collected. If these tests are to be useful in making fertilizer recommendations, a coordinated laboratory-field research program must be conducted in order to obtain the desired information.

Deficiency symptoms

Careful inspection of growing seedling or plants can help identify specific nutrient stress. If a plant is lacking in a particular nutrient, characteristic symptoms may appear. Nutrient deficiency symptoms must be related to some function of the nutrient in the plant. Visual symptoms may be caused by more than one nutrient. In a set of nutrient omission and addition pot experiments, exact limiting nutrients can be identified.

Tissue tests

The concentration of the nutrients in the cell sap is usually a good indication of how well the plant is supplied at the time of testing. These semi-quantitative tests are intended mainly for verifying or predicting deficiencies of N, P, K, S and several micronutrients.

Method: the plant parts may be chopped up and extracted with reagents. The intensity of color developed is compared with standards and used as a measure of nutrient concentration. Tissue tests are quick, easy to conduct and interpret.

For tissue tests, the time of sampling and plant part to be sampled have already been standardized for many crops. Tissue test can be done 5-6 times in a season and concentration can be monitored in the *farm premises*.

There can be two peak periods of nutrient demand, one during maximum vegetative growth and second during reproductive stage. Fertilization can be done to maintain the peak concentration at critical stages.

Total plant analysis

As in tissue tests, a standardized method for time and method of sampling of plant part are available for total analysis, which is done at *laboratory*. The critical nutrient concentration is commonly used in interpreting plant analysis results and diagnosing nutritional problems.

Diagnosis and Recommendation 23 (12/16) **System (DRIS)**

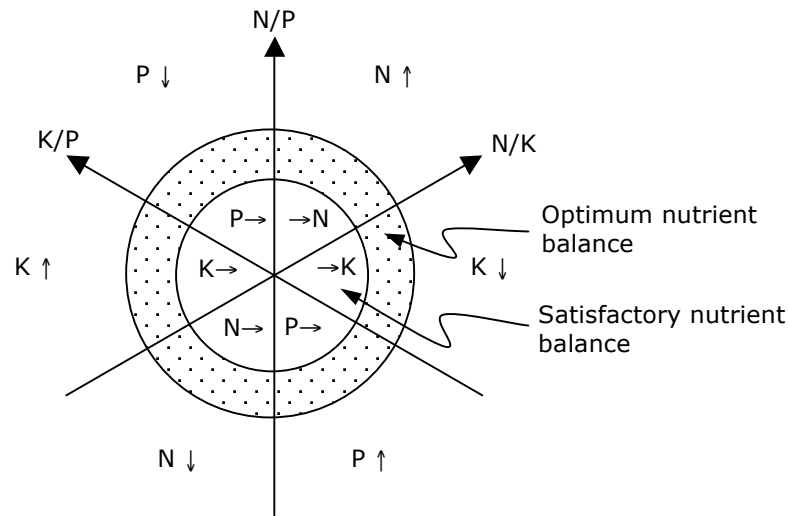
DRIS is a system that identifies all the nutritional factors limiting crop production. Index values measure how far particular nutrients in the leaf or plant are from optimum levels. Index values are used in the calibration to classify yield factors in the order of limiting importance. To develop a DRIS for a given crop, the following criteria are to be well considered.

- All factors having effect on yield
- Relationship among factors
- Calibration norms
- Continually refined recommendations

DRIS was developed based on **nutrient ratios**. When compared to concentration that normally varies with season, nutrient ratio does not vary much. When a nutrient ratio has an optimal value, optimum yield occurs unless some other limiting factor reduces the yield.

$\frac{N \rightarrow}{P \rightarrow}$	$\frac{N \uparrow}{P \uparrow}$	$\frac{N \downarrow}{P \downarrow}$
Both numerator and denominator optimal	Both numerator and denominator excessive	Both numerator and denominator insufficient

When the ratio is too low a response in the numerator will be obtained if it is limiting. If the nutrient in the denominator is excessive, a yield response may or may not occur depending on the level of other yield factors.



General diagram for a DRIS; constructed on nutrient ratios for N-P-K

When the ratio is too high the reverse is true. Usually N/S, K/Mg, K/Ca, Ca + Mg /K, N/P ratios are commonly used. Initially relationship among N-P-K is calibrated.

Thus, DRIS has several advantages to integrate much nutrient concentration at various stages, in different seasons suitable for many cultivars of a crop.

DRIS has been found suitable for several grain crops and perennial fruit trees.

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CROP LOGGING

An excellent example of the use of plant analysis in crop production is the crop logging carried out for sugarcane in Hawaii. The crop log, which is a graphic record of the progress of the crop, contains a series of chemical

and physical measurements. Critical nutrient concentration approach is used in the crop log system.

In sugarcane, plant is sampled at 35 days and analyzed for N, sugar, moisture and weight of young sheath tissue. Nutrients like P and K are monitored at critical stages. Based on moisture, irrigation is scheduled. Based on nutrient content, fertilizer application is done. By this record keeping, the productivity of crop is increased.

BIOLOGICAL TESTS

Simpler and rapid laboratory/ green house techniques utilize small quantity of soil to quantify nutrient supplying power of a soil.

Tests using higher plants:

***Neubauer seedling method:* The Neubauer technique is based on the uptake of nutrients by a large number of plants grown on a small amount soil. The roots thoroughly penetrate the soil, exhausting available nutrient supply within a short time. Usually 100 seedlings of rye or oats made to feed 100 g soil mixed with 50 g sand. Blair (1956) is also run. Total P_2O_5 and K_2O uptake is calculated and blank value is detected to get root soluble P_2O_5 and K_2O . Values designated as Neubauer Nos. (mg/ 100 g soil) are used to determine the deficiency. These tables give the maximum values of available macro and micronutrients for satisfactory yields of various crops.**

Standard and Demont technique: It is a modified neubauer technique. Round cardboard cartons with bottom removed are nested in a container and filled with sand. Seeds are sown. After 2-3 weeks of growth, a carton containing the plants is nested in a second carton holding 200 g soil or soil + fertilizer. When the mat of roots meets soil, it is allowed to feed for 3-4 days. Then nutrient uptake is estimated.

Deficiency test of sunflower for Boron

Sunflower is grown in the test soil supplied with nutrient solution with all essential nutrients excepting boron. From the day of appearance of B deficiency symptoms of leaves, the soil is identified as deficient (<28 days), moderately deficient (28-36 days), and not deficient (>36 days).

Microbiological methods:

In the absence of nutrients, certain microorganisms exhibit behavior similar to that of higher plants. For example, growth of *Azotobacter* or *Aspergillus niger* reflects nutrient deficiency in the soil. The soil is grouped from very deficient to not deficient in the respective elements, depending on the amount of colony growth. In comparison with methods that utilize growing of higher plants, microbiological methods are rapid, simple and require little space.

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Sacket and Stewart technique

For identifying P and K deficiency test soil is divided in to 4 portions. Solution containing soluble P, K, and P+K are added in 3 portions and one portion was allowed as check. They are inoculated with *Azotobacter* and incubated for 72 hrs. Based on colony growth deficiency is identified.

Melich Cunninghamella – plaque test:

Cunninghamella is sensitive for P. Test soil is mixed with nutrient solution and a paste is prepared. The paste is spread on a clay dish. *Cunninghamella* is inoculated at the centre and incubated for 5-6 days. Based on the diameter of mycelial growth, the soil is diagnosed as deficient (<10 cm), moderately deficient (11-21 cm), or not deficient (>22 cm).

Mulder *Aspergillus niger* test for Cu and Mg

Colours of mycelial and spores are used to delineate the deficiency of Cu and Mg. This method is used for Mo, Co, Mn, S, Zn also.

LECTURE 16

SOIL TESTING AND CORRELATION

The composite samples obtained from fields are used in pot-culture plant studies to assess the crop responses (in terms of dry matter) to added fertilizers. Calibration of the responses to soil - test values was obtained by using different methods. Fixation studies are conducted to ascertain the capacity of soil to fix nutrient to be applied, finally, the results are interpreted to confirm nutrient deficiencies, index soil fertility, and establish "critical level" for each nutrient. The results are verified in the next stage, in field experiments.

Fertility group/ Index

The International soil fertility evaluation and improvement programme (Waugh and Fitts, 1965) advocated grouping of soils into low-medium-high categories.

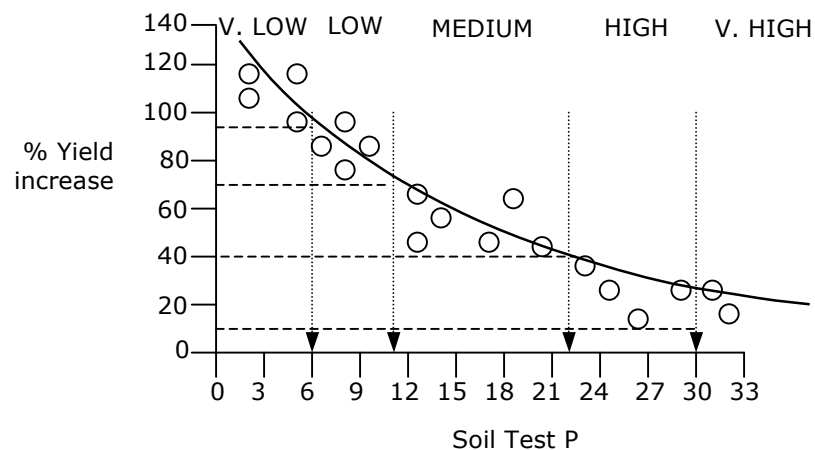
The method:

- Collection of representative soil samples and analysis by using different extractants for the 'available' nutrient
- Conducting of potted-plant studies with graded doses of added nutrient supplying all other nutrients to meet the crop requirement
23 (3/16)
- Computing of the percentage yield responses
- Plotting of the soil-test data obtained with different methods and the percent yield response; and to find the scatter distribution for the best correlating soils test methods. The scatter diagram will be generally curvilinear. The response is less, as the soil test value increases.
- The general groups are low, medium and high

The fertility groups followed in Tamil Nadu

Fertility group	Available nutrients (kg/ ha)		
	KMnO ₄ -N	NaHCO ₃ -P	NH ₄ OAc-K
Low	<280	< 11	< 118
Medium	280-450	11- 22	118-280
High	>450	> 22	>280

This classification indicates that low classes of soils would markedly respond to added fertilizers and high status of soils does not respond to them. In the medium range, nothing could be predicted. In addition, by this grouping, it was not possible to indicate how much fertilizer was to be added to get economic yields. Thus, this grouping is qualitative. Arbitrarily, the recommended dose of fertilizer for a crop is increased by 25% in low status and reduced by 25 % in high status.



Fertility index

Fertility index expresses the **relative sufficiency as a percentage of soil nutrient amount adequate for optimum yields**. The probability of a response to fertilizer application increases with decreasing soil test level.

More than 85% of soils testing very low may give greater response and profit. About 60-85% of soils, having medium soil test value may give little profit. Around 15% soils with very high soil test may have little response.

In general, the very low to very high classification is easily understood by the grower. However, separate group classification need to be done accounting for greater variability associated with crops and soils.

Soil Test Rating	Probability of Crop Response (% Yield increase)	Fertility Index
Very low	95-100	0-10
Low	70-95	10-25
Medium	40-70	25-50
High	10-40	50-100
Very High	0-10	100+

LECTURE 17

SOIL TESTING

Soil Testing, STL Functions

Soil Testing

Soil testing is defined as a 'programme for procedural evaluation of soil fertility by Rapid chemical analysis particularly to assess the *available nutrient status and reaction* of a soil'.

A **soil test** is a chemical method for estimating nutrient supplying power of a soil. Compared to plant analysis, the primary advantage of soil testing is its ability to determine **the** nutrient status of the soil before the crop is planted.

The result of a soil test is known as **soil test value**. A soil test value measures a *part of the total nutrient supply in the soil and* represents only as an index of nutrient ability.

Soil test do not measure the exact quantity of a nutrient potentially taken up by a crop. To predict nutrient needs of crops a **soil test must be calibrated against the response of crops** in nutrient rate experiments in greenhouse and fields. Thereafter, interpretation and evaluation of the soil test values primarily form the basis for fertilizer recommendation.

Soil test programmes have the following objectives:

- To provide an index of nutrient availability
- To predict the probability of profitable response to fertilizer

- To provide a basis for fertilizer recommendation
- To evaluate the soil fertility status and a county soil area or a statewide basis by the use of the soil test summaries.

Phases of Soil Testing programme

1. Collecting the soil samples
2. Extraction and determining the available nutrients
3. Calibrating and interpreting the analytical results
4. Making the fertilizer recommendation and management

Soil sampling

The most critical aspect of soil testing is *obtaining a soil sample* that is **representative of the field**. There is always a considerable opportunity for sampling error. If a sample does not represent a field, it is impossible to provide a reliable fertilizer recommendation.

The soils are normally **heterogeneous**, and wide variability can occur even in a uniform fields. Intensive soil sampling is the most efficient way to evaluate variability. The sampling error in a field is generally greater than the error in the laboratory analysis.

Soil Unit: It is an area of soil tested by a composite sample. After the soil unit is determined, the soil samples are collected throughout the area. The number of samples for combining into each representative composite sample varies from 5-20 samples in an area of an acre. Usually a composite sample of one kg of soil is taken from a field.

The size of the area may be sometimes even less for areas that vary in appearance, slope, drainage, soil types, past treatment These areas are

to be sampled for separately. The purpose of the procedure of making a composite sample is to minimize the influence of any local non-uniformity in the soil.

Normally for all field crops, sampling soil up to 15 cm depth is practiced. For deep-rooted crops and tree crops samples up to 1-2 m may be necessary. While sampling, first a uniform portion is taken from the surface to the depth desired. Second, the same volume is obtained from each area.

Preparation of the composite soil sample in the laboratory

It involves the following steps: Drying, grinding, sieving, mixing, partitioning, weighing, and storing. Uniform mixing and sampling is done by **Quartering Technique**:

The soil sample is coned in the center of the mixing sheet. Cone is flattened and divided through the center with a flat wooden sheet. One half is moved to the side quantitatively. Then each half is further divided into half, the four quarters being separated into separate 'quarters'. Two diagonally 'opposite quarters' are discarded quantitatively. The two other are mixed by rolling. This process is repeated, until 250-500 g composite soil material is obtained.

24 (3/4)

For micronutrient analysis – sampling and processing of samples should alone be done only with stainless steel materials, plastic, or wood to avoid contamination.

The soil test values calibrated nutrient functions are advocated to the farmers as a package of nutrient management that aims at **judicious use of fertilizers**. Ultimately any soil testing and interpretation must involve

'**economics**' because it is used to make a fertilizer recommendation to achieve an economic goal that would give *maximum profit per hectare* of land.

Extraction and determining the available nutrients

Many chemical extractants have been developed for use in soil testing. The ability of an **extractant** to extract a plant nutrient in quantities related to plant requirements depends on the reactions that control *nutrient supply and availability*. The extractants commonly used in soil testing programmes are given below.

Plant nutrient	Common extractant	Nutrient source extracted
NO_3^-	KCl, CaCl_2	Solution
NH_4^+	KCl	Solution - Exchangeable
Available N	KMnO_4 - NaOH	Mineralizable Organic N
$\text{H}_2\text{PO}_4^- / \text{HPO}_4^{2-}$ (Available P)	NH_4F - HCl (Bray-p)	Fe/ Al mineral solubility
	NaHCO_3 - P (Olsen-P)	Ca mineral solubility
K^+ (Available K)	NH_4OAc -K	Exchangeable
Ca^{2+} , Mg^{2+}	EDTA	Exchangeable
SO_4^{2-}	CaCl_2	Solution AEC
Zn^{2+} , Fe^{3+} , Mn^{2+} , Cu^{2+}	DTPA	Chelation

H ₃ BO ₃ ⁰	Hot water	Solution
Organic C	Chromic acid	Oxidizable C

SOIL TESTING LABORATORY

Soil Testing Laboratories of the Department of Agriculture funded by State Government are functioning at identified centres in each district. Soil testing services are also extended to the farming community in the Soil Laboratories operated by Central government and Agricultural Universities.

The major functions of State Soil Testing Laboratory are:

- Analysis of soil samples which are collected from the farmers by the Assistant Agricultural Officers for texture (by feel method), lime status, Electrical conductivity, pH and available N, P and K status at lower charges/ sample; and advocating fertilizer recommendation for different crops. Available micronutrients will be analyzed on request.
- Analyzing irrigation water samples for EC, pH, cations, and anions; Assessing their quality based on different parameters; and suggesting suitable ameliorative measures for different soil condition and crops.
- Adopting two villages for a particular period by each soil testing laboratory; collecting and anal 10 (4/8) and irrigation water samples at free of cost and advocating the recommendations.
- Collection of benchmark water samples from the wells marked in a particular block/ water shed/ taluk. After analyzing the water samples for different properties, water quality map will be prepared.

- Based on the soil test value for the soil samples collected during the particular year they are rated as low, medium, and high; and village fertility indices will be prepared.
- Conducting trials related to soil fertility to solve the site-specific problems.

Functions of mobile soil testing laboratory

- The staff of the Mobile STL will visit the villages, collecting and analyzing the soil and irrigation water samples in the village itself and giving recommendations immediately.
- Showing the audio-visual programmes through projectors in the villages educating the importance of soil testing, plant protection measures and other practices related to crop production.
- In addition, Mobile STL is carrying out other regular functions of stationary soil-testing laboratory.

LECTURE 18

FERTILITY SURVEY AND MAPPING

Survey, village indices

Soil Fertility Survey

Soil survey essentially aims at taxonomical classification of soils in well-defined units. The properties studied in the survey are ultimately used to plot the extent of boundaries on a map. The maps are referred for various purposes particularly for predicting yields based on soil fertility.

Fertility surveys are carried out in profile studies. Profiles in representative locations in each soil series are opened and thoroughly examined. From samples collected at different depthwise layer, soil physical, chemical, and biological properties are thoroughly studied. The factors limiting crop growth are identified in field and laboratory estimations.

Parameter on the depth of soil, rooting depth, bulk density, particle density, porosity, water holding capacity, possible profile moisture storage, soil reaction, salinity, total and available nutrients, presence of hard pans. By interpretive analysis the fertility, data are grouped and used for mapping.

The division of Soil Survey and Land Use Planning of State Department of agriculture, which is operating in selected districts of the Tamil Nadu compiles the information and publish them as a Report. The reports are available on cost basis to needy persons and institutions. The results of survey are further classified and mapped by National Bureau of

Soil Survey and Land Use Planning located in Nagpur, Bangalore and in many other locations in India. The Maps are distributed on cost basis for their effective use. Soil Maps of Agro-climatic regions, fertility status, irrigability, soil depth, crop suitability, salinity, etc are available.

Besides, the State Agricultural Universities and other national Institutes conduct soil surveys and prepare maps on nutrient status marking the macro and micronutrient deficient soils for ready recognition. The remote sensing tools are also used in Mapping.

Village Fertility Indices and Mapping

In our country, the soil testing laboratories are functioning in all the states. In Tamil Nadu, the soil testing and mobile soil testing laboratories are functioning in almost all the districts.

One of the major functions of these laboratories is to analyze the soil samples collected from the farmers for available N, P and K status. For every year few taluk will be adopted. After analyzing the soil samples for available NPK, they are grouped as low, medium and high based on the soil test value as follows.

After grouping soils as low, medium and high, **Village Fertility Index (VFI)** will be worked out for every revenue village.

$$VFI = \frac{N_L + 2 N_M + 3 N_H}{N_L + N_M + N_H}$$

Where N_L , N_M , N_H are the number of soil samples falling under the category low, medium and high, which are given weight of 1,2,3

respectively. Arbitrarily an index below 1.5 is low, between 1.5-2.5 is medium, and above 2.5 is high.

Using these fertility indices, the current area wise fertilizer recommendation for each crop can be modified. A soil fertility map may be prepared in any outline map of block / taluk by plotting the index values within the boundary of villages.

LECTURE 19

PERMANENT MANURIAL EXPERIMENTS

OPM, NPM, LTFE, Findings

Permanent Manurial Experiments

Permanent manurial experiments are conducted to study the long term effect of continuous application of plant nutrients either singly or in combination and with or without organic manure on crop yield, nutrient uptake, and physico-chemical and biological properties of soil.

The first one started was the classical field experiment at **Rothamsted** Experimental Station, Harpenden in **England** in 1854 by Lawes and Gilbert.

Most of PME's test common treatment combinations like: Fertilizer N or P or K alone, Fertilizer N and K, Fertilizer N and P, Fertilizer NPK, Farmyard Manure (FYM), Residual effect of FYM, Hand weeding, Zn or S addition, Control (no manure), tillage, irrigation, etc.

Similar to Rothamsted experiment, in India PME was started at **Coimbatore** in **1909** and this was the first of its kind in our country. This called as Old Permanent Manurial experiment (**OPM**) is being conducted in red soil (Alfisol) with cereal-cotton crop rotation under *rainfed* conditions.

Subsequently in **1925**, a second experiment was started with the same treatments and called as New Permanent Manurial (**NPM**) experiment to test the effect under *irrigated* conditions.

In **OPM** and **NPM** a uniform fertilizer dose of 25-60-75 kg N, P₂O₅ and K₂O/ha is being applied in all these years. As these are designed with very low dose of fertilizers and manures without any replication and randomization, they do not match to the present day use pattern of fertilizer/manure and statistical analysis.

Therefore, to study the effect of **intensive cropping and manuring** new set of experimental design was implemented all over India by ICAR by a coordinated scheme on Long Term Fertilizer Experiment (**LTFE**). During 1972, LTFEs were started at 11 centres and later further expanded at seven more centres.

Under this scheme, a third experiment was started in 1972 at Coimbatore called as Long Term Fertilizer Experiment (LTFE) in medium black soil (Inceptisol) to test intensive cropping system with Ragi-maize cropping system.

The **major findings** in these experiments are:

- Application of single nutrient (N or P or K) alone resulted in lower crop yield. Combination of NP and NPK gave higher yield.
- Phosphorus became a limiting factor when it was not applied and it reduced the yield to the extent of 50-60 per cent. Application of P along with N, K, and FYM raised the available soil P from low to medium status.
- Potassium was depleted even when it is applied continuously.

- Continuous use of N fertilizer alone reduced the soil productivity. Addition of FYM with NPK significantly increased the crop yield to the tune of 15-20 per cent over NPK alone. Addition of organic manure improved pore space and water holding capacity of soil. Combined application of organic manure and inorganic fertilizer not only increased the yield of crops but also improved the soil productivity.
- Population of bacteria, fungi, *Actinomyces* and *Azotobacter* were increased due to organic manure incorporation. The activities of enzyme urease, dehydrogenase, cellulase, and amylase were favored by organic manure application.

LECTURE 20

FERTILIZERS - USE AND LEGISLATION

Definition, Classification, Indian Scene, products, consumption, Legislation

Fertilizers

Fertilizers are the materials either natural or manufactured, containing nutrients essential for normal growth and development of plants. It may also be defined that any material or substance intended for use as a nutrient carrier in soil or crops for boosting crop yields.

In India, the use of artificial fertilizers was first initiated in 1896 when imported Chilean nitrate was used as a fertilizer. By about 1905 calcium nitrate, calcium cyanamide, ammonium sulphate, super phosphate and potassium sulphate were also imported and used.

After the World War I, the Imperial Chemical Industries carried out valuable field experiments on different crops particularly on rice with ammonium sulphate during the period 1920-30, which established the general superiority over other nitrate fertilizers. The manufacture of ammonium sulphate in India was first started at **Belegolla in Mysore** in 1938 on a small scale.

Share of total fertilizer consumption (%) in India	
Rice	40.5
Wheat	24.2
Sugarcane	8.7

Later in 1947, its manufacture was started at **Alwaye**. In 1951, the Government of India set up fertilizer factory at **Sindri** for the production of ammonium sulphate in the public sector. Gradually several factories were established and use of fertilizers become increasingly popular.

Presently India is the **Third** producer of N and P fertilizers in the world.

Classification of fertilizers

The fertilizer materials may be classified in several ways

Based on fertilizer mixture behavior

- Straight or simple nitrogenous, phosphatic or Potassic fertilizers;
- Complex fertilizers having more than one nutrient in single material and fertilizers having more than one nutrient in single material
- Fertilizer mixtures home mixed or factory mixed materials.

Based on their chemical reaction and nature

- Acidic, neutral, and basic fertilizers

Based on nutrients present

- Simple fertilizers which contain only one nutrient (Single carrier)
- Compound fertilizers which contain more than one nutrient (Multinutrient carrier)

Physical properties of fertilizers:

Physical properties of fertilizers have bearing on bagging storage, transportation, handling, and application. They are properties include –

hygroscopic nature, free moisture content, particle size, melting point, solubility, specific gravity, segregation, granule hardness, angle of response, drillability etc.,

Chemical properties of fertilizers:

Chemical properties include the nature and amount of **nutrients** present, **associated elements**, their **chemical reaction**, and **salt index**. These make a basis for their selection by the cultivators so that they may achieve highest productivity with least damage to soil fertility and least unit cost of fertilizers.

INDIAN FERTILIZER SCENE

India is the **Third** largest producer and consumer of fertilizers in the world. At present, there are 59 large size fertilizer plants in the country manufacturing range of fertilizers. The current installed capacity is 12.1 m tonnes per annum (tpa).

This fertilizer sector is highly subsidized. It relies heavily on imports to meet domestic demand. Indian Government incurs a total subsidy bill about 14% of fiscal deficit every year.

The major grades of fertilizers are Nitrogenous (N), Phosphatic (P) and Potassic (K). N accounts for 71%, P for 22%, and K for 7% of the total fertilizer consumption. Potassic grade of fertilizer is totally imported and is not manufactured in India.

Urea (85% of N fertilizer consumption) constitutes 58% of the total consumption of fertilizers in India. Di-ammonium phosphate (DAP) accounts for approximately 66% of consumption of phosphatic fertilizers.

The N based fertilizer uses indigenously available feedstock (raw material) to produce ammonia, which is processed further to make urea.

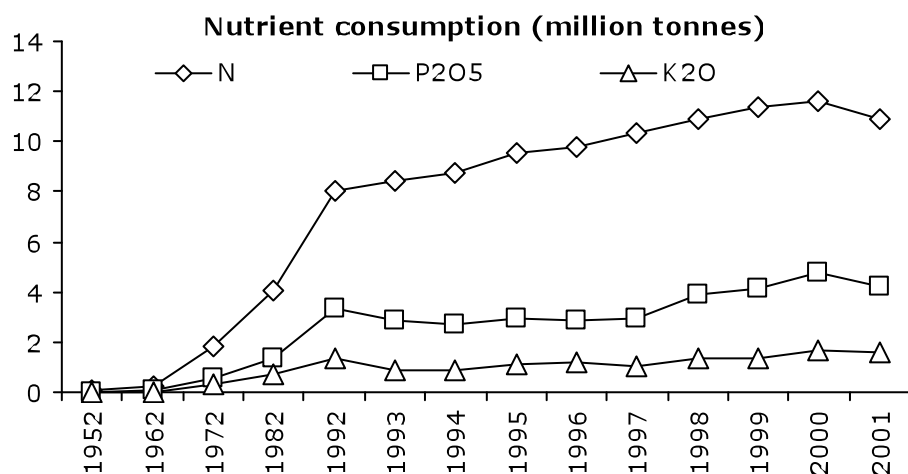
Rock phosphate and potash, the key raw materials for Phosphatic and Potassic fertilizers respectively are **imported** into India, due to lack of domestic availability.

Before April 1, 1997, the State Governments fixed fertilizer prices at non-remunerative levels. In addition, there were procedural delays in fixing prices for each crop season, and delays in reimbursing subsidy to the producers.

The reimbursement price fixation is now done by the Central Government, which may lead to more realistic price levels, and faster disbursements of subsidies.

Consumption of Fertilizer by Nutrients ('000 tonnes)

Year	N	P ₂ O ₅	K ₂ O	Total
1951-52	58.7	6.9	-	65.6
1961-62	249.8	60.5	28.0	338.3
1971-72	1798.0	558.2	300.6	2656.8
1981-82	4068.7	1322.3	676.2	6067.2
1991-92	8046.3	3321.2	1360.6	12728.0
1992-93	8426.8	2843.8	883.9	12154.5
1993-94	8788.3	2669.3	908.7	12366.3
1994-95	9507.1	2931.7	1124.8	13563.6
1995-96	9822.8	2897.5	1155.8	13876.2
1996-97	10301.8	2976.8	1029.6	14308.1
1997-98	10901.8	3913.6	1372.5	16187.8
1998-99	11353.8	4112.2	1331.5	16797.5
1999-00	11592.7	4798.3	1678.7	18069.7
2000-01	10861.9	4212.4	1557.1	16631.4



Important Fertilizer Products in India

	Grade (%)	Consumption (1999-2000) '000 tonnes
Produced in India		
Straight Nitrogenous		
Urea	46 N	20277.66
Ammonium sulphate	20.6 N	638.10
Ammonium chloride	25 N	75.19
Calcium ammonium nitrate	25 N	347.25
Straight Phosphatic		
Single super phosphate	16 P ₂ O ₅	3600.99
Diammonium phosphate	18-46-0	6937.68
NP/NPK Complex Fertilizers N: P ₂ O ₅ : K ₂ O		
Ammonium Phosphate Sulphate	16-20-0	220.89
Nitro Phosphate with Potash	15-15-15	341.82
Urea Ammonium Phosphate	27 (4/8) 28-0	173.66
	14-35-14	184.32
Nitro Phosphate	20-20-0	1531.56
	23-23-0	222.19
Others	10-26-26	529.79
	12-32-16	499.45
	17-17-17	681.00
	19-19-19	126.63

	14-28-14	11.47
Imported Fertilizers		
Straight Potassic		
Muriate of potash	60 K ₂ O	2049.24
Sulphate of potash	50 K ₂ O	17.50
Straight Phosphatic		
Rock phosphate	12-18 P ₂ O ₅	102.96

LECTURE 21

PROSPECTS OF FERTILIZER USE

Growth in the future will have to come from an increase in cropping intensity and productivity growth, which implies the higher use of fertilizers. This is because during 1991-2000, food grain production grew at a rate of 1.7% (population growth over the same period: 1.9%), while net sown area stagnated at 1.41 m hectares.

Agriculture constitutes 33% of GDP and farmers constitute over 60% of the vote bank in India. Considering the importance and sensitivity of the sector and the strong lobby of farmers in Indian politics, it is unlikely that the government will frame a clear longterm policy in near future to resolve problems faced by manufacturers. Hence, regulated pricing and subsidies is likely to continue.

Availability of natural gas will be crucial to the fortunes of fertilizer manufacturers as it is the preferred feedstock. Any reduction in availability and changes in its pricing will affect production and profitability of the companies in this sector.

In a much-deregulated environment, market forces will dictate the competition. Distribution network competitiveness and regional imbalances will assume importance. In such a scenario, efficient producers and distributors will do well. Potash fertilizer will continue to be imported, as it cannot be manufactured domestically due to the absence of supplies of critical raw materials.

FERTILIZER LEGISLATION

Chemical fertilizers are becoming increasingly expensive day by day due to hike of prices of petroleum, inflation etc., which tempts dealers to adopt malpractices for earning more profits through adulteration, supplies of underweight materials or blending of degraded fertilizers etc. Thus, the farmers are ditched and often they fail to get good response of applied fertilizers. Therefore, the laws regulating the manufacture and sale of various fertilizers are essential to ensure that the consumer or the farmer is supplied with fertilizers of standard quality.

Keeping these points in mind, the Government of India brought in the fertilizer Control Act.

FERTILIZER CONTROL ACT

The Union Government of India promulgated the fertilizer Control Act (F.C.O) in **1957** under the ***Essential Commodities Act***, 1955 (section 3) with a view to regulate fertilizer business in India.

The F.C.O. keeps a strict watch on quality control of fertilizers, provides for the registration of dealers and statutory control of fertilizer prices by Government. Therefore, everybody involved in fertilizer business as a manufacturer, dealer or a salesperson, must have proper understanding of the F.C.O. in order to avoid infringement of Government regulations.

The provisions given in the Order will also help the consumers/ farmers to know their rights and privileges in respect of fertilizer quality and Authorities to be approached for their grievances regarding supply of sub-standard materials, overcharging or containers of underweight supplies.

The F.C.O. is published by the Fertilizer Association of India (F.A.I.), updated when ever felt necessary. The Order has provisions on quality for

each consumed fertilizer product and F.C.O. should be consulted under infringement of any of them.

Control of Quality of Fertilizers

The F.C.O. has provisions to penalize manufactures, distributors, and dealers for supply of spurious or adulterated fertilizers to consumers or farmers. The F.C.O. has fixed specifications for various fertilizers, which must be present in them failing which the legislation comes in force, and guilty is punished.

Example: The specifications for **urea**

Moisture % by weight (Max.)	...	1.00
Total nitrogen % by weight (Min.)	...	46.00
Biuret % by weight (Max.)	...	1.50

Particle size:

Granules must pass through IS sieve 320 and

Not less than 80% by weight shall be retained on IS sieve 100.

If it is in the form of **prill**, it shall pass IS sieve 200 and

Not less than 80% by weight shall be retained on IS sieve 100.

Example: The specifications for **Rock phosphate**

Particle size:

The material must completely pass through 6.3 mm IS sieve and not less than 20 % material shall pass through 1.50 micron IS sieve.

Total P₂O₅ content is to be guaranteed by the dealer.

Example: The specifications for Potassium **Schoenite**

Moisture per cent by weight	...	1.50
Potassium % (K ₂ O) by weight (Max.)	...	23.00

MgO % by weight (Min. on dry basis)	...	10.0
Total chloride % (Cl) by weight (Max. on dry basis)	...	2.5
Sodium % (as NaCl) (Max. on dry basis)	...	1.60

LECTURE 22

Tolerance limit in Plant Nutrient for various fertilizers

Category	Limit
Straight fertilizers containing <20% plant nutrients	: 0.1 Unit of nutrient
Straight fertilizers containing >20% plant nutrients	: 0.2 Unit of nutrient
Calcium ammonium nitrate	: 0.3 Unit of nutrient
Complex/ Mixed fertilizers	: 0.5 unit for each and maximum of 2.5 % for all nutrients

Fertilizer Movement Control Order

The Fertilizer Movement Order (F.M.O.) was promulgated by Government of India in April 1973 to ensure **an equitable distribution** of fertilizers in various States. According to the fertilizer movement order, no person or agency can export chemical fertilizers from any State. However, Food Corporation of India, Warehousing Corporation of India and Indian Potash Limited; materials like Rock phosphate, bone meal (both raw and steamed) and zinc sulphate are exempted from the movement restriction.

Agency responsible for Enforcement of F.C.O

The Controller of Fertilizers for India, usually a **Joint Secretary** to the Government of India (Ministry of Agriculture) is responsible for the enforcement of F.C.O. throughout the country.

Electrical Conductivity of the soil saturation extract

Measurement of EC of the soil saturation extract is essential for the assessment of saline soil for the plant growth.

EC (dS m ⁻¹)	<2	-	Salinity effects mostly negligible
	2-4	-	Yields of very sensitive crops may be restricted
	4-8	-	Yields of many crops restricted
	8-16	-	Only tolerant crops yield satisfactorily
	>16	-	Only a few tolerant crops yield satisfactorily

Concentration of water soluble boron

The determination of water-soluble boron concentration is also another criteria for characterization of saline soils. The critical limits of boron concentration for the plant growth are given below.

Boron concentration (ppm)	<0.7	-	Crops can grow (safe)
	0.7-1.5	-	$10 \frac{19}{26}$
	>1.5	-	Unsafe

Reclamation of Saline Soils

In saline soils, reclamation consists mainly in removing the excess salts. This can be done either

- By scraping the salts from the surface (or)

- Washing them down into lower layers beyond the root zone preferably completely out of the solum (or)
- By growing salt tolerant crops (or) by a combination of two (or) more of these methods

Scraping helps to remove salts that have formed an encrustation on the surface, but it is never very helpful in complete reclamation. Substantial quantities of soluble salts are still present in the soil body and hinder plant growth.

Salt tolerant crops

High salt tolerant crops - Rice, sugarcane, Sesbania, oats

Medium salt tolerant crops - Castor, cotton, sorghum, cumbu

Low salt tolerant crops - Pulses, pea, sunnhemp, sesamum

The growing of salt tolerant plants with a view to remove salts is also not a practical proposition. Although these plants remove substantial quantities of salts from the soil, comparatively larger quantities are still left behind. Salt formation is a continuous process; hence, the reclamation is never complete

LEACHING REQUIREMENT (LR)

It may be defined as

The fraction of the irrigation water that must be leached through the root zone to control the soil salinity at any specified level.

$$LR = \frac{D_{dw} \times 100}{D_{iw}} = \frac{EC_{iw} \times 100}{EC_{dw}}$$

Where

LR - Leaching requirement in percentage

D_{dw} - Depth of drainage water in inches

D_{iw} - Depth of irrigation water in inches

EC_{iw} - EC of irrigation water (dSm^{-1})

EC_{dw} - EC of drainage water (dSm^{-1})

If the soil is not free draining, artificial drains are opened (or) tile drains laid underground to help to wash out the salts.

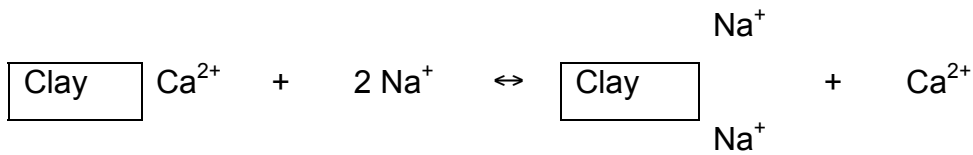
ALKALI SOIL (*sodic/ Solonetz*)

Alkali (or) sodic soil is defined as a soil having a conductivity of the saturation extract less than $4 dS m^{-1}$ and an ESP of > 15 . The pH is usually between 8.5 and 10.0. Formerly these soils were called “**black alkali soils**”

Genesis/ origin

It is evident that soil colloids adsorb and retain cations on their charged surfaces. Cation adsorption occurs due to electrical charges at the surface of the soil colloids. While, adsorbed cations are combined chemically with the soil colloids, they may be replaced by other cations that occur in soil solution. The reaction of cation in solution that replaces an adsorbed cation is called as cation exchange and is expressed as $cmol (p^+) kg^{-1}$.

Calcium and magnesium are the principal cations found in the soil solution and on the exchange ^{10 (20/26)} normal soils in arid regions. When excess soluble salts accumulate in these soils, sodium frequently becomes the dominant cation in the soil solution. In arid regions as the solution becomes concentrated through evaporation or water absorption by plants, the Ca^{2+} and Mg^{2+} are precipitated as $CaSO_4$, $CaCO_3$ and $MgCO_3$ with a corresponding increase in sodium concentration. When the Na^+ concentration is **more than 15% of the total cations** a part of the original exchangeable Ca^{2+} and Mg^{2+} replaced by sodium resulting in alkali soils.



Though the reaction is reversible, Ca^{2+} are removed in drainage water as soon as they formed. Hence, the reaction proceeds in one direction from left to right only. The process whereby a normal soil is converted into an alkali soil is known as “**alkalization**”.

Characteristics various methods are available to characterize

- A direct determination of exchangeable sodium

$$\text{Exchangeable sodium} = \text{Total sodium} - \text{Soluble sodium}$$

- The soil pH also gives an indication of soil alkalinity indirectly. An increase in pH reading of 1.0 or more, with change in moisture content from a low to high value has itself been found useful in some area for detecting alkaline conditions.

The higher the ESP, the higher is the soil pH.

- Sodium Adsorption Ratio (SAR)

The US Salinity Laboratory developed the concept of SAR to define the equilibrium between soluble and exchangeable cations

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2}}}$$

10 (21/26)

(Na^+ , Ca^{2+} , Mg^{2+} are concentrations in saturation extract in me L^{-1})

The value of SAR can be used for the determination of exchangeable sodium percentage (ESP)

$$\text{ESP} = \frac{100(-0.0126 + 0.01475 \text{ SAR})}{1 + (-0.0126 + 0.01475 \text{ SAR})}$$

The following regression equation is also used to work out ESP

$$Y = 0.0673 + 0.035 X$$

Where Y - indicates ESP and X - indicates SAR

Soils having SAR value greater than 13 are considered as sodic soils.

Impact of soil sodicity

- Dispersion of soil colloids leads to development of compact soil
- Due to compactness of soil, aeration, hydraulic conductivity, drainage and microbial activity are reduced
- High sodicity caused by Na_2CO_3 increases soil pH
- High hydroxyl (OH^-) ion concentration has direct detrimental effect on plants.
- Excess of Na^+ induces the deficiencies of Ca^{2+} and Mg^{2+}
- High pH in alkali soil decreases the availability of many plant nutrients like P, Ca, N, Mg, Fe, Cu, and Zn.