Soil Fertility Management:

By Dr. Divya Bhayal :)

Soil Science CoA , Indore

Soil fertility

Soil fertility refers to a soils capacity to support plant growth by providing essential nutrients, water and suitable physical and chemical conditions. Its about the soils ability to maintain healthy plant development and achieve optimal crop yields.

History of Soil Fertility and Nutrition

1.Ancient Agriculture

Egyptians, Mesopotamians, and Chinese practiced early soil management using organic waste.

Use of **manure and crop residues** dates back over 3,000 years.

Terracing and irrigation used to preserve fertility and water.

2. Greek and Roman Contributions

Theophrastus (300 BC) wrote about soil types and crop productivity.

Romans applied **green manures and fallowing**.

Soil fertility was linked with **humus theory** (soil organic matter).

3. Middle Ages (500–1500 AD)

Decline in scientific agriculture.

Three-field system: rotated crops to maintain soil health.

4. 17th–18th Century: Early Scientific Insights

Jan Baptista van Helmont (1600s) – plant growth not solely from soil, but from water.

Jethro Tull (1700s) – promoted plowing for better aeration and root growth.

Rise of **mechanical farming tools**.

5. 19th Century – Birth of Soil Chemistry

Justus von Liebig (1840s) – "Law of the Minimum":

- Plants need essential nutrients (N, P, K).
- Introduced the concept of **mineral fertilizers**.

Discovery of **nitrogen fixation**.

6. 20th Century – Fertilizer Revolution

Development of **synthetic fertilizers** (e.g., Haber-Bosch process for ammonia).

Green Revolution (1940s–60s): High-yield crops + fertilizers = global food increase.

Problems emerged: **soil degradation, salinization, and pollution**.

7. 21st Century – Sustainable Soil Management

Focus on **organic farming**, **biofertilizers**, and **integrated nutrient management**.

Use of **precision agriculture** and **soil testing**.

Emphasis on **climate-smart agriculture**.

Criteria of essentiality (Arnon and Stout 1939)

The criteria of essentiality are a set of guidelines used to determine whether a particular nutrient is essential for plant growth. There are several criteria of essentiality that have been established by plant physiologists and soil scientists over the years, including:

1. **The nutrient must be required for the completion of the life cycle of the plant:** This means that the plant cannot complete its life cycle without the nutrient, and the absence of the nutrient must result in a failure to complete the life cycle.
2. **The nutrient must be directly involved in plant metabolism:** The nutrient must be involved in essential metabolic processes such as photosynthesis, respiration, and protein synthesis.
3. **The nutrient cannot be replaced by any other element:** The nutrient must be unique in its ability to perform its essential function in plant metabolism and cannot be replaced by any other element.

Macro nutrients

Nitrogen (N) (Indian soil- 0.02 to 1%)

Functions: Nitrogen is a major component of amino acid, proteins,enzyme, hormones, chlorophyll and vitamins for plant life, as well as genetic material (nucleic acids).

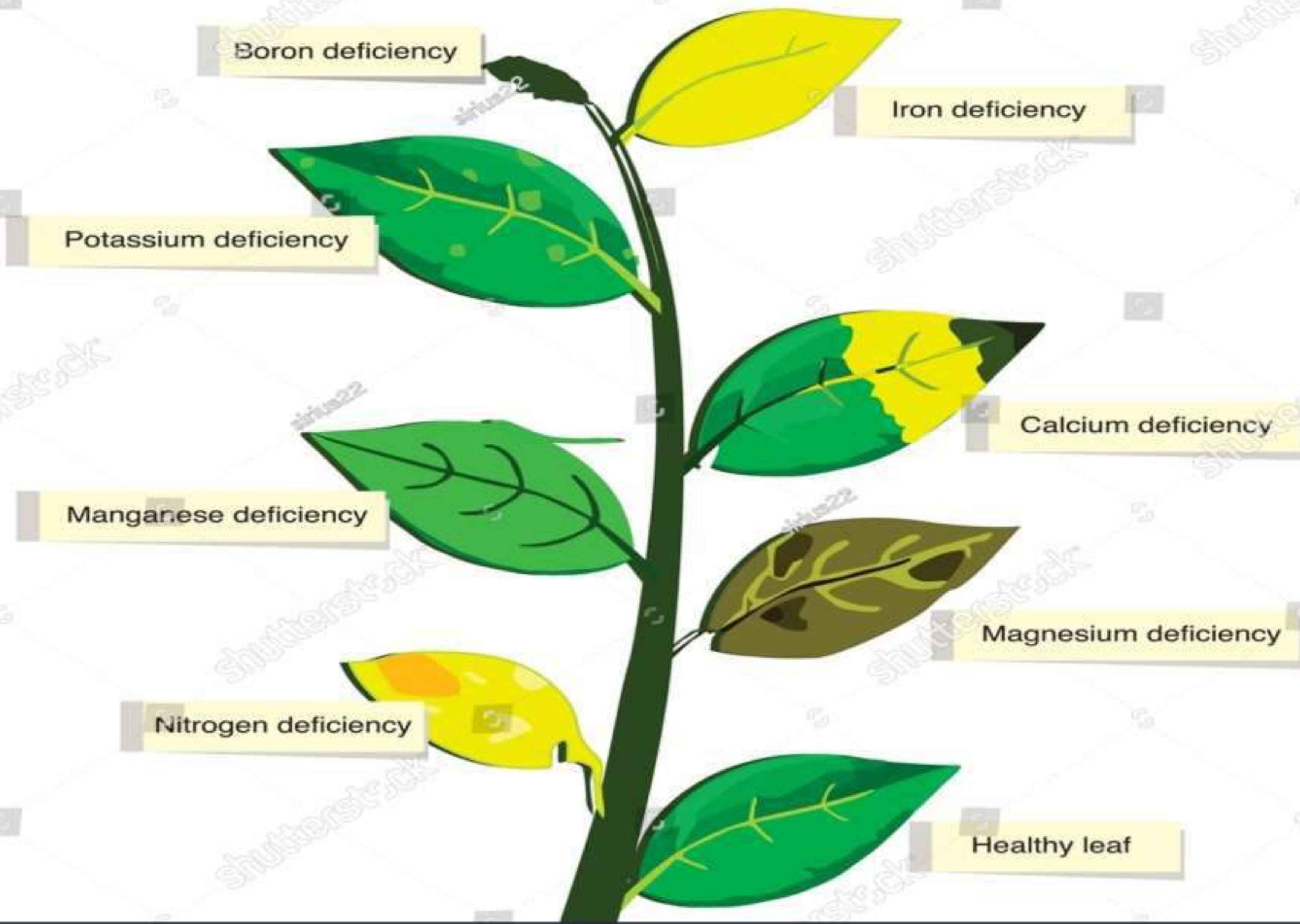
Nitrogen metabolism is a major factor in stem and leaf growth (vegetative growth).

Typical deficiency symptoms: older leaf yellowing, stunted growth, chlorosis.

Disorder- Buttoning of cauliflower

Starvation disease due to nitrogen difficiency

N Toxicity- plants manifests as dark green, sometimes shiny leaves with a cupped or thickened appearance. Other symptoms include leaf tips and margins turning brown or yellow, wilting, premature leaf drop, and potentially dead root tips or stunted growth. In severe cases, plants may exhibit necrosis (tissue death) on stems and leaves, and vascular browning, particularly if ammonium is the predominant form of nitrogen.


Boron deficiency
Iron deficiency
Potassium deficiency
Calcium deficiency
Manganese deficiency
Magnesium deficiency
Nitrogen deficiency
Healthy leaf

Phosphorus (P) (Key of life)

Functions: As a component of ATP, ADP the molecule that stores energy in the living cell, phosphorus is essential for all energy-consuming processes in the plant. Promote root growth. Phosphorus is also related to the genetic material in plants, and necessary for seed germination, photosynthesis, protein formation, flower and fruit formation, and almost all growth and metabolism processes.

Typical deficiency symptoms: stems and leaves turn purple, retarded growth and maturation, poor flowering, premature drop of flowers and fruits.

Toxicity- discoloration and damage to leaves, including yellowing (chlorosis), dark or purplish leaves, and leaf tip or edge burn. Additionally, plants may exhibit stunted growth, twisted leaves, and decreased yields.

P deficiency in grape wine

Potassium (K)

Functions: Potassium is necessary for the formation of sugars and starch in the plant. It is involved in protein synthesis and cell division. Being a vital component of the cell wall, potassium enhances plant rigidity and hardiness.

Potassium is responsible for the opening and closing of stomata, hence necessary for adjustment of water balance in the plant. Disease tolrance , drought resistance.

Potassium also enhances flavor and color on fruit and vegetable crops and increases the oil content of fruits and is important for leafy crops.

Typical deficiency symptoms: leaf yellowing between the veins, mottled, spotted or curled leaves, scorches or burns may be seen on leaves.

Deficiency symptoms appear on older leaves first.

K deficiency in potato

Toxicity - plants is rare but can occur, primarily causing imbalances in the uptake of other essential nutrients. While potassium itself is not directly toxic, excess levels can interfere with the absorption of magnesium, calcium, iron, and zinc, leading to deficiencies in those nutrients.

Luxury consumption- of potassium refers to when plants absorb more potassium than they need for optimal growth and development, even though it's not causing any negative effects on the plant. This can occur when there's a high concentration of potassium in the soil, leading to plants taking up more than necessary. While not harmful to the plant itself, it can be an economic concern for farmers if they are applying too much potassium fertilizer.

Hidden hunger" refers to a state of nutrient deficiency in plants where there are no visible deficiency symptoms, even though the plant's growth and yield are being negatively impacted.

Secondary nutrients

Calcium (Ca)

Functions: Calcium is an important structural component of cell walls. It is necessary for cell growth and division, and influences water movement in cells. In some plants, calcium is required for the uptake of nitrogen. All in all, calcium is a “quality nutrient” that enhances yield quality and prolongs shelf life.

Typical deficiency symptoms: localized rot of tissues, and a consequent growth inhibition, leaf tip burn and root tip burn. Blossom End Rot (BER) is a common physiological disorder in tomato and pepper, associated with calcium deficiency. Eggplant and watermelon are susceptible to a lesser extent.

Ca deficiency in tomato

Toxicity- can include stunted growth, deficiencies in other nutrients, and in some cases, the development of "gold spot" in tomatoes.

Magnesium (Mg)

Functions: Magnesium is a key component of the chlorophyll molecule, hence essential for photosynthesis and formation of carbohydrates. Magnesium is involved in enzymatic reactions and assists in generation of energy. Light trap , central atom of chlorophyll

Typical deficiency symptoms: yellow bands between leaf veins. The symptoms appear first on older leaves and move towards young leaves as deficiency worsens. In severe cases, necrosis may appear.

Toxicity- in plants is rare but can occur, primarily affecting nutrient absorption rather than directly damaging the plant tissue. While magnesium is an essential macronutrient, excessive amounts can interfere with the uptake of other important nutrients, particularly calcium and potassium.

Mg deficiency in tomato

Disorder- Sand drown disease of tobacco
Grass tetany- common in cattle grazing on Mg deficiency pasture.

Sulfur (S)

Functions: Sulfur is a component of amino acids, proteins, and enzymes. It is also essential for the synthesis of chlorophyll. Essential for oil seeds crop.

Typical deficiency symptoms: yellowing of younger leaves, leaves turn light green.

Toxicity - Excessive sulfur can lead to a build-up of salts, stunting plant growth, and causing dark coloring and stunted leaves, similar to salt damage. In most garden settings, it's more common to see sulfur deficiency, which manifests as pale green or yellowing of the young leaves.

Disorder Akicochi disease of Rice – due to toxicity of H_2S

S deficiency in oilseed crop sunflower

Iron (Fe)

Functions: Iron deficiency in plants, often manifesting as interveinal chlorosis (yellowing between leaf veins), is a common problem, especially in calcareous (high pH) soils. This deficiency affects chlorophyll production, hindering photosynthesis and plant growth, leading to stunted growth, poor fruit quality, and reduced yields

Typical deficiency symptoms: young leaf yellowing, interveinal chlorosis.

Fe deficiency in cherry

Fe in tomato

Toxicity - in plants occurs when plants take up and accumulate excessive amounts of iron, leading to damage and reduced growth.

Manganese (Mn)

<u>Functions</u>: Manganese (Mn) is required for photosynthesis and respiration. It improves green color and increases sugar and protein content. Manganese enhances plant tolerance to high light intensity.

<u>Typical deficiency symptoms:</u> primarily appear in young leaves chlorotic mosaic patterns on leaves.

Toxicity- in plants manifests as leaf symptoms like chlorosis (yellowing), necrotic spots (dark spots), and crinkled leaves, ultimately hindering plant growth.

Disorder- **Phala blight of sugarcane, grey spike of oat .**

Marsh spot of pea

Crincle leaf of cotton toxicity Mn.

Mn deficiency in plum

Mn deficiency in tomato

Boron (B)

Functions: Boron is necessary for cell wall formation, membrane integrity and calcium uptake. It assists in the translocation of sugars and affects numerous functions in plants, including flowering, pollen germination, fruiting, cell division, water relationships and the transport of hormones.

Typical deficiency symptoms: Impaired growth and broken stems, death of shoot tips, leading to multiple lateral branches (bush-like shape).

Toxicity- in plants manifests as leaf damage, primarily chlorosis (yellowing) and necrosis (tissue death), often starting at the margins and tips of older leaves.

B deficiency in tomato

B toxicity in lettuce

ZINC- Functions: Zinc is a component or functional cofactor in many enzymes, including auxins (plant growth hormones). It is essential for carbohydrate metabolism, protein synthesis and internodal elongation (stem growth)
Typical deficiency symptoms: mottled leaves with irregular chlorotic areas.
Toxicity- occurs when the concentration of zinc in the plant exceeds the threshold required for optimal growth, causing various physiological and biochemical impairments

Zn deficiency in mango

Copper (Cu)

Functions: Copper is involved in nitrogen and carbohydrates metabolism. It is a component of several enzymes, including enzymes that take part in photosynthesis and respiration.

Typical deficiency symptoms: brown spots on terminal leaves, shoot tips die back.

Copper toxicity- in plants manifests as various negative effects, including stunted growth, altered nutrient uptake, and oxidative stress, primarily affecting root and shoot development.

Cu deficiency in pear

Molybdenum (Mo)

Functions: Molybdenum is involved in many enzymes and is closely linked with nitrogen metabolism as it is an important component of nitrate-reductase and nitrogenase enzymes.

Typical deficiency symptoms: pale green leaves with rolled or cupped margins.

Toxicity- Symptoms of molybdenum toxicity in plants may include yellow or orange-yellow leaf discoloration, sometimes with brownish tints, and may start in the youngest leaves

Cobalt- Cobalt plays a beneficial, though not always essential, role in plant growth and metabolism, particularly in nitrogen fixation and certain plant species. It is a component of vitamin B12, essential for bacterial nitrogen fixation in legumes and other plants.

Cobalt deficiency in plants- , while less commonly discussed than other nutrient deficiencies, can affect growth, particularly in legumes, and also lead to other issues like reduced seed production and poor nodulation

Toxicity- in plants manifests as various symptoms, including leaf yellowing, discolored veins, leaf fall, and reduced plant growth and biomass. High cobalt concentrations can also lead to iron deficiency and premature leaf closure.

Indicator plants - can reveal information about soil nutrient status and other conditions by displaying specific growth patterns or characteristics.

S. no.	Nutrients	Indicator plants
1	N, Ca	Cabbage, cauliflower
2	P	Rape
3	K, Mg	Potato
4	Fe	Cauliflower, cabbage, potato, oats
5	Zn	Maize
6	Na, B	Sugar beet
7	Mn	Sugar beet, oats, potato
8	Mo	Lucerne
9	Cu	Wheat

Mechanisms of nutrient transport to plants,

Absorption of plant Nutrients

1. By roots

2. By leaves

Plants require a variety of nutrients to grow and develop properly, including macronutrients like nitrogen, phosphorus, and potassium, as well as micronutrients like iron and zinc. These nutrients must be obtained from the soil and transported into the plant's tissues for use in metabolic processes. There are several mechanisms of nutrient transport to plants, including:

•**Diffusion**: Nutrients can move into the plant's root system by diffusion, which is **the movement of molecules from an area of high concentration to an area of low concentration**. Nutrients in the soil are constantly being dissolved in water and are available in higher concentrations near the root surface. By diffusion, the nutrients move from areas of high concentration in the soil to areas of low concentration in the root system.

Mass flow: Water and nutrients can also be taken up by the plant through mass flow, which is the movement of water and dissolved nutrients from areas of high pressure to areas of low pressure. When the plant actively transports ions into the root, it creates a negative charge in the root, which draws in positively charged ions from the surrounding soil. This creates a flow of nutrients from the soil to the plant, driven by the flow of water.

Root interception: As the root system grows and expands, it can physically intercept and absorb nutrients from the soil. This process is especially important for immobile nutrients like phosphorus, which does not move easily through the soil. The root system actively searches for nutrients in the soil and can absorb them through root hairs and other structures.

Mycorrhizae: **Mycorrhizal fungi form symbiotic relationships with the plant's roots, forming structures called arbuscules that increase the surface area of the root system and enhance nutrient uptake**. The fungi can access nutrients in the soil that are otherwise inaccessible to the plant and transport them into the root system.

Foliar uptake: In some cases, nutrients can be absorbed through the **plant's leaves or other above-ground structures**. This is especially important for micronutrients that may be present in low concentrations in the soil. Foliar uptake can be facilitated by spraying the plant with a nutrient solution or by using fertilizers that are absorbed through the leaves.

In summary, nutrient transport to plants involves a complex interplay of physical and biological processes, including diffusion, mass flow, root interception, mycorrhizal associations, and foliar uptake. Understanding these mechanisms is important for developing effective nutrient management strategies that promote optimal plant growth and health.

Factors affecting nutrient availability to plants

Several factors can affect the availability of nutrients to plants, including:

- Soil pH: Soil pH can have a significant impact on nutrient availability. Most plant nutrients are **most available to plants when the soil pH is between 6.0 and 7.5.** However, some nutrients, such as iron and manganese, are more available to plants in acidic soils (pH less than 6.0), while others, such as calcium and magnesium, are more available in alkaline soils (pH greater than 7.5).
- **Soil texture**: Soil texture refers to the relative proportions of sand, silt, and clay in the soil. Soils with a high clay content tend to hold onto nutrients more tightly, making them less available to plants. In contrast, sandy soils tend to have lower nutrient retention, which can lead to leaching and nutrient loss.
- **Organic matter content**: Soil organic matter plays an important role in nutrient availability, as it can act as a source of nutrients and improve soil structure and water-holding capacity. Organic matter can also help to release nutrients from minerals in the soil through the process of mineralization.
- **Soil moisture**: The availability of nutrients to plants is also affected by soil moisture levels. Nutrient uptake by plants is most efficient when the soil is moist but not waterlogged. In dry soils, nutrient uptake may be limited due to reduced root activity, while in waterlogged soils, oxygen availability may be limited, which can lead to nutrient deficiencies.
- **Soil temperature**: Soil temperature can also affect nutrient availability, as it can influence soil biological activity, mineralization rates, and plant root growth. Most plant nutrients are more available in warm soils, while cold soils can limit nutrient uptake and plant growth.

•**Soil compaction**: Soil compaction can limit root growth and reduce nutrient uptake by plants. Compacted soils can also reduce water infiltration and retention, which can further limit nutrient availability.

Nutrient interactions: The availability of one nutrient can be influenced by the presence or absence of other nutrients. For example, excessive applications of nitrogen can limit the uptake of phosphorus and vice versa. Similarly, high levels of one nutrient can lead to a deficiency of another nutrient if it is taken up in excess.

1. Excess of elements (Mn, Cu and Zn) may be toxic to living materials (protoplasm) of the plant. 2. Excess of one plant food element may cause deficiency of another such as: (a) Excess of N causes K deficiency in certain crops like potato, (b) Excess of K causes deficiency of Mn in tomato.

(c) Excess of P causes deficiency of Zn in most of the crops.

Apart from these, imbalanced fertilization increases cost of production because any amount more than required does not help in producing higher crop yields. Thus, the consumption of more than required quantity of elements is called 'luxury consumption', which is nothing but a waste. This type of loss is in addition to leaching, washing and other losses of elements.

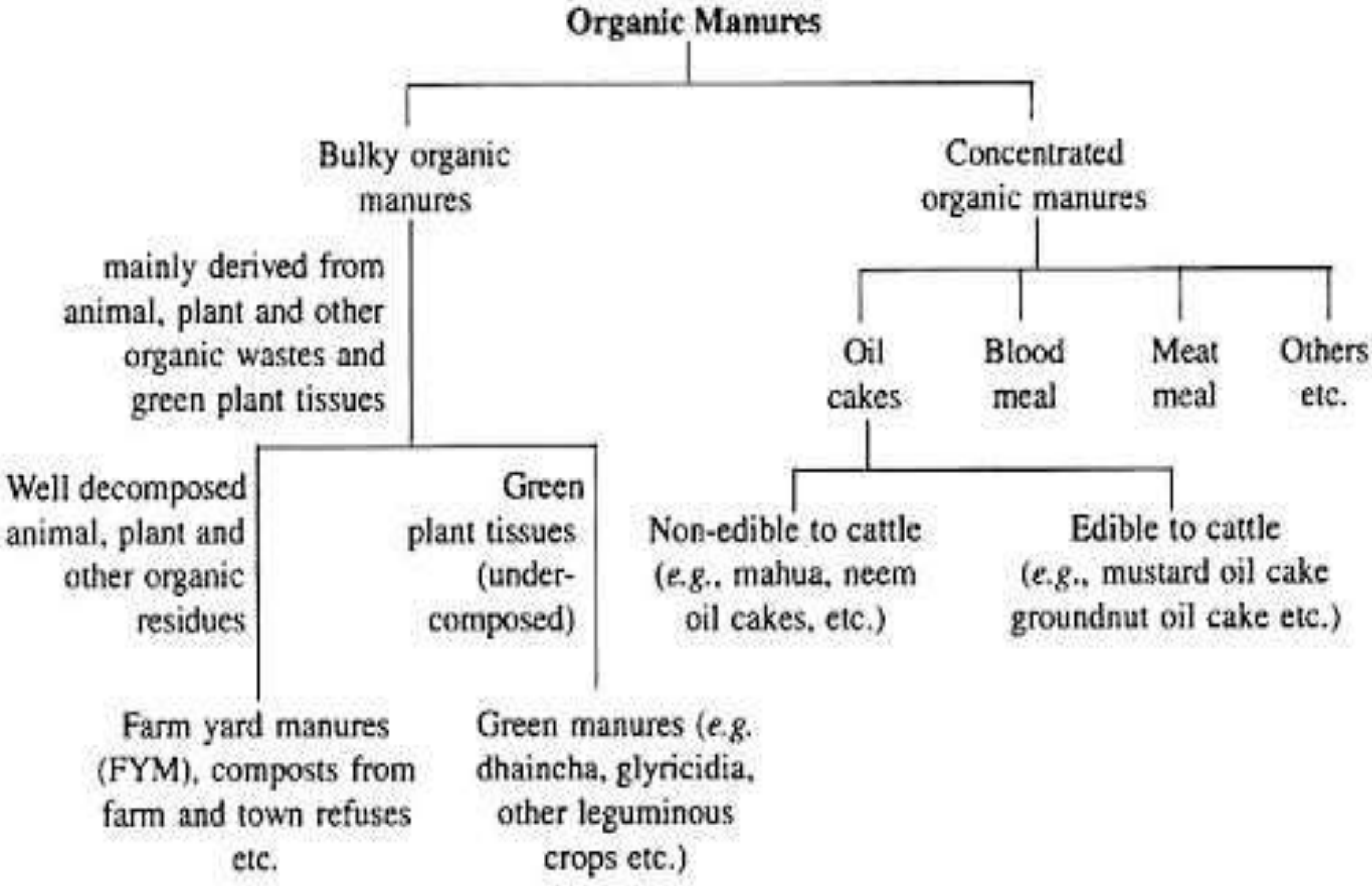
Introduction to Manures: Nature's Soil Enrichers

Manures are organic materials derived from plant and animal residues, used to improve soil fertility and plant nutrition.

They are a rich source of essential nutrients, organic matter, and beneficial microorganisms that enhance soil health.

•Unlike chemical fertilizers, manures provide a slow-release form of nutrients, promoting long-term soil fertility and sustainability.
Manures improve soil structure, water-holding capacity, and aeration, creating a favorable environment for plant growth.
Example: Farmyard manure (FYM) is a common type of manure composed of cattle dung, urine, and crop residues, widely used in agriculture.

Classification of organic manures -



BULKY ORGANIC MANURES

Bulky organic manures contain small percentage of nutrients and they are applied in large quantities. Farmyard manure (FYM), compost and green-manure are the most important and widely used bulky organic manures. Use of bulky organic manures has several advantages:

They supply plant nutrients including micronutrients

•They improve soil physical properties like structure, water holding capacity etc.,

▪They increase the availability of nutrients

•Carbon dioxide released during decomposition acts as a CO_2 fertilizer and

•Plant parasitic nematodes and fungi are controlled to some extent by altering the balance of microorganisms in the soil.

•Ex. Fym, compost, green manuring , vermicompost.

•Fym contents 0.5, 0.2 P_2O_5 and 0.5 K_2O .

Types of Bulky Manures:

- **Farmyard Manure (FYM):** A mixture of cattle dung, urine, and crop residues, rich in nitrogen, phosphorus, and potassium.
- **Compost:** a dark , crumby , earthy smelling material produced by the natural decomposition of organic matter, like food scraps and yard waste and is used as a valuable soil amendment and fertilizer.
- **Green Manure:** Fresh green plant material incorporated into the soil to add organic matter and nutrients, often leguminous crops.
- **Vermicompost:** Compost produced by earthworms, rich in nutrients and beneficial microorganisms, enhancing soil fertility and plant growth.
- **Poultry Manure:** Manure from poultry birds, containing high levels of nitrogen and phosphorus, requiring careful management to avoid nutrient imbalances.

  Example: Using green manure crops like Sesbania can significantly increase soil nitrogen levels before planting the main crop.

BULKY ORGANIC MANURE

CONCENTRATED ORGANIC MANURES-

Concentrated organic manures have higher nutrient content than bulky organic manure. The important concentrated organic manures are oilcakes, blood meal, fish manure etc. These are also known as organic nitrogen fertilizer. Before their organic nitrogen is used by the crops, it is converted through bacterial action into readily usable ammoniacal nitrogen and nitrate nitrogen. These organic fertilizers are, therefore, relatively slow acting, but they supply available nitrogen for a longer period.

Ex. Oil cakes, bone meal , guano, fish manure

- **Bone meal consits of calcium phosphate together with fats and protiens. This are good source of lime.**
- **Contain 20-22 % P2O5.**
- **Ground nut cakes content N 7.3 %.**
- **Safflower content N 7.9 %.**

Introduction to Fertilizers:

- Fertilizers are synthetic or inorganic compound containing essential plant nutrients, applied to the soil to supplement nutrient deficiencies and enhance crop growth.
- They provide a readily available source of nutrients, allowing for rapid plant uptake and increased crop yields.
- **Father of fertilizer chemistry- Justus Von Leibig.**
- **The first successful commercial fertilizer- Super Phophate By Jonhn Benet Lawes In England In 1842.**
- Fertilizers are typically classified as nitrogenous, phosphatic, potassic, or complex fertilizers, based on their primary nutrient content.
- Proper fertilizer management is crucial to avoid nutrient imbalances, environmental pollution, and negative impacts on soil health.
- **Example**: Urea is a common nitrogenous fertilizer containing 46% nitrogen, widely used to promote vegetative growth in crops.

Fertilizers are classified based on their nutrient content-

1. Straight Fertilizers

Straight fertilizers contain only one primary nutrient (either Nitrogen, Phosphorus, or Potassium). They are applied when a single nutrient is required to correct a deficiency in the soil.

Examples of Straight Fertilizers:

Nitrogen Fertilizers:

- **Urea (46-0-0)**: Contains 46% nitrogen, used to promote vegetative growth in plants.
- **Ammonium Nitrate (34-0-0)**: Provides nitrogen to support plant growth and leaf development.
- **Calcium Ammonium Nitrate (CAN)(21%N, 18% Ca)**: Contains both nitrogen and calcium.

Phosphorus Fertilizers:

- **Single Super Phosphate (SSP) (0-20-0)**: Contains 20% phosphorus, improves root development and flowering.
- **Triple Super Phosphate (TSP) (0-46-0)**: Contains a higher concentration of phosphorus for strong root systems.

Potassium Fertilizers:

- **Muriate of Potash (KCl) (0-0-60)**: Contains 60% potassium, used to improve plant stress tolerance and disease resistance.
- **Potassium Sulfate (K2SO4)**: Provides both potassium and sulfur

2. Complex fertilizers-

Their are made by chemically combining two or more primary nutrients (usually nitrogen, phosphorus, and potassium). These fertilizers contain multiple nutrients in one compound, offering balanced nutrition to plants.

Examples of Complex Fertilizers:

- **DAP (Diammonium Phosphate) (18-46-0)**: Contains 18% nitrogen and 46% phosphorus. It is widely used for promoting root development and flowering.
- **MAP (Monoammonium Phosphate) (11-52-0)**: Contains 11% nitrogen and 52% phosphorus, used to correct phosphorus deficiencies.

3. Mixed Fertilizers

Mixed fertilizers are made by physically mixing straight fertilizers to provide a blend of multiple nutrients. The ratios are determined based on the crop’s specific nutrient needs. These fertilizers are often customized to provide the right balance of nutrients for specific plants or soil types. Example-

Mixed Fertilizers:

NPK 10-10-10: Contains 10% nitrogen, 10% phosphorus, and 10% potassium, commonly used for general- purpose plant nutrition.

Types of Fertilizers: Meeting Specific Crop Needs

- **Nitrogenous Fertilizers:** Provide nitrogen for vegetative growth, including urea, ammonium sulfate, and ammonium nitrate.
- **Phosphatic Fertilizers:** Supply phosphorus for root development and flowering, such as superphosphate and diammonium phosphate (DAP).
- **Potassic Fertilizers:** Provide potassium for plant strength and disease resistance, including muriate of potash (MOP) and sulfate of potash (SOP).

Fertilizer Recommendation Approaches:

- **Fertilizer recommendation approaches aim to determine the optimal amount and type of fertilizers needed to meet crop requirements and maximize yields.**
- **These approaches consider factors such as soil type, crop species, growth stage, yield potential, and environmental conditions.**
- **Common fertilizer recommendation approaches include soil testing, plant analysis, nutrient budgeting, and crop modeling.**
- **Accurate fertilizer recommendations are crucial for efficient nutrient use, minimizing environmental impacts, and maximizing economic returns.**
- **Example: Soil testing-based fertilizer recommendations involve analyzing soil samples to determine nutrient deficiencies and calculating fertilizer rates accordingly.**

Fertilizer Recommendation Concept

1. Build up and maintenance
2. Cation ration concept
3. Sufficiency level concept

- **Fertilizer recommended approaches:**
- **1. Soil Testing and Analysis**: Soil-test based fertilizer recommendation: In this approach, soils are grouped into different fertility classes such as low, medium and high with respect to status of the nutrient in question, and the recommendation is developed for the medium fertility class. For soils testing low or high, the fertilizer recommendation for the medium fertility class is increased or decreased by 25%

- **Importance:**
- Before applying any fertilizer, it's crucial to determine the soil's nutrient status through soil testing.
- Sampling:
- Collect representative soil samples from different areas of the field to get an accurate assessment of nutrient levels.
- Analysis:
- Analyze the soil samples to determine the levels of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), as well as other micronutrients.

. Integrated Nutrient Management (INM):

- **Definition:**

INM involves using a combination of organic and inorganic fertilizers, along with other soil management practices, to optimize nutrient availability and use efficiency.

- **Benefits:**

INM helps to improve soil health, reduce reliance on synthetic fertilizers, and minimize environmental impacts.

- **Components:**
    - **Organic Fertilizers:** Use of compost, manure, and other organic materials to improve soil structure and fertility.
    - **Inorganic Fertilizers:** Apply synthetic fertilizers based on soil test results and crop requirements.
    - **Green Manuring:** Incorporate cover crops to add organic matter and nutrients to the soil.
    - **Crop Rotation:** Rotate crops to improve soil health and nutrient cycling.

Modern Approaches:

•**Soil Test Crop Response (STCR):**

This approach uses soil test results and crop response data to determine fertilizer recommendations.

•**Diagnosis Recommendation Integrated System (DRIS):**

This approach uses foliar analysis and other plant-based indicators to assess nutrient status and make fertilizer recommendations.

•**Site-Specific Nutrient Management:**

Use technologies like aerial imagery and GPS to identify areas within a field that have different nutrient needs.

Key Concepts in Soil Fertility Management

Soil Analysis: Understanding Soil Composition

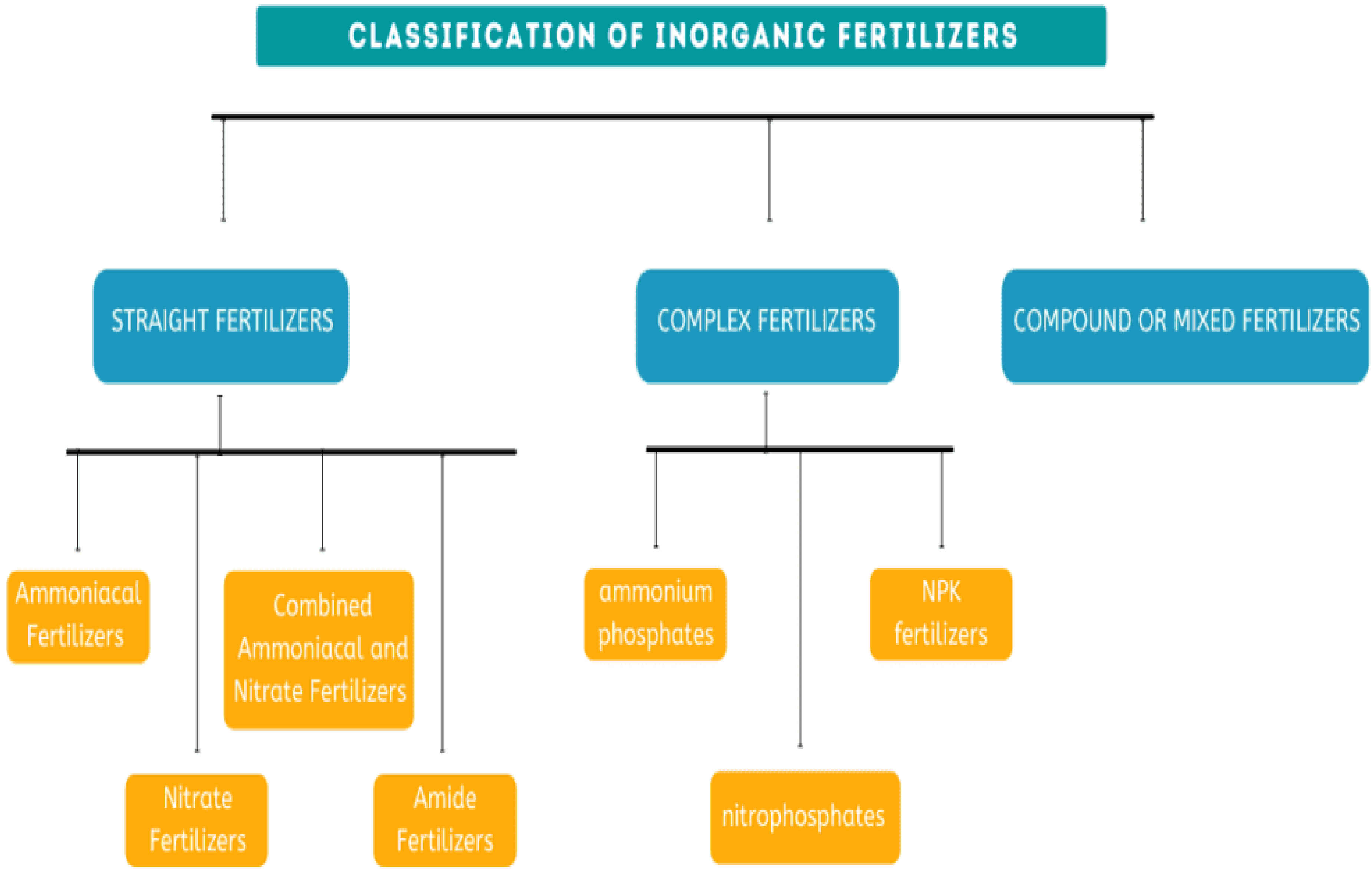
Nutrient Cycle: Natural Nutrient Flow

Fertilizer Application: Precise Nutrient Delivery

Organic Farming: Sustainable Practices

Crop Yield: Maximizing Productivity

Water Management: Efficient Irrigation


CLASSIFICATION OF INORGANIC FERTILIZERS
STRAIGHT FERTILIZERS
COMPLEX FERTILIZERS
COMPOUND OR MIXED FERTILIZERS
Ammoniacal Fertilizers
Combined Ammoniacal and Nitrate Fertilizers
Nitrate Fertilizers
Amide Fertilizers
ammonium phosphates
NPK fertilizers
nitrophosphates

CLASSIFICATION OF NITROGENOUS FERTILIZER

Ammoniacal

1. *Ammonium Sulphate*
2. *Ammonium chloride*
3. *Anhydrous ammonia*

Nitrate

1. *Sodium Nitrate*
2. *Calcium Nitrate*
3. *Potassium Nitrate*

Ammoniacal and Nitrate

1. *Ammonium Nitrate*
2. *Calcium Ammonium Nitrate*
3. *Ammonium Sulphate Nitrate*

Amide fertilizer

1. *Urea*
2. *Calcium Cynamide*

Classification of Nitrogenous Fertilizer:

The nitrogenous fertilizers are classified on the basis of chemical form in which nitrogen is present within a fertilizer i. e.

- Ammonium (NH_4^+),
- Nitrate (NO_3^-),
- Amide ($-NH_2$), or Cynamide ($-CN_2$).

.

Nitrate fertilizers: Contain nitrogen in the form of nitrate (NO_3^-)		
1.	Potassium nitrate	13% N, 44% K_2O
2.	Calcium nitrate	15.5% N, 19.5% Ca
3.	Sodium nitrate or Chilean nitrate or chili salt petre	16% N
Ammonium fertilizers: Contain nitrogen in the form of ammonium (NH_4^+)		
1.	Ammonium sulphate	20.60% N, 24% S
2.	Ammonium phosphate	20% N +20% P_2O_5 or 16%N +20% P_2O_5
3.	Ammonium chloride	24 to 26%N

4.	**Anhydrous ammonia**	**82%N**
Nitrate and ammonium fertilizer: Contain nitrogen in the form of both nitrate (NO_3^-) and ammonium (NH_4^+).		
1.	Ammonium nitrate	33-34%N
2.	Calcium ammonium nitrate (CAN)	26%N
3.	Ammonium sulphate nitrate	26%N
Amide fertilizer: Contain nitrogen in the form of amide and cynamide		
1.	Urea [Co (NH2)2]	46% N
2.	Calcium cyanamide (Ca CN2)	21% N, 39.1% Ca

Key Properties of Nitrogenous Fertilizers:

- **Solubility:**
How easily the fertilizer dissolves in water, impacting how quickly plants can absorb the nitrogen.
- **Hygroscopicity:**
The tendency of the fertilizer to absorb moisture from the air, which can affect storage and application.
- **Leaching:**
The tendency for nitrogen to move through the soil and into groundwater, potentially causing environmental problems.
- **Chemical Form:**
The nitrogen can be in ammoniacal or nitrate forms, influencing how quickly and readily available the nitrogen is to plants.
- **Acidity/Alkalinity:**
Some fertilizers can alter the soil's pH, either making it more acidic or alkaline, which can affect the availability of other nutrients.
- **Physical Properties:**
These include particle size, density, and the tendency to cake or clump, affecting handling and application.

Specific Examples:

- **Ammonium Nitrate (NH_4NO_3):** Highly soluble, can be deliquescent (absorbs moisture), and can contribute to soil acidification.
- **Urea ($CO(NH_2)_2$):** Readily soluble, hygroscopic, and undergoes hydrolysis in the soil.
- **Ammonium Sulfate ($(NH_4)_2SO_4$):** Soluble, less hygroscopic than urea, and also acidifying.
- **Anhydrous Ammonia (NH_3):** A gaseous nitrogen source, stored as a liquid, and more resistant to leaching.
- **Nitrogen Solutions:** Mixtures of nitrogen fertilizers dissolved in water, offering a convenient application method.

Phosphatic fertilizers are classified based on their phosphorus solubility in water and citric acid. This leads to three main groups: water-soluble, citric acid-soluble, and water/citric acid-insoluble.

1. Water-Soluble Phosphatic Fertilizers:

Monocalcium Phosphate ($Ca(H_2PO_4)_2$): Highly soluble in water, providing readily available phosphorus to plants.

Example: Single superphosphate (SSP) (16-18% P_2O_5), double superphosphate (DSP) (32% P_2O_5), triple superphosphate (TSP) (46-48% P_2O_5), and ammonium phosphates (20% N + 20% P_2O_5 or 16% N + 20% P_2O_5).

2. Citric Acid-Soluble Phosphatic Fertilizers:

Dicalcium Phosphate ($Ca_2(HPO_4)_2$ or $Ca(HPO_4)$): Soluble in citric acid, making phosphorus available over a slightly longer period.

Examples: Basic slag (14-18% P_2O_5), Rhenania phosphate (23-26% P_2O_5), and raw/steamed bone meal (partially soluble in citric acid).

3. Water and Citric Acid-Insoluble Phosphatic Fertilizers:

Tricalcium Phosphate ($Ca_3(PO_4)_2$): Not readily soluble in water or citric acid, phosphorus availability is slower.

Examples: Rock phosphate (20-40% P_2O_5) and raw bone meal (20-25% P_2O_5).

Properties of phosphate Fertilizer-

Reduced Leaching:

While initially soluble, the phosphorus in phosphatic fertilizers quickly becomes less soluble in the soil, minimizing the risk of leaching or loss of the nutrient through drainage.

Soil pH Sensitivity:

These fertilizers are generally best used in slightly acidic, neutral, or alkaline soils. In acidic soils, the soluble phosphorus can bind with iron and aluminum, making it unavailable to plants.

Root Zone Application:

Due to the limited mobility of phosphorus in the soil, it's crucial to apply phosphatic fertilizers directly in the root zone of the plants to ensure efficient nutrient uptake.

Not Suitable for Topdressing:

The slow mobility of phosphorus makes phosphatic fertilizers unsuitable for topdressing, where nutrients are applied to the soil surface after the crop has been established.

Benefits for Plant Growth:

Phosphorus plays a critical role in various plant processes, including root development, energy transfer, photosynthesis, and cell division.

Potassic fertilizers are typically classified based on their chemical composition, specifically their content of potassium. The main classes include potassium chloride (KCl), potassium sulfate (K2SO4), potassium nitrate (KNO3), and potassium magnesium sulfate (K2SO4-MgSO4). These fertilizers are readily soluble in water, making the potassium available to plants.

Here's a more detailed breakdown:

1. Potassium Chloride (KCl):

Commonly known as muriate of potash (MOP) .

Composition: Contains approximately 60% potassium oxide (K2O) and about 47% chlorine.

Solubility: Highly soluble in water, ensuring quick availability to plants.

Note: The chlorine content can be a concern for certain crops like tobacco and potatoes.

2. Potassium Sulfate (K2SO4):

Also known as sulfate of potash (SOP) .

Composition: Contains about 48% potassium oxide (K2O).

Solubility: Soluble in water, making it readily available to plants.

Note: Does not contribute to soil acidity or alkalinity.

3. Potassium Nitrate (KNO_3):

Composition: Provides both nitrogen and potassium.

Solubility: Highly soluble in water, making it suitable for foliar application and drip irrigation.

Note: Useful for crops that require both nitrogen and potassium.

4. Potassium Magnesium Sulfate (K_2SO_4-$MgSO_4$):

Also known as sulfate of potash magnesia (SOPM) .

Composition: Provides potassium, magnesium, and sulfur in one package.

Solubility: Water-soluble.

Key properties of potassium fertilizers:

Solubility:

Most potassium fertilizers are highly soluble in water, allowing for rapid nutrient uptake by plants.

Availability:

Potassium from fertilizers becomes available to plants through cation exchange in the soil, where potassium ions replace other cations like calcium and magnesium.

Neutral Reaction:

Some potassium fertilizers, like potassium chloride, are neutral in their reaction, meaning they don't affect soil pH.

Importance of Potassium:

Potassium plays crucial roles in plant health, including regulating water and mineral transport, activating enzymes, and enhancing photosynthesis.

Impact on Plant Quality:

Potassium is crucial for various plant quality parameters, including fruit size, appearance, color, and sugar content.

Secondary Nutrients with Dual Composition: Ca, Mg, S

Plants need **secondary nutrients** like **Calcium (Ca)**, **Magnesium (Mg)**, and **Sulfur (S)** in moderate quantities. These nutrients are often supplied through fertilizers that may contain **two or more** of these elements together.

Below are the most common fertilizers that supply **two secondary nutrients** in one compound, along with their **function, composition, and usage**.

1. Gypsum (Calcium Sulfate – $CaSO_4 \cdot 2H_2O$)

✅ **Contains:**

Calcium (Ca) – ~23%

Sulfur (S) – ~18%

Use: Great for correcting calcium and sulfur deficiencies without affecting soil pH. Often used in acidic or sodic soils.

◈ 2. Dolomitic Lime (Calcium Magnesium Carbonate – $CaMg(CO_3)_2$)

✅ **Contains:**

Calcium (Ca) – ~20–30%

Magnesium (Mg) – ~10–20%

Use: Ideal for raising soil pH while supplying both Ca and Mg.

3. Kieserite (Magnesium Sulfate Monohydrate – $MgSO_4 \cdot H_2O$)

✅ Contains:

Magnesium (Mg) – ~16%

Sulfur (S) – ~20%

Use: Water-soluble and fast-acting. Often used in fertigation or foliar feeding

4. Epsom Salt (Magnesium Sulfate Heptahydrate – $MgSO_4 \cdot 7H_2O$)

✅ Contains:

Magnesium (Mg) – ~9.8%

Sulfur (S) – ~13%

Use: Soluble in water, good for foliar spray or quick correction.

Micro nutrient classification -

Fertilizer Name	Micronutrient (%)	Main Element	Form / Notes
Zinc Sulfate ($ZnSO_4 \cdot 7H_2O$)	~21% Zn	Zinc	Crystalline solid
Ferrous Sulfate ($FeSO_4 \cdot 7H_2O$)	~20% Fe	Iron	Greenish crystals
Manganese Sulfate ($MnSO_4 \cdot H_2O$)	~30% Mn	Manganese	Pink powder
Copper Sulfate ($CuSO_4 \cdot 5H_2O$)	~25% Cu	Copper	Bluish crystals
Borax	~11% B	Boron	White powder
Boric Acid	~17% B	Boron	Soluble, used in foliar spray
Sodium Molybdate	~39% Mo	Molybdenum	White powder
Chelated Micronutrients	Varies (e.g., Fe-EDTA 12%)	Fe, Zn, Mn etc.	Used for foliar or alkaline soils

Nano fertilizer-

Nano fertilizers are a new type of fertilizer that utilizes nanoparticles to deliver nutrients to plants more efficiently and sustainably than traditional fertilizers. They are designed to release nutrients gradually, reducing the need for frequent application and minimizing nutrient loss. Examples of nano fertilizer materials include carbon nano tubes, graphene, and quantum dots.

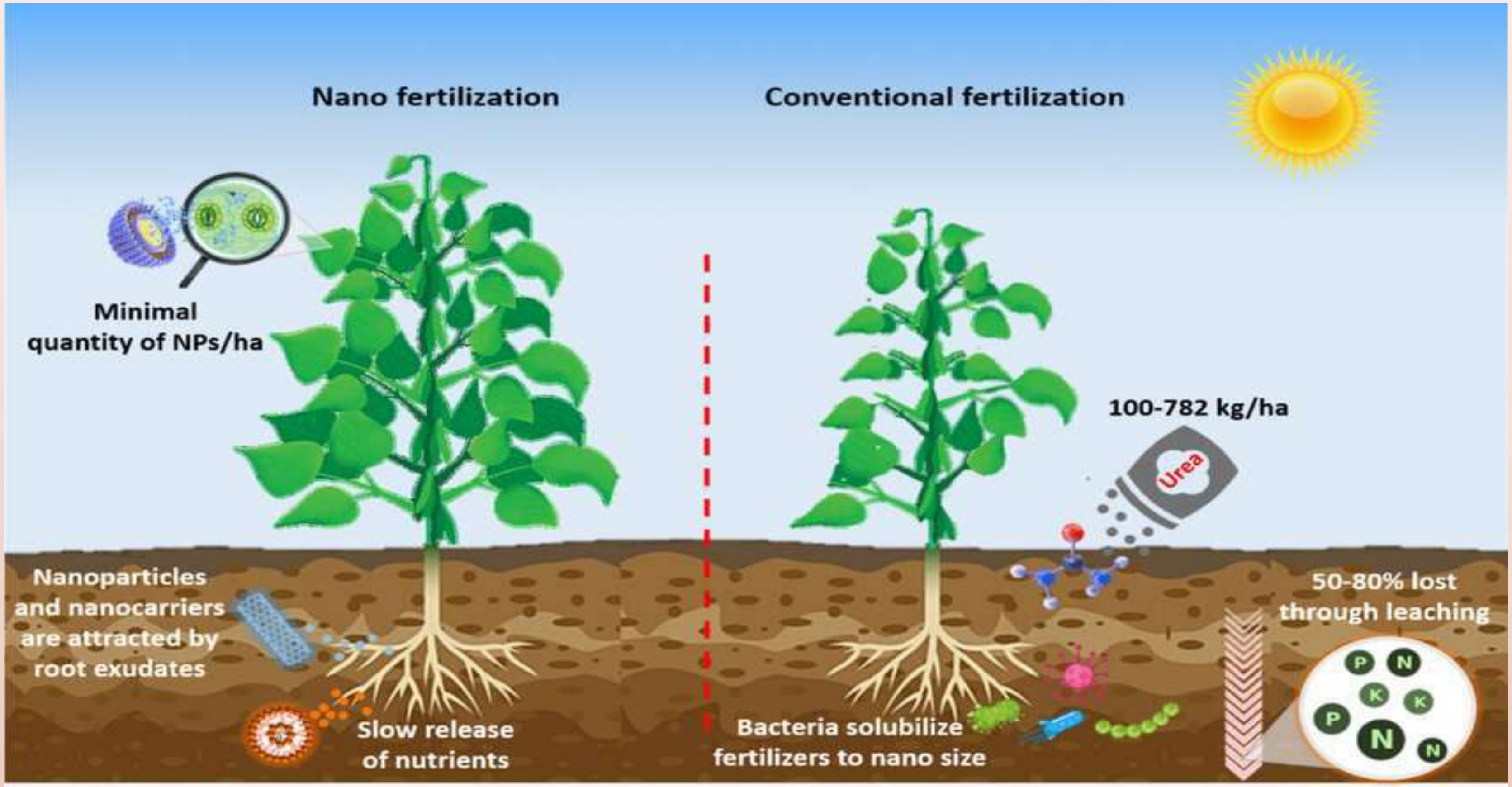
•Nanofertilizers are fertilizers where at least 50% of the particles are smaller than 100 nanometers.
•They use nano particles to encapsulate and release nutrients.
•This controlled release mechanism improves nutrient uptake and reduces environmental impact.

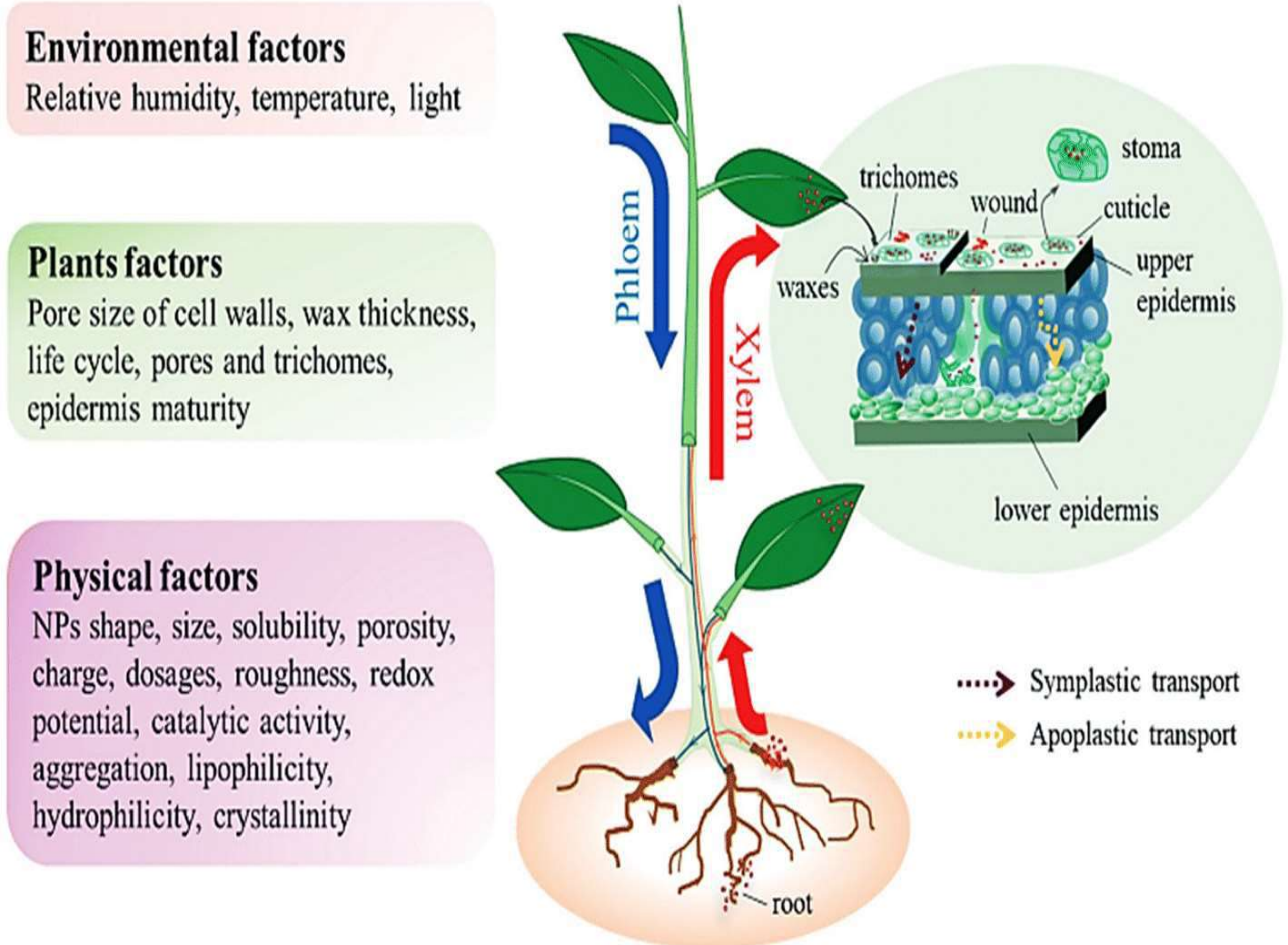
•**FFCO Nano Urea (liquid) is world's first Nanofertilizers which has been notified by Fertilizer Control Order (FCO, 1985), Government of India. Nano Urea contains 4.0 % total nitrogen (w/v). Nano nitrogen particle size varies from 20-50 nm.******

Effect of Nano fertilizer on plant-

•Increase significantly all the parameters(plant length, number of leaves per plant, Stem diameter, Chlorophyll content (SPAD),

•Fresh and dry weight of vegetative growth and roots.




Environmental factors
Relative humidity, temperature, light
Plants factors
Pore size of cell walls, wax thickness, life cycle, pores and trichomes, epidermis maturity
Physical factors
NPs shape, size, solubility, porosity, charge, dosages, roughness, redox potential, catalytic activity, aggregation, lipophilicity, hydrophilicity, crystallinity
Phloem
Xylem
stoma
trichomes
wound
cuticle
waxes
upper epidermis
lower epidermis
root
Symplastic transport
Apoplastic transport

Soil Amendments

Soil amendments are materials added to soil to improve its physical, chemical, or biological properties,
ultimately enhancing plant growth and overall soil health. They can be organic (like compost and manure) or inorganic
(like lime and minerals) and address various soil issues, such as poor drainage, low nutrient content, or compaction.

Types of Soil Amendments:

•Organic Amendments:

- **•Compost:** Decomposed organic matter, providing nutrients and improving soil structure.
- **Manure:** Animal waste, rich in nutrients and beneficial for soil health.
- **•Leaf Mold:** Decomposed leaves, adding organic matter and improving aeration.
- **•Biochar:** Charcoal produced from burning biomass, enhancing soil structure and water retention.
- **•Green Manures:** Legumes or other plants grown and then incorporated into the soil, improving nitrogen and organic matter content.
- **•Peat Moss:** A natural material that improves water retention and soil structure.

- **Inorganic Amendments:**
  - **Lime:** Increases soil pH, making it more alkaline and improving nutrient availability.
  - **Gypsum:** Can improve soil structure in clay soils and reduce the risk of sodicity.
  - **Vermiculite:** An expandable mineral that improves aeration, drainage, and water-holding capacity.
  - **Perlite:** A volcanic glass that improves aeration, drainage, and water-holding capacity.
  - **Sand:** Used to improve drainage in clay soils.

Soil Amendments for Phytoextraction

Organic Matter

Incorporate organic materials like compost to improve soil structure and nutrient availability.

pH Adjustment

Use lime or sulfur to modify soil pH, optimizing conditions for specific plant species.

Nutrient Addition

Apply fertilizers tailored to enhance the growth of phytoremediation plants during extraction processes.

Microbial Inoculants

Introduce beneficial microbes to the soil to enhance nutrient uptake and plant growth efficiency.

Fertilizer Storage

Fertilizer storage is an important aspect of fertilizer management, as proper storage can help to maintain the quality and effectiveness of fertilizers and prevent environmental pollution. Here is a detailed explanation of fertilizer storage:

Storage location: Fertilizers should be stored in a **dry, cool, and well-ventilated** area that is away from direct sunlight, heat sources, and moisture. The storage area should be located on a level surface that is free of debris and other materials that could cause contamination. The storage area should also be located away from water sources and areas with high traffic to prevent accidental spills.

Storage containers: Fertilizers should be stored in **airtight, durable containers** that are designed for the specific type of fertilizer being stored. The containers should be labeled with the name of the fertilizer, the date of purchase, and the expiration date. It is also important to keep the containers tightly closed to prevent moisture and air from entering.

Handling and transportation: Fertilizers should be handled and transported with care to prevent damage to the containers and spills. The containers should be loaded and unloaded carefully and stored in a stable position during transportation. It is also important to avoid mixing different types of fertilizers during transportation, as this can lead to chemical reactions and hazardous situations.

Spill prevention and cleanup: Spills and leaks can occur during fertilizer storage and transportation, so it is important to have spill prevention and cleanup measures in place. This can include spill containment barriers, spill response kits, and proper training for employees on spill response procedures. Any spills or leaks should be cleaned up immediately and disposed of properly to prevent environmental contamination.

Fertilizer rotation: To prevent the accumulation of old or expired fertilizers, it is important to rotate the fertilizer stock by using the oldest fertilizers first. This can help to ensure that the fertilizers being used are still effective and have not expired.

Fertilizer Control Order

The Fertilizer Control Order (FCO) is a legal document issued by the Ministry of Agriculture and Farmers' Welfare in India under the **Essential Commodities Act, 1955**. The FCO regulates the production, distribution, and sale of fertilizers in India, and is designed to ensure the quality and safety of fertilizers for agricultural use. Here is some information about the Fertilizer Control Order:

Scope: The FCO applies to all types of fertilizers, including chemical fertilizers, organic fertilizers, biofertilizers, and micronutrient fertilizers. The order specifies the minimum standards for quality, labeling, packaging, and transportation of fertilizers.

Quality standards: **The FCO sets out the minimum standards for the physical, chemical, and biological properties of fertilizers. These standards are based on the type of fertilizer and the nutrient content. Fertilizers must meet these standards in order to be registered and sold in India.**

Labeling requirements: The FCO specifies the labeling requirements for fertilizers, which include the name of the fertilizer, the nutrient content, the guaranteed analysis, the batch number, and the date of manufacture. The label must also include the net weight, the name and address of the manufacturer, and the directions for use.

Registration: All fertilizers must be **registered with the Department of Agriculture and Cooperation** before they can be sold in India. The registration process requires the manufacturer to submit samples of the fertilizer for testing to ensure that it meets the quality standards set out in the FCO.

Enforcement: The FCO is enforced by the Department of Agriculture and Cooperation, which is responsible for monitoring the production, distribution, and sale of fertilizers. The department conducts regular inspections of fertilizer manufacturing facilities and distribution centers to ensure compliance with the FCO.

Penalties: Violation of the FCO can result in penalties such as fines, suspension of registration, or cancellation of registration. The severity of the penalty depends on the nature and extent of the violation.

Nutrient Use efficiency

Nutrient use efficiency (NUE) in plants refers to how effectively a plant absorbs, transports, utilizes, and stores nutrients, ultimately impacting yield and sustainability.

NUE is the fraction of fertilizer nutrients removed from the field with the crop harvest. NUE= (crop nutrient removal/ nutrient input) *100

Nutrient	Efficiency	Cause of low efficiency
Nitrogen (N)	30% - 50%	Immobilization, Volatilization, denitrification, leaching, soil erosion & run-off
Phosphorus (P)	15% - 20%	Fixation in soil Acidic soil :- Al-P Fe-P Basic soil :- Ca-P
Potassium (K)	70% - 80%	Fixation in clay- lattices
Sulphur (S)	8% - 10%	Immobilization, Leaching
Micronutrients (Zn, Fe, Cu, Mn, B)	1% - 2%	Fixation in soil.

Method to increase NUE

1. Prior to sowing Nutrient use efficiency Some of water insoluble fertilizers such as rock phosphate and basic slag are applied 2 to 4 weeks before sowing to enable conversion of water insoluble form to soluble form for efficient crop utilization.
2. At sowing Application of fertilizer at the time of sowing or just before sowing is called basal application.
3. After sowing the crop Application of fertilizers after the crop establishment of crop is called top dressing.
4. Split application When fertilizer is applied in 2 or more different time, the system is called a split application

5. Method of fertilizer application

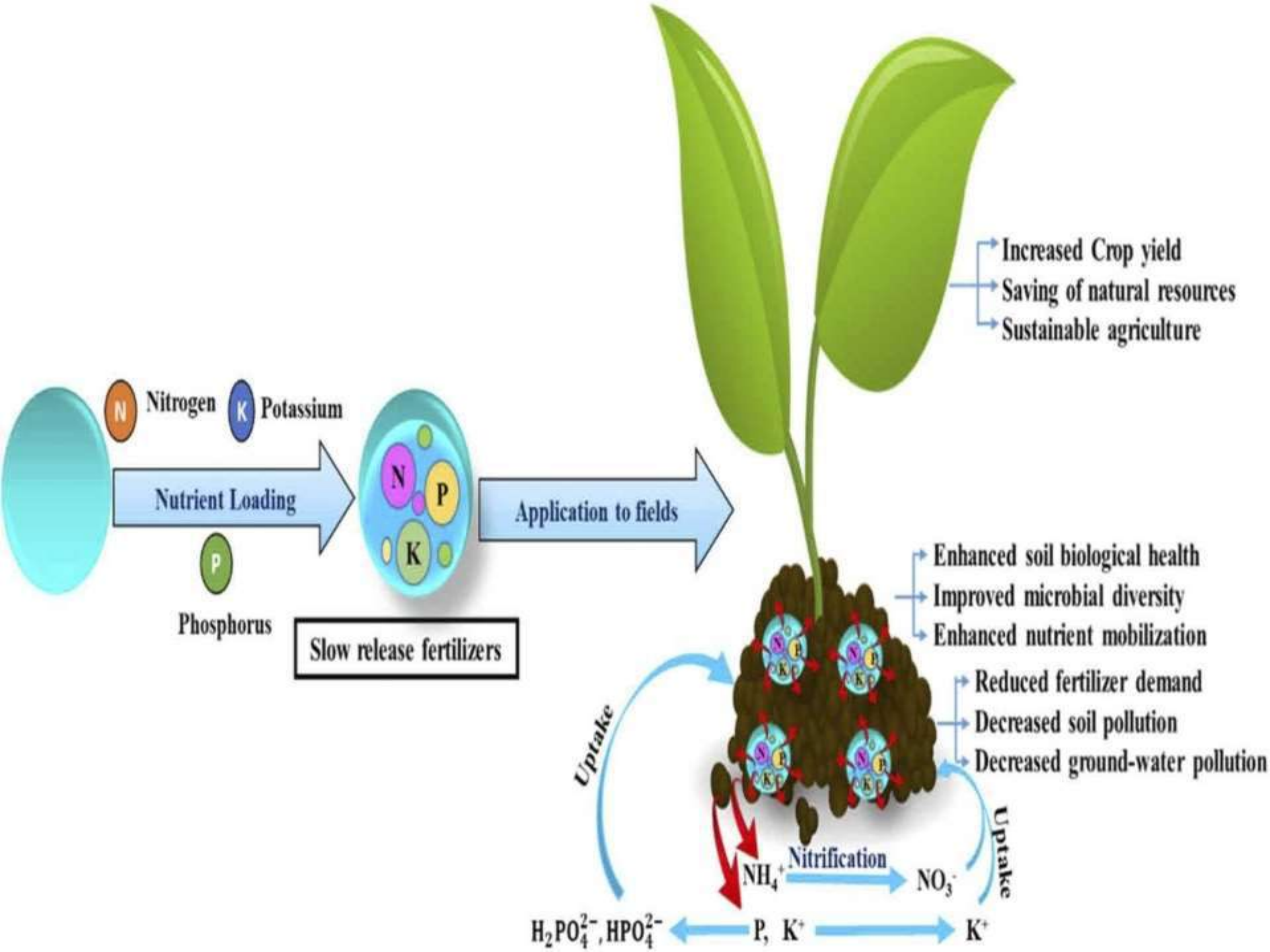
A. Soil application

1. Broadcasting
2. Band placement
3. Point placement
4. Fertigation

B. Application to plant

1. Root dipping
2. 2. Foliar application

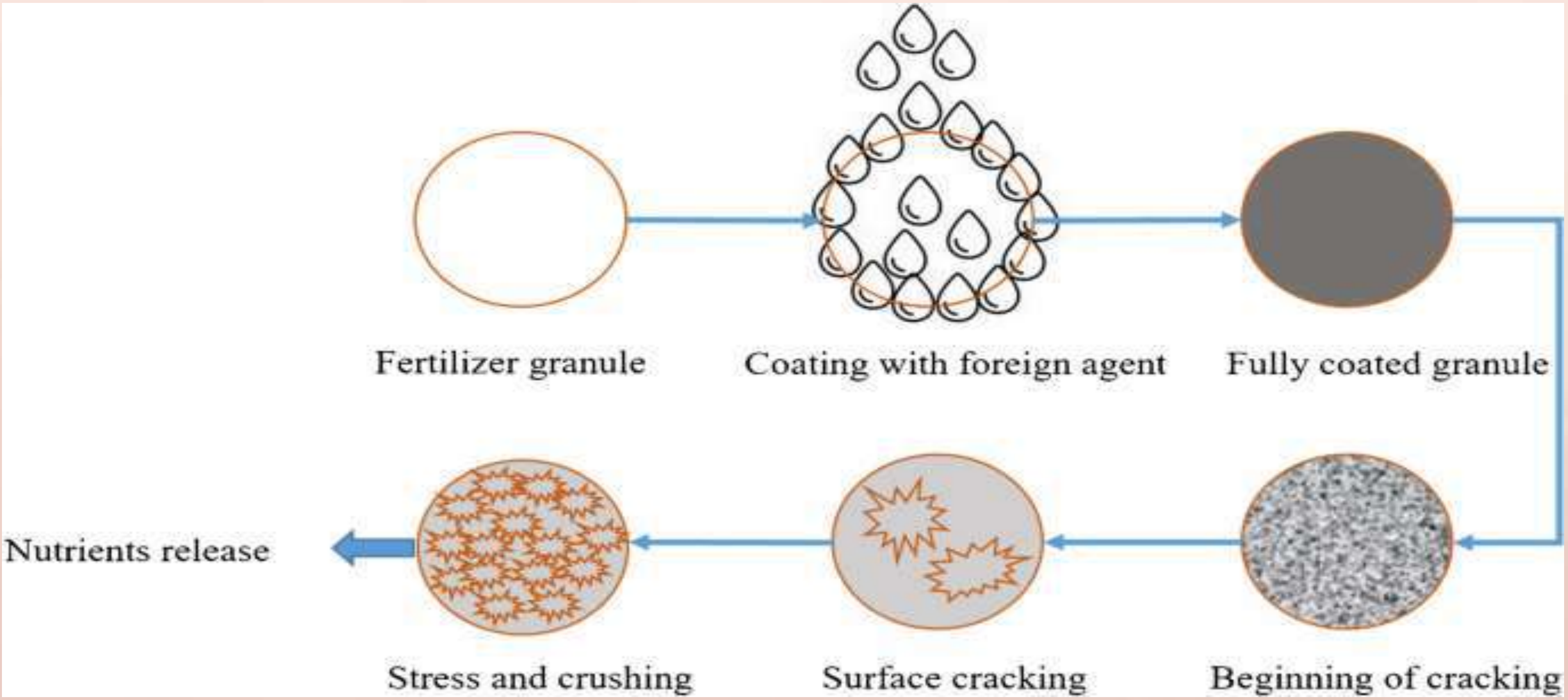

Slow-Release Fertilizers
& the science behind them



Nitrogen
Potassium
Phosphorus
Nutrient Loading
N
P
K
Slow release fertilizers
Application to fields
Increased Crop yield
Saving of natural resources
Sustainable agriculture
Enhanced soil biological health
Improved microbial diversity
Enhanced nutrient mobilization
Reduced fertilizer demand
Decreased soil pollution
Decreased ground-water pollution
Uptake
Uptake
Nitrification
NH_4^+
NO_3^-
$H_2PO_4^{2-}$, HPO_4^{2-}
P, K^+
K^+

Slow Release Fertilizer

Slow-release fertilizers (SRF) provide a steady supply of plant nutrients over an extended period of time. or
Slow-release fertilizer releases nutrients gradually with time, and it can be an inorganic or organic form.



Type of materials used in Sloe Release Fertilizer

1. Coated Fertilizers:

Polymer Coatings:

Synthetic polymers like polyolefins and polyurethanes are commonly used to coat fertilizer granules, creating a barrier that regulates water penetration and nutrient diffusion.

Sulfur Coatings:

Sulfur coatings, often combined with polymers, provide a physical barrier and can be further enhanced with a sealant to control nutrient release.

Osmotic Coatings:

Some coated fertilizers utilize osmotic pressure to control nutrient release. These coatings create a semi-permeable membrane that allows water to enter and dissolve the nutrient, which then diffuses out at a controlled rate.

Examples:

Coated urea, potassium nitrate, potassium sulfate, ammonium sulfate, and iron sulfate.

2. Composite Materials:

Rice Husk Silica Composites:

Combining rice husk-generated silica with polymers like hydroxypropyl methylcellulose and polyvinyl alcohol can create slow-release fertilizers with good water retention.

Hydrogel Composites:

Hydrogels, often made from starch and polyacrylic acid, can encapsulate fertilizers and release nutrients over an extended period, also improving water retention in the soil.

Biochar Composites:

Biochar, a charcoal-like material produced from biomass, can be combined with fertilizers to improve soil structure, water retention, and slow down nutrient release.

Examples:

Composites of rice-husk-generated silica, hydroxypropyl methylcellulose, polyvinyl alcohol, and paper coated urea.

Examples of N type slow-release fertilizers:

Urea-formaldehyde (UF): A common type of slow-release nitrogen fertilizer.

Isobutylidene diurea (IBDU): Another example of a slow-release nitrogen compound.

Sulfur-coated urea (SCU): Urea granules coated with sulfur to control release.

Polymer-coated fertilizers: Fertilizer granules coated with a polymer to regulate nutrient release.

Nitroform: A slow-release nitrogen fertilizer containing urea-formaldehyde.

N-Code: A slow-release fertilizer that penetrates leaf pores.

Nutricote and Duratec: Examples of commercially available slow-release fertilizers.

Milorganite: An organic slow-release nitrogen fertilizer.

Slow-Release Phosphorus Fertilizers:

Bone Meal:
A natural source of phosphorus and calcium, bone meal provides a slow and steady release of nutrients, especially beneficial for root development, flowering, and fruiting.

Rock Phosphate:
A natural mineral, rock phosphate is a slow-release source of phosphorus that gradually releases nutrients into the soil, promoting strong root systems and enhancing flowering and fruiting.

Other Slow-Release Phosphorus Fertilizer Options:

Hydrochars:
Created by heating biomass in the absence of oxygen, hydrochars can be engineered to act as slow-release phosphorus fertilizers, enhancing crop growth and soil health.

Starch-based composites:
Materials like cassava starch combined with hydroxyapatite (a phosphorus source) can be processed into slow-release fertilizers, offering a sustainable and biodegradable option.

Coated Fertilizers:
Fertilizers can be coated with materials like attapulgite clay to create slow-release versions, improving nutrient utilization and reducing environmental impact.

Struvite:
A slow-release phosphorus fertilizer due to its low water solubility, struvite helps to reduce nutrient losses and prolongs the availability of phosphorus to crops.

Zeolites:
These minerals can be used to create slow-release fertilizers, with the ability to release phosphorus over extended periods

Slow-Release Potassium Fertilizers:

Sulfate of Potash is a highly concentrated source of slow release potassium

Importance of Slow Release fertilizers

1. Enhanced Nutrient Availability:

Steady Nutrient Supply:

Slow-release fertilizers release nutrients gradually, matching the plant's uptake rate, which prevents nutrient spikes and deficiencies.

Reduced Leaching and Runoff:

By releasing nutrients slowly, they minimize the risk of nutrients being washed away by water, making them more available to the plants and reducing environmental pollution.

Improved Nutrient Use Efficiency:

Plants can absorb nutrients more efficiently when they are released gradually, leading to better growth and development.

2. Reduced Application Frequency:

Fewer Applications:

Slow-release fertilizers require less frequent application compared to traditional fertilizers, saving time, labor, and resources.

3. Improved Crop Yield and Quality:

By providing a consistent nutrient supply, slow-release fertilizers can lead to healthier and more productive crops.

This is especially beneficial for crops with long growing seasons or those that require a steady supply of nutrients, such as fruit trees and vineyards.

Studies have shown that slow-release fertilizers can improve crop yields and enhance the quality of agricultural products.

4. Enhanced Soil Health:

Slow-release fertilizers, especially organic varieties, can improve soil structure, water retention, and microbial activity.

As they break down, they add organic matter to the soil, which is essential for long-term soil health and fertility.

Improved soil health can lead to better nutrient availability, water infiltration, and overall plant growth.

5. Reduced Application Frequency:

The extended nutrient release of slow-release fertilizers means fewer fertilizer applications are needed compared to traditional fertilizers.

This reduces labor costs, saves time, and minimizes the risk of over-fertilization.

In turf management, slow-release fertilizers can help maintain healthy, green turf with less frequent applications, reducing maintenance costs.

6. Environmental Benefits:

By reducing nutrient loss, slow-release fertilizers minimize the risk of water pollution from fertilizer runoff.

They also contribute to a more sustainable agricultural system by reducing the need for frequent fertilizer applications and promoting soil health.

The controlled release of nutrients can also help reduce greenhouse gas emissions associated with fertilizer production and use.

Nano-Fertilizer

The term “Nano” means one billionth part of a meter and is adapted from the Greek word meaning “dwarf.” Particles with at least one dimension less than 100 nm are considered as “nanoparticles”

Nano fertilizers are nutrients that are encapsulated or coated within nano material in order to enable controlled release, and its subsequent slow diffusion into the soil.

Iffco launched the world's first 'Nano Liquid Urea' fertilizer in June 2021 and came up with Nano-DAP (di-ammonium phosphate) fertilizers in April 2023. "The adoption of nano fertilizers is lower than anticipated as compared to solid fertilizers," said Awasthi, after announcing the financial results for Iffco.

Nano fertilizers can be categorized into five types: action-based, controlled-release, targeted delivery, plant growth-stimulating, and water and nutrient loss controlling.

Nano fertilizers often include metal or metal oxide (iron or zinc oxide), or organic materials, (chitosan or humic acids). These particles are designed to improve the uptake and utilization of essential plant nutrients.

1. Action-Based:
These nanofertilizers are designed to perform specific actions, such as enhancing nutrient uptake, improving plant growth, or protecting against diseases.
Examples include nano-encapsulated fertilizers and those that facilitate targeted delivery of nutrients to specific plant parts.
2. Controlled-Release:
These nanofertilizers release nutrients gradually over time, preventing nutrient loss and ensuring a sustained supply to the plant.
This controlled release mechanism can be achieved through various nano-structures that encapsulate the nutrients.
3. Targeted Delivery:
These nanofertilizers are designed to deliver nutrients directly to specific plant cells or tissues, maximizing their effectiveness and minimizing waste.
This targeted approach can be particularly useful for addressing nutrient deficiencies in specific plant parts.
4. Plant Growth-Stimulating:
These nanofertilizers contain nanomaterials that directly promote plant growth and development, such as by enhancing root growth or increasing photosynthetic activity.
Examples include nano-formulations of plant growth regulators or nano materials that enhance nutrient absorption.
5. Water and Nutrient Loss Controlling:
These nanofertilizers help to reduce water and nutrient loss from the soil, improving water-use efficiency and nutrient availability for plants.
This can be achieved through various mechanisms, such as reducing evaporation or preventing nutrient leaching.

Nano fertilizers are crucial for modern agriculture due to their ability to enhance nutrient use efficiency, reduce environmental impact, and improve crop yields. They offer a more sustainable approach to fertilization by delivering nutrients precisely and efficiently, minimizing waste and pollution associated with traditional fertilizers.

Here's a more detailed look at their importance:

1. Increased Nutrient Use Efficiency:

Nanofertilizers can be designed to release nutrients slowly and in a controlled manner, ensuring plants receive the right amount of nutrients at the right time.

This targeted delivery minimizes nutrient losses due to leaching, runoff, and volatilization, common problems with conventional fertilizers.

By enhancing nutrient uptake, nanofertilizers help plants grow healthier and more productive.

2. Reduced Environmental Impact:

The precise and controlled release of nutrients reduces the overall amount of fertilizer needed, minimizing the risk of nutrient pollution in water bodies and soil.

This can help mitigate issues like eutrophication and soil contamination, promoting a healthier environment.

Nanofertilizers can also reduce greenhouse gas emissions associated with fertilizer production and application, according to Frontiers.

3. Enhanced Crop Yield and Quality:

By providing essential nutrients in a readily available form, nanofertilizers can significantly boost crop yields.

The improved nutrient management can lead to healthier, more robust plants with better growth and development.

This, in turn, can contribute to increased food production and improved food security.

4. Sustainability and Economic Benefits:

Nanofertilizers offer a more sustainable approach to agriculture by reducing the reliance on synthetic fertilizers and minimizing their negative environmental impact.

The reduced fertilizer usage can also lead to lower cultivation costs for farmers.

By improving nutrient use efficiency, nanofertilizers can help optimize resource utilization and promote more efficient and sustainable farming

Soil Amendments

Soil amendments are materials added to soil to improve its physical, chemical, or biological properties,
ultimately enhancing plant growth and overall soil health. They can be organic (like compost and manure) or inorganic
(like lime and minerals) and address various soil issues, such as poor drainage, low nutrient content, or compaction.
Types of Soil Amendments:

- **Organic Amendments:**
  - **Compost:** Decomposed organic matter, providing nutrients and improving soil structure.
  - **Manure:** Animal waste, rich in nutrients and beneficial for soil health.
  - **Leaf Mold:** Decomposed leaves, adding organic matter and improving aeration.
  - **Biochar:** Charcoal produced from burning biomass, enhancing soil structure and water retention.
  - **Green Manures:** Legumes or other plants grown and then incorporated into the soil, improving nitrogen and organic matter content.
  - **Peat Moss:** A natural material that improves water retention and soil structure.

- **Inorganic Amendments:**
  - **Lime:** Increases soil pH, making it more alkaline and improving nutrient availability.
  - **Gypsum:** Can improve soil structure in clay soils and reduce the risk of sodicity.
  - **Vermiculite:** An expandable mineral that improves aeration, drainage, and water-holding capacity.
  - **Perlite:** A volcanic glass that improves aeration, drainage, and water-holding capacity.
  - **Sand:** Used to improve drainage in clay soils.

Fertilizer Storage

Fertilizer storage is an important aspect of fertilizer management, as proper storage can help to maintain the quality and effectiveness of fertilizers and prevent environmental pollution. Here is a detailed explanation of fertilizer storage:

Storage location: Fertilizers should be stored in a **dry, cool, and well-ventilated** area that is away from direct sunlight, heat sources, and moisture. The storage area should be located on a level surface that is free of debris and other materials that could cause contamination. The storage area should also be located away from water sources and areas with high traffic to prevent accidental spills.

Storage containers: Fertilizers should be stored in **airtight, durable containers** that are designed for the specific type of fertilizer being stored. The containers should be labeled with the name of the fertilizer, the date of purchase, and the expiration date. It is also important to keep the containers tightly closed to prevent moisture and air from entering.

Handling and transportation: Fertilizers should be handled and transported with care to prevent damage to the containers and spills. The containers should be loaded and unloaded carefully and stored in a stable position during transportation. It is also important to avoid mixing different types of fertilizers during transportation, as this can lead to chemical reactions and hazardous situations.

Spill prevention and cleanup: Spills and leaks can occur during fertilizer storage and transportation, so it is important to have spill prevention and cleanup measures in place. This can include spill containment barriers, spill response kits, and proper training for employees on spill response procedures. Any spills or leaks should be cleaned up immediately and disposed of properly to prevent environmental contamination.

Fertilizer rotation: To prevent the accumulation of old or expired fertilizers, it is important to rotate the fertilizer stock by using the oldest fertilizers first. This can help to ensure that the fertilizers being used are still effective and have not expired.

Fertilizer Control Order

The Fertilizer Control Order (FCO) is a legal document issued by the Ministry of Agriculture and Farmers' Welfare in India under the **Essential Commodities Act, 1955**. The FCO regulates the production, distribution, and sale of fertilizers in India, and is designed to ensure the quality and safety of fertilizers for agricultural use. Here is some information about the Fertilizer Control Order:

Scope: The FCO applies to all types of fertilizers, including chemical fertilizers, organic fertilizers, biofertilizers, and micronutrient fertilizers. The order specifies the minimum standards for quality, labeling, packaging, and transportation of fertilizers.

Quality standards: **The FCO sets out the minimum standards for the physical, chemical, and biological properties of fertilizers. These standards are based on the type of fertilizer and the nutrient content. Fertilizers must meet these standards in order to be registered and sold in India.**

Labeling requirements: The FCO specifies the labeling requirements for fertilizers, which include the name of the fertilizer, the nutrient content, the guaranteed analysis, the batch number, and the date of manufacture. The label must also include the net weight, the name and address of the manufacturer, and the directions for use.

Registration: All fertilizers must be **registered with the Department of Agriculture and Cooperation** before they can be sold in India. The registration process requires the manufacturer to submit samples of the fertilizer for testing to ensure that it meets the quality standards set out in the FCO.

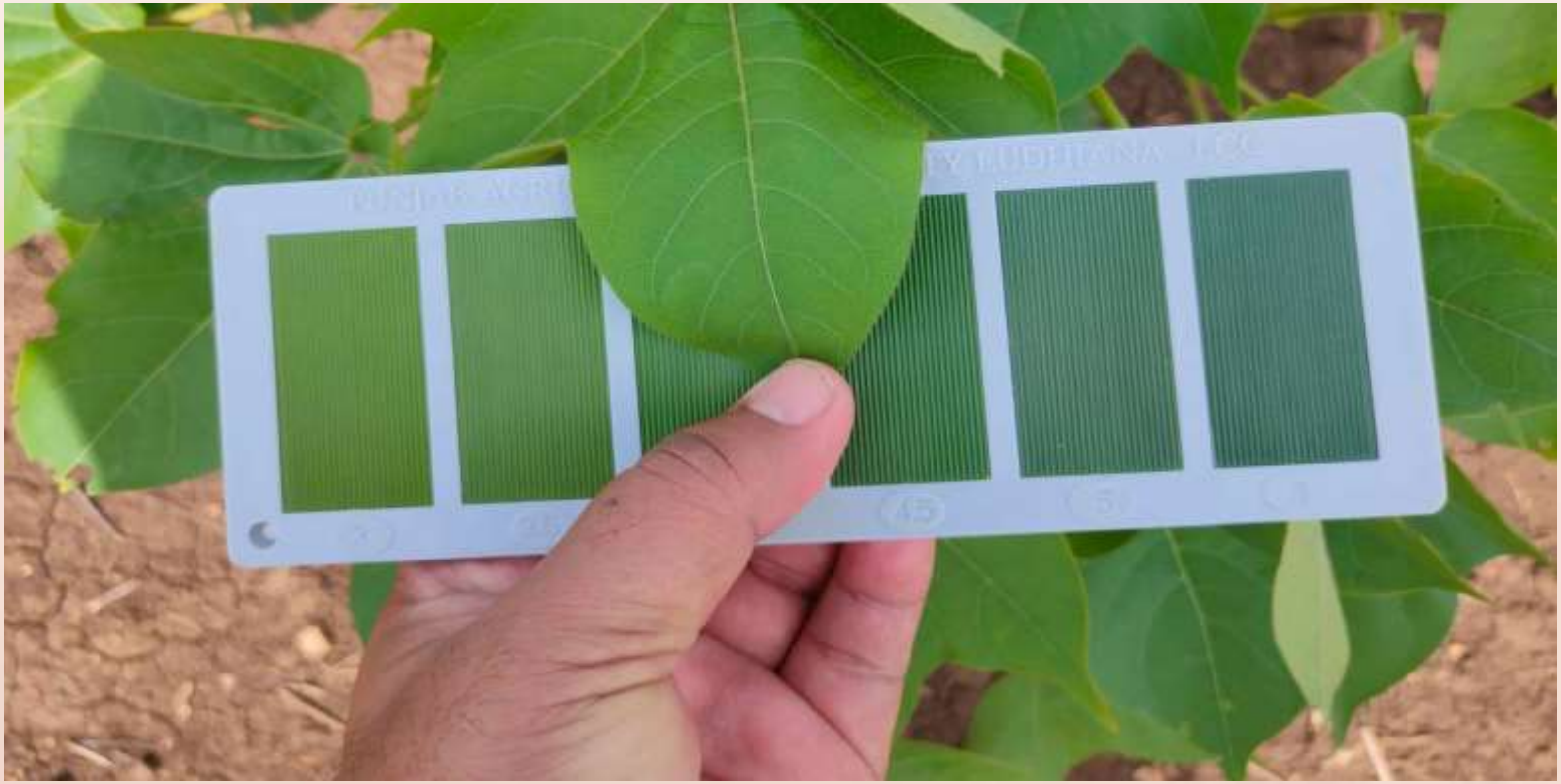
Enforcement: The FCO is enforced by the Department of Agriculture and Cooperation, which is responsible for monitoring the production, distribution, and sale of fertilizers. The department conducts regular inspections of fertilizer manufacturing facilities and distribution centers to ensure compliance with the FCO.

Penalties: Violation of the FCO can result in penalties such as fines, suspension of registration, or cancellation of registration. The severity of the penalty depends on the nature and extent of the violation.

What is Real Time Nitrogen Management?

It is a method of rapid assessment of leaf N content that is closely related to the photosynthetic rate and biomass production and is a sensitive indicator of changes in crop N demand within the growing season. Tools for real time nitrogen management:

1. Leaf color chart: LCC is an easy-to-use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the leaf chlorophyll content and leaf nitrogen status. Japanese scientists developed an N management tool called LCC which was subsequently modified by Chinese scientists. The International Rice Research Institute (IRRI) used the concept and jointly further improved the LCC in the late 1990s to assist farmers to apply N fertilizer at right amount as and when needed by the plant. LCC is made of high quality plastic material, consisting of six green shades from light yellowish green to dark green color strips fabricated with veins resembling those of rice leaves. The colour panels of the LCC are designed to indicate whether rice plants are hungry or over-fed by nitrogen fertilizer. By matching the colour of the rice leaf to the colour on the LCC, farmers can decide proper time and amount of N fertilizer for the application.



Leaf color chart

How to measure LCC?

An average of five disease free rice plants were randomly selected in the plot The color of the youngest fully expanded leaf of the selected plant was compared by placing its middle part on top of the color strip in the chart. The leaf colour of the index leaf (fully opened third leaf from top up to panicle emergence and boot leaf after panicle emergence) of selected plants was compared with the color strips of the chart. If the leaves read below required value, fertilizer N was applied.

Soil plant and analysis development (SPAD) meter:

SPAD meter is a simple, quick and nondestructive in situ tool for measuring the relative content of chlorophyll in the leaf that is directly proportional to leaf N content. It instantly provides an estimate of leaf N status as chlorophyll content by clamping the un plucked leafy tissue in the meter.

Soil plant and analysis development (SPAD) meter:

Measuring SPAD values in the field 1. SPAD readings are taken at 9-15 day intervals, starting from 14 DAT for transplanted rice and 21DAS for wet direct seeded rice, Periodic readings continue up to the first (10%) flowering. 2. The youngest fully expanded leaf of a plant is used for SPAD measurement. 3. Readings are taken on one side of the midrib of the leaf blade. 4. A mean of 10-15 readings per field or plot is taken as the measured SPAD value.

3. Greenseeker optical sensor: Optical sensor is an important tool for replacing blanket fertilizer nitrogen recommendations in rice because it reduces the bias in making measurements and tells the quantity of fertilizer N required to achieve maximum grain yield. The Green Seeker is an instrument that provides a vegetation index of normalized difference vegetative index (NDVI), whose interpretation can contribute to the rapid and directed diagnostic nutritional conditions (especially from Nitrogen), physiological state, incidence of stress, and the potential yield of crops. Procedure for taking NDVI values Before taking the readings, the battery should be charged properly. Then shoulder strap was put around the body and sensor angle was such adjusted that it was parallel to sensing area at a height of about 70 cm above the canopy. The trigger of Green Seeker optical sensor was pressed continuously while moving in the two middle crop rows and trigger was released after completing one plot. A photodiode detector within the sensor measured the magnitude of the light reflected off the target and NDVI was computed.

Greenseeker optical sensor

Conclusion: Use of LCC, SPAD and Green seeker as tools of Real Time Nitrogen Management were found to be superior than the existing & widely adopted blanket method of N application. These tools have tremendous potential to increase the productivity and profitability of rice besides sustaining the soil and environment health. Thus, the N management in rice will undergo radical change in the coming years which will benefit the farming community besides optimizing 'N' requirement of rice.

Integrated Plant Nutrition System (IPNS)

Integrated Plant Nutrition System (IPNS) is defined as maintenance or adjustment of soil fertility and supply of plant nutrient to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible resources of plant nutrients in an integrated manner.

IPNS is a strategy that combines different nutrient sources to ensure plants receive the necessary nutrients for optimal growth while minimizing negative environmental effects. It considers the specific needs of the crop, the soil conditions, and the available resources.

.

The IPNS approach aims

1. To enhance crop and soil productivity through a balanced use of mineral fertilizers combined with organic and biological sources of plant nutrients to ensure sustainability of the production systems.

2. To improve the capital stock of plant nutrients in the soil

3. To improve the efficiency of plant nutrients use, limiting losses of N and P to the environment

Benefits of IPNS

Increased Crop Yields:
Balanced nutrient supply leads to healthier plants and higher yields.

Improved Soil Health:
Organic matter addition and reduced tillage practices enhance soil structure and fertility.

Reduced Environmental Pollution:
Minimized nutrient losses help protect water resources and reduce greenhouse gas emissions.

Cost-Effective and Sustainable:
Optimizing nutrient use reduces the need for expensive chemical inputs while ensuring long-term productivity.

Carbon Sequestration

Soil carbon sequestration, the process of capturing atmospheric carbon dioxide and storing it in soil, plays a crucial role in mitigating climate change. This process is closely linked to carbon trading, where carbon credits can be generated by sequestering carbon in soils and then traded on carbon markets.

Also know as " Carbon capture and storage"

Think of it like taking carbon "waste" out of the air and putting it into long-term storage.

Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids and in a form that is not immediately reemitted.

OR

It refers to the provision of long term storage of carbon in the terrestrial biosphere, underground, or oceans so build up of carbon dioxide(the principal of greenhouse gas) concentration in the atmosphere will reduce or slow down.

This transfer or "sequestering" of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity.

Q2: Why is carbon sequestration necessary?

- The primary reason is to combat climate change.
- Human activities, mainly burning fossil fuels, have released massive amounts of CO_2 into the atmosphere.
- This excess CO_2 acts like a blanket around the Earth, trapping heat and causing global temperatures to rise (the Greenhouse Effect).
- Sequestration is one of the key strategies to reduce the amount of CO_2 in the atmosphere and slow down this warming trend

Soil carbon sequestration means adopting practices – most often in the agricultural sector – that increase the amount of carbon stored in soils. Agricultural management practices might include: increasing plant growth or cover. adding compost or mulch.

Types of carbon sequestration

- Biological carbon sequestration.
- Ocean carbon sequestration.
- Geological carbon sequestration.
- Technological carbon sequestration.

How is Carbon Sequestered in Soils?

Since the size of the stable pool is generally static, soil carbon is effectively increased in the labile and slow pools by increasing the net balance of carbon that enters the soil every year relative to what is lost. Agricultural managers can strongly influence this dynamic in four ways:

1.) Decreasing the level of soil disturbance (i.e. tillage) to enhance the physical protection of soil carbon in aggregates.

2.) Increasing the mass and quality of plant and animal inputs to soils.

3.) Improving soil microbial diversity and abundance.

4.) Maintaining continuous living plant cover on soils year-round. Managing these processes can quickly lead to increases in soil carbon that may be highly useful in drawing down atmospheric CO2. The extent and permanence of soil-based carbon sequestration is currently under investigation and debate. Some of these contested issues are covered more completely in the following sections.

Where is the captured carbon stored

Carbon can be stored in several major natural and artificial reservoirs:

◦ **Forests and Plants (Biomass):** Stored in the trunks, branches, leaves, and roots of trees and plants.

◦ **Soils:** Stored as organic matter in agricultural lands, grasslands, and wetlands.

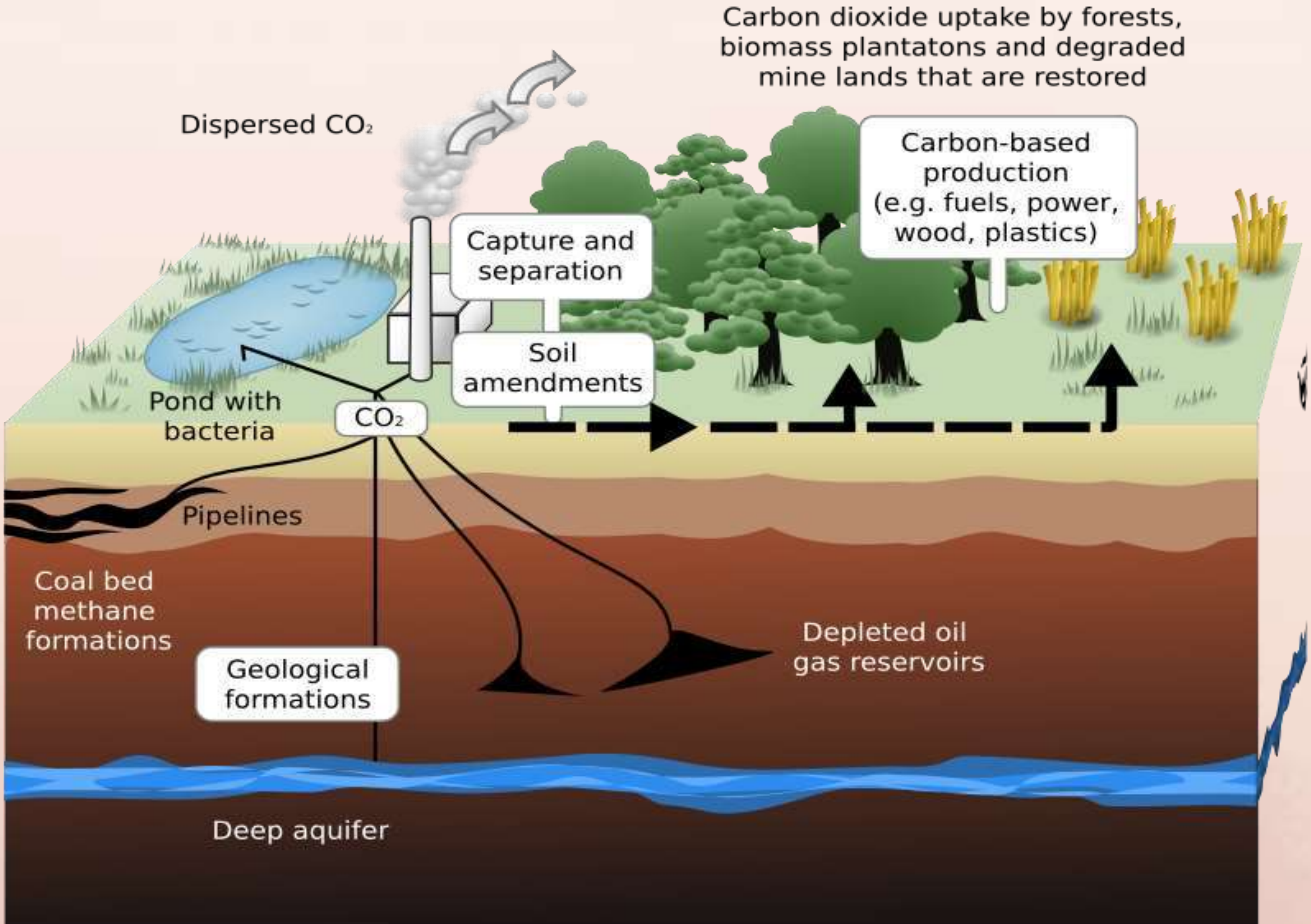
◦ **Oceans:** Dissolved in seawater and used by marine life.

◦ **Geological Formations:** Injected deep underground into porous rock formations, such as old oil and gas fields or deep saline aquifers.

How is carbon sequestered?
(**The Methods) • There are two main categories of sequestration methods:**

1. Natural (or Biological) Sequestration: ◦ Photosynthesis: This is the most well-known method. Trees, plants, and algae naturally breathe in CO_2 from the air and convert it into carbon, which they store in their biomass. ◦ Soil Carbon Sequestration: When plants and animals die, the carbon in their bodies decomposes and becomes part of the soil. Farming practices like no-till farming and planting cover crops can dramatically increase the amount of carbon stored in agricultural soil. ◦ Ocean Sequestration: The ocean naturally absorbs vast amounts of CO_2 from the atmosphere.

• **2. Artificial (or Technological) Sequestration:** ◦ Carbon Capture and Storage (CCS): This involves capturing CO_2 at its source, like a power plant or a factory, before it is released into the atmosphere. The captured CO_2 is then compressed and transported to a storage site. ◦ Direct Air Capture (DAC): This uses large machines with special chemical filters to pull CO_2 directly out of the ambient air. It's like a giant air purifier for the planet. ◦ Once captured by these technologies, the CO_2 is typically injected deep underground for permanent storage.


Carbon dioxide uptake by forests, biomass plantatons and degraded mine lands that are restored
Dispersed CO_2
Carbon-based production (e.g. fuels, power, wood, plastics)
Capture and separation
Soil amendments
Pond with bacteria
CO_2
Pipelines
Coal bed methane formations
Depleted oil gas reservoirs
Geological formations
Deep aquifer

The Kyoto Protocol is an international agreement that commits industrialized countries to reduce greenhouse gas emissions, which are believed to cause global warming. It's a key part of the United Nations Framework Convention on Climate Change (UNFCCC). Essentially, it sets targets for reducing emissions like carbon dioxide, aiming to mitigate climate change

Policy Milestones: International agreements like the Kyoto Protocol (1997) and the Paris Agreement (2015) created frameworks and incentives that spurred research and investment in sequestration technologies and practices

What are the impacts of carbon sequestration on agriculture?

• This is a hugely important area with both positive impacts and challenges.

• **Positive Impacts**: ◦ Improved Soil Health: The primary benefit. Increasing carbon in the soil makes it richer, improves water retention, reduces erosion, and enhances nutrient availability. ◦ Increased Crop Yields: Healthier soil leads to more productive and resilient crops. ◦ New Revenue Stream: Farmers can earn money through carbon credits. Companies or governments pay them for adopting farming practices that verifiably store carbon in their soil. This is part of a movement called regenerative agriculture.

• **Negative Impacts:** ◦ Measurement and Verification: It is difficult and expensive to accurately measure how much carbon is being stored in the soil over time. ◦ Cost and Knowledge: Switching to sequestration-friendly farming (like no-till farming) can require new equipment and expertise. ◦ Permanence: The stored carbon can be released back into the atmosphere if the land is tilled again in the future, so it requires a long-term commitment

The advent of fertilizers in agriculture has dramatically increased global agricultural productivity and simplified management by providing crops with readily available nitrogen, an element essential to plant growth. But from an ecological perspective, this shift in management represents an enormous change in the nutrient balance in soil ecosystems with a potential to affect soil carbon dynamics.

Here's a more detailed look at the advantages:

Aggregated Soil:

Organic carbon helps bind soil particles together, forming stable aggregates that improve soil structure. This leads to better aeration, water infiltration, and drainage, reducing runoff and erosion.

Enhanced Water Retention:

SOC acts like a sponge, increasing the soil's capacity to hold water. This is crucial for drought resistance, as plants have access to water for longer periods.

Reduced Erosion:

Stable soil structure and improved water infiltration help minimize soil erosion caused by wind and water.

2. Enhanced Nutrient Availability and Cycling:

Nutrient Reservoir:

Organic matter serves as a reservoir of essential plant nutrients like nitrogen, phosphorus, and sulfur.

Nutrient Release:
As organic matter decomposes, it releases these nutrients gradually, making them available to plants when they need them.

Reduced Nutrient Leaching:
By holding onto nutrients, SOC reduces the risk of nutrient loss through leaching, making the soil more efficient in nutrient use.
3. Increased Microbial Activity and Biodiversity:

Food Source for Microbes:
Organic carbon is a primary food source for beneficial soil microorganisms, which play vital roles in nutrient cycling, decomposition, and soil health.

Enhanced Microbial Activity:
Increased microbial activity leads to faster decomposition of organic matter, making more nutrients available to plants.

What are some modern scenarios and applications of carbon sequestration?

- **Direct Air Capture (DAC) Plants:** Companies like Clime works have built large-scale DAC plants (e.g., the "Orca" plant in Iceland) that filter CO_2 from the air and store it underground by mineralizing it into rock.
- **Corporate Carbon Neutrality:** Major corporations like Microsoft, Google, and Amazon are investing billions of dollars in both natural and technological sequestration projects to offset their own emissions and meet their "carbon neutral" or "carbon negative" pledges.
- **Carbon-Enhanced Products**: Startups are developing ways to use captured CO_2 to create products like concrete, plastics, and even carbon-neutral fuels, locking the carbon away in durable goods.
- **Regenerative Agriculture Movement**: There is a growing global movement to shift farming practices towards those that rebuild soil organic matter and sequester carbon, promoted by both environmental groups and food companies

Carbon Trading

Carbon trading in agriculture, also known as carbon farming, allows farmers to generate revenue by selling carbon credits earned through practices that reduce greenhouse gas emissions or sequester carbon in the soil. These practices, such as conservation tillage, agro forestry, and cover cropping, improve soil health and contribute to climate change mitigation.

Carbon markets are carbon pricing mechanisms enabling governments and non-state actors to trade greenhouse gas emission credits. The aims is to achieve climate targets and implement climate actions cost effectively. There are two types of carbon markets: Compliance and voluntary.

Introduction to Carbon Trading

- Carbon trading is a market-based mechanism that allows countries, companies, or individuals to buy and sell **carbon credits**, which represent the right to emit a certain amount of greenhouse gases, such as carbon dioxide (CO2).
- The goal of carbon trading is to reduce greenhouse gas emissions and mitigate **climate change**, as stated in the Paris Agreement (2015) and other international agreements.
- Carbon trading is also known as **cap-and-trade** or **emissions trading**, and it has been implemented in various forms around the world, including the European Union's Emissions Trading System (EU ETS) and the Regional Greenhouse Gas Initiative (RGGI) in the United States.

How Carbon Trading Works

The first step is to set a **cap** on the total amount of greenhouse gas emissions allowed within a certain region or industry.

The second step is to allocate **carbon credits** to companies or individuals, which represent the right to emit a certain amount of greenhouse gases.

The third step is to allow companies or individuals to **buy and sell** carbon credits on the market, which creates a financial incentive to reduce emissions.

Benefits of Carbon Trading

Carbon trading provides a **financial incentive** for companies and individuals to reduce their greenhouse gas emissions, which can lead to cost savings and increased competitiveness.

Carbon trading can also **promote innovation** and the development of new technologies that reduce greenhouse gas emissions.

Additionally, carbon trading can **raise revenue** for governments and support **sustainable development** projects, such as reforestation and renewable energy.

Challenges and Limitations of Carbon Trading

- One of the main challenges of carbon trading is **ensuring the integrity** of the carbon credits, which requires robust monitoring, reporting, and verification (MRV) systems.
- Another challenge is **addressing leakage**, which occurs when companies or individuals reduce their emissions in one area, but increase them in another area, such as by outsourcing production to countries with less stringent climate policies.
- Additionally, carbon trading can be **vulnerable to market fluctuations** and **regulatory uncertainties**, which can affect the stability and effectiveness of the market.

Conclusion and Future Outlook

- Carbon trading is a critical component of global efforts to reduce greenhouse gas emissions and mitigate climate change.
- While there are challenges and limitations to carbon trading, it has been shown to be effective in reducing emissions and promoting sustainable development.
- As the world continues to transition to a low-carbon economy, carbon trading is likely to play an increasingly important role in supporting this transition.

Key Takeaways and Call to Action

- Carbon trading is a market-based mechanism that allows countries, companies, or individuals to buy and sell carbon credits.
- Carbon trading can provide a financial incentive to reduce emissions, promote innovation, and raise revenue for sustainable development.
- To support the growth and effectiveness of carbon trading, it is essential to ensure the integrity of carbon credits, address leakage, and promote regulatory certainty.
- Individuals and organizations can support carbon trading by reducing their greenhouse gas emissions, investing in renewable energy, and advocating for climate policies that support carbon trading.

Properties and methods of preparation of farmyard manure and compost

1. FARM YARD MANURE (FYM/ Cattle manure)

Definition: The physical composition of cattle manure is called Farm Yard Manure, which consists of dung and urine of cattle and the litter, a bedding material like hay, straw used for cattle. Cattle manure is slow acting, bulky organic and however is a low analysis fertilizer, obtained from dung and urine of farm animals mixed with litter and other miscellaneous farm wastes.

Constituents of FYM: Dung: The dung is solid excreta voided by farm animals, which represents the undigested and non-digestible portion of the animal feed. Besides, it is also admixed with digestive juices, tissues of alimentary canal, microbial cells etc., **The percentage of moisture varies from 70-80 per cent**. Urine : The liquid excreta of farm animals, which is composed essentially of the by products of nitrogen metabolism of farm animals .It also consists of 90 per cent water with small amounts of urea, hippuric acid, sulphates of sodium and potassium and also chlorides and phosphates of Ca, Mg ,K and Na etc.,

Methods to prepare FYM:

A. **Pit method (Below ground level) :** In this method, the manure is stored in a pit with non –absorbent bottom and sides. The pit is provided with a bund at the rim of the pit to prevent the surface run-off of waters during rainy season .The dimensions of the pit can be variable depending on the quantity of dung ,urine and litter produced on the farm per day .The losses also occur in this method due to exposure to sun and rain ,but it is relatively a better method than the heap method.

B. **B. Heap method (Above the ground level)** : This is the most common method adopted in Indian villages. Manure is heaped on the ground preferably under the shade of a tree. Ideal procedure is to dump the dung first and to cover it with litter soaked urine .This is further covered with a layer of litter /ash / earth to prevent the loss of moisture and to avoid direct exposure to sun .It is also desirable to put up a small bund around the base of the heap to protect against surface run-off washing out the manurial ingredients .It is beneficial to cover the exposed portion of the heap with Palmyra leaves or any other available material. The maximum losses of nutrients occur in this method of storage, resulting in poor quality manure. Direct exposure to the vagaries of climate such as sunshine and rainfall causes looseness and dryness of manure, which hasten the losses of nutrients and rapid oxidation of organic matter.

C. Covered pit method: Of all the methods described, it is the best method .In this method, the bottom and sides of the pit are made non-absorbent by granite stone lining. The pit is also provided with a bund of 1½ feet height to prevent surface fl ow of water (Rain water) and a suitable cover by way of roofing with locally available materials like Palmyra or phoenix leaves etc., organic matter and 8nutrient losses can be effectively controlled in this method of storage in order to obtain better quality manure [FYM: 0.68 % N- 0.5%P – 1 % K].

Key Properties of FYM Composition:

Nutrient Content:

While low in concentration compared to mineral fertilizers, well-decomposed FYM contains essential macronutrients like nitrogen (N), phosphorus (P2O5), and potassium (K2O), as well as micronutrients such as iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu).

Organic Matter:

FYM is rich in organic carbon, which is crucial for soil fertility and the activation of soil microbial life.

Physical Properties:
When applied to soil, FYM improves its physical characteristics by increasing water holding capacity, improving soil structure and aggregate stability, and reducing bulk density.
Chemical Properties:
It can influence soil pH, increase cation exchange capacity, and contribute to higher levels of available nutrients like phosphorus and potassium in the long term.
Composition Variation:
The exact composition of FYM can vary based on factors such as the type of animal, their diet, the amount of litter used, and the method of storage and preparation. For example, lost urine can contain significant amounts of nitrogen and potassium.

Properties and methods of preparation of compost

Compost: The word compost is derived from the Latin word **"COMPONERE"** to mean put together. Compost is a product of decomposition of plant and animal wastes with various additives. The compost had the largest variation of all organic material ranging from neglected garbage dumps to carefully composted and treated substances with high fertility.

S.No	Constituent	Percentage
1	Dry matter	30-50
2	N	0.3
3	P	0.1
4	K	0.3

1. **ADCO process:** Agricultural Development Company was initiated, [A private concern operating at Harpenden, England] developed by Hutchinson, H.B and Richards , E.H. during 1914-1918, at Rothamsted Experimental Station , England . Materials needed: Basic raw material: Straw and other wastes - Starters: Ammonium sulphate/Ammonium phosphate /Super phosphate/Muriate of potash, Ground limestone/ urea .

Procedure: The basic raw material straw is spread in layers and sprinkled over with a solution of ammonium sulphate. Then powdered lime stone is applied as broadcast. Then another straw layer is put on. The piling of the layer is continued till a decent heap of convenient height is built up. After about 3 months of fermentation the resulting material is similar to FYM and hence called "synthetic FYM" The ADCO process was patented and concentrated starters were put in the market with the trade names of ADCO accelerator and ADCO complete manure with full direction for their use.

3. Indore process: This process is developed in India by Howard and Ward at the Indian Institute of plant Industry, Indore. Materials needed: a) Straw or organic farm wastes as basic raw materials b) Cattle dung as starter (urine, earth and wood ashes) Procedure : A compost pit of dimensions of 30 x 14 x 3 feet with sloping sides (narrow at bottom and at wide surface) is prepared and the raw material is spread in layers of 3” thickness. A mixture of urine, earth, and wood ashes is sprinkled and this is followed by 2” layer of dung. The pit is filled up this way until the material occupies a height of 3 feet above the ground level . As air can conveniently penetrate only to a depth of 1.5 to 2.0 feet extra aeration has to be provided, which is done by means of artificial vents (holes) of 4” diameter pipe for every 4 feet length of the pit. The pit is watered twice a day i.e., morning and evening with rose can. The material is turning over 3 times, i.e., First – at the end of the first fort night Second – at the end of the second fort night Third – when the material is two months old in the process of composting. Compost is ready by 3-4 months .One cattle pair produced 50-60 cartloads per year.

4. Bangalore process [Aerobic and anaerobic process] : This process of composting was developed by **Dr. C.N. Acharya in the year 1949**. 1. Basic raw material used : Any organic material 2. Starters or inoculants : FYM or mixture of dung and urine or litter [Undecomposed] 3. Additives :Bone meal or oil ca key , wood ash Procedure [**Pit size: 20 x 4 x 3 feet]:** The basic raw material is spread in a pit of 20 x 4 x 3 feet dimensions to a depth of 6 " layer, moistened with 20-30 gallons of water if the material is dry .Over this FYM or preferably a mixture of dung, urine and litter (un-de composed) from the cattle shed is placed as a layer of 2" thickness. It is again covered on the top with a layer of earth to a thickness of 6 " .It is beneficial to mix the earth with bone meal or oilcakes, wood ash etc., to improve manurial value of the compost .The piling of layers is continued till the heap raises above the ground level to a height of 2 feet , .Then the heap is kept open for one week to facilitate aerobic decomposition . Later the heap is plastered with a layer of moist clay for anaerobic fermentation t o occur .Fissures , or cleavages (cracks) that occur in the clay layer , have to be sea led off periodically .The compost will be ready in 4-5 months period starting from the day of preparation .This process is called as aerobic and anaerobic decomposition of compost . In this process the basic raw material is not so well decomposed as in the other methods .But organic matter and N contents are well conserved .The number of turnings are reduced .The out turn of the compost is relatively greater and cheapest process .

Green manure preparation involves growing specific plants (legumes or others) and incorporating them into the soil to improve its fertility and structure. This process, also known as green manuring, helps enrich the soil with nutrients and organic matter as the plants decompose.

1. **Choosing the Right Plants:**

Select fast-growing plants, often legumes like sun hemp, that can be easily incorporated into the soil.
Legumes are particularly good choices due to their nitrogen-fixing ability, which enhances soil fertility.
Other options include plants like sun flax or roots of pulses.
. Sowing the Green Manure Crop:
Prepare the soil by loosening it and removing any large weeds.
Sow the green manure seeds thickly to ensure a dense cover.
Water the area well after sowing, especially during dry periods, to promote germination.

Allowing the Plants to Grow:
•Let the green manure plants grow until they reach a suitable stage for incorporation (e.g., flowering).
•The specific timing will depend on the chosen plant and the local climate.

Incorporating the Green Manure:
Cut down the green manure crop (if necessary).
Plow or till the plants into the soil.
Alternatively, you can mow the plants and leave the residues on the surface as mulch.
Ensure thorough incorporation to promote decomposition.

Decomposition and Planting:
Allow sufficient time for the green manure to decompose fully before planting the next crop.
The decomposition time will vary based on factors like weather, plant type, and soil conditions.

Benefits of Green Manure:

•**Improved Soil Fertility:** Green manure adds essential nutrients like nitrogen to the soil.

•**Enhanced Soil Structure:** Decomposition of plant matter improves soil aeration and water retention.

•**Weed Suppression:** A dense green manure cover can help suppress weed growth.

Vermicomposting is a process that uses earthworms to decompose organic waste, creating a nutrient-rich soil amendment called vermicompost. To prepare it, you'll need a container, bedding materials, organic waste, and earthworms. The process involves layering the waste, introducing worms, maintaining moisture and temperature, and periodically turning the compost. After a few months, the waste will transform into dark, crumbly vermicompost, ready for use in gardens.

Steps for Preparing Vermicompost:

1. Choose a suitable container:

Select a container with good ventilation and drainage, such as a plastic or wooden bin.

Prepare the bedding:

Line the bottom of the container with bedding material like shredded newspaper, cardboard, or coconut coir.

3. Introduce earthworms:

Add composting worms like Eisenia fetida (red wigglers) or Eudrilus eugeniae (African nightcrawlers).

1.Add organic waste:
Introduce a variety of kitchen and garden scraps, avoiding meat, dairy, and oily foods.
2.5. Maintain moisture and temperature:
Keep the compost moist, like a damp sponge, and ensure the temperature remains within the optimal range for earthworms (55-77°F or 13-25°C).
3.6. Turn the compost:
Periodically turn the compost to ensure proper aeration and mixing.
4.7. Harvest the vermicompost:
After a few months, the waste will transform into dark, crumbly vermicompost. You can harvest it by prompting the worms to migrate to one side of the bin

Books	Writer
Soil Fertility And Fertilizers	**John L. Havlin , Samuel L. Tisdale**
Introductory Soil Science	**Dilip Kumar Das**
Principal And Practices of Soil Fertility And Nutrient Management	**Dr. Jaiprakash Mehra , Dr. Jitendra Patidar , Dr. Satish Kumar**
Soil fertility fertilizer and Integrated nutrient Management	**Shivanand Tolanur**
Fundamentals of Soil Science	**Indian Society of Soil Science**
Text book of soil science	**T D Biswas, S .K Mukherjee**

Thank You