AGRICULTURE

Fertilizers

- **Fertilizers** are natural or artificial substances that supply essential elements to plants for improved growth and productivity.
- They:
  - Increase the natural fertility of soil, or
  - Replace nutrients removed by previous crops.
- **Soil fertility** is the ability of soil to produce sufficient nutrients required for plant growth.
- Plant growth also depends on:
  - Light
  - Humidity
  - Temperature
  - Soil structure
- When soil fertility is poor, nutrients are added through fertilizers.

Sources of Fertilizers

Natural sources:

- Compost
- Animal manure
- Harvested minerals
- Crop rotation
- Organic by-products (fish waste, blood meal, animal remains)

Artificial (synthetic) sources:

- Chemically manufactured fertilizers developed after the 19th century.
- Enabled large-scale agriculture and increased food production.

Organic vs Inorganic Fertilizers

- **Organic fertilizers**
  - Nutrients released slowly during decomposition
  - Improve soil structure and ecosystem
  - Better for long-term soil health
- **Inorganic fertilizers**
  - Nutrients absorbed rapidly by plants
  - Useful for quick crop response

Composition of Fertilizers

Macronutrients

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)

Micronutrients (Trace Elements)

- Zinc (Zn)
- Manganese (Mn)
- Copper (Cu)
- Iron (Fe)
- Calcium (Ca)
- Boron (B)
- Magnesium (Mg)
- Molybdenum (Mo)

Functions of Different Types of Fertilizers

Nitrogen Fertilizers

- Promote leafy growth and overall plant development
- Most important during the middle growth stage
- Applied at the start of the growing season
- **Common examples:**
  - Ammonium nitrate
  - Calcium ammonium nitrate
  - Urea

Phosphorus Fertilizers

- Strengthen roots and stems
- Essential at all stages of growth
- Enhance:
  - Flowering
  - Seed formation
  - Fruit development
- **Examples:**
  - Superphosphate
  - Triple superphosphate
  - Diammonium phosphate (DAP)
  - Ammonium dihydrogen phosphate

- Ammonium polyphosphate

Potassium Fertilizers

- Improve root development
- Support photosynthesis
- Increase resistance to diseases
- Deficiency symptoms:
  - Yellow or brown leaf edges
  - Leaf wilting and falling
- **Examples:**
  - Potassium chloride (KCl)
  - Potassium sulphate (K_2SO_4)
  - Potassium nitrate (KNO_3)

Impact of Fertilizers on Soil Health

Positive Effects

- Proper nutrient application improves:
  - Crop health
  - Crop yield
  - Soil productivity

Negative Effects of Imbalanced Use

- Changes soil pH
- Increases pest attacks
- Causes:
  - Soil acidification
  - Soil erosion
  - Loss of soil organic carbon
  - Reduction of beneficial soil organisms
- Leads to:
  - Reduced plant growth
  - Lower yields
  - Greenhouse gas emissions

Pesticides

Pesticides are chemical substances used in agriculture to control or kill pests such as insects, fungi, weeds, rodents, and nematodes. Pests damage crops and reduce agricultural yield. Different pesticides work through different mechanisms of action.

Types of Pesticides

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1. Insecticides

Insecticides are chemicals used to control insects.

Examples and mechanisms:

- **Organophosphates and Carbamates**
  - Inhibit the enzyme *acetylcholinesterase*.
  - Cause accumulation of acetylcholine.
  - Result in overstimulation of the nervous system and paralysis of insects.
- **Pyrethroids**
  - Disrupt sodium channels in insect nerve cells.
  - Cause repetitive nerve impulses and paralysis.
- **Neonicotinoids**
  - Act on nicotinic acetylcholine receptors in insects.
  - Disrupt nerve signal transmission, leading to paralysis.

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2. Herbicides

Herbicides are chemicals used to control unwanted plants (weeds).

Examples:

- **Glyphosate**
  - Controls broadleaf weeds and grasses.
  - Inhibits protein synthesis, causing plant death.
- **2,4-D and Dicamba**
  - Mimic the plant hormone auxin.
  - Cause uncontrolled growth and eventual death of plants.
- **Paraquat**
  - Inhibits photosynthesis.
  - Leads to rapid death of plants.

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3. Fungicides

Fungicides kill or prevent the growth of fungi that damage crops.

Examples:

- **Triazoles**
  - Inhibit ergosterol biosynthesis (essential for fungal cell membranes).
  - Disrupt membrane integrity, causing cell death.
- **Strobilurins**
  - Interrupt the mitochondrial electron transport chain.
  - Stop energy production in fungal cells.
- **Copper-based fungicides**
  - Disrupt various cellular processes in fungi, leading to cell death.

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4. Rodenticides (Rodent Poisons)

- **Anticoagulant rodenticides**
  - Inhibit vitamin K.
  - Prevent blood clotting, causing internal bleeding in rodents.
- **Zinc phosphide**
  - Reacts with stomach acid to release phosphine gas.
  - Phosphine gas is highly toxic to rodents.

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5. Nematicides

Nematicides are used to control plant-parasitic nematodes.

Examples:

- **Organophosphates**
  - Disrupt the nervous system of nematodes.
- **Biopesticides**
  - Derived from natural sources (plants, bacteria, minerals).
  - Examples: canola oil, baking soda.
  - Control nematodes through natural mechanisms.

Benefits and Risks of Pesticides

Pesticides provide effective pest control but also pose risks to human health and the environment. A balance is necessary for safe use.

Benefits of Pesticides

1. Protect crops from pests and diseases, increasing yield and food production.
2. Help control the spread of diseases among plants, animals, and humans.
3. Often more cost-effective than alternative pest control methods.
4. Improve the quality of fruits and vegetables by preventing pest damage.
5. Contribute to global food security and agricultural stability.

Negative Aspects of Pesticides

1. Some pesticides are **carcinogenic** and **neurotoxic**, posing health risks to farmers, workers, and consumers.
2. Harm non-target organisms such as beneficial insects, birds, and aquatic life.
3. Pesticide residues on food crops may cause health problems in consumers.
4. Continuous use can lead to **pesticide resistance** in pests.
5. Reduce populations of beneficial insects, causing ecological imbalance.
6. Harm pollinators like bees, affecting crop pollination and yield.
7. Improper use or disposal can contaminate soil and water, leading to environmental pollution.

Acid Rain

Normal rainwater contains dissolved carbon dioxide and has a pH of about **5.6**.
Rainwater with a pH **lower than 5.6** is called **acid rain**.

Causes of Acid Rain

Acid rain is mainly caused by air pollutants:

- **Sulphur dioxide (SO_2)**
- **Nitrogen oxides (NOx)**

These gases dissolve in rainwater to form strong acids:

- SO_2 → **Sulphuric acid (H_2SO_4)**
- NOx → **Nitric acid (HNO_3)**

As a result, the pH of rainwater can drop to **as low as 2.1**, which is more acidic than lemon juice or vinegar.

Effects of Acid Rain

When acid rain falls on soil and plants, it causes chemical reactions that:

- Alter soil chemistry
- Reduce nutrient availability
- Decrease crop growth and agricultural yield

Impact of Acid Rain on Soil and Crops

Acid rain has several harmful effects on soil and crop productivity.

1. Increased Soil Acidity

- Acid rain lowers soil pH, making it more acidic.
- Essential nutrients such as:
  - Calcium (Ca^{2+})
  - Magnesium (Mg^{2+})
  - Potassium (K^{+})
  - Sodium (Na^{+})

  are leached out of the soil and replaced by hydrogen ions (H^{+}).

Example reaction:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O$$

- Loss of nutrients reduces soil fertility and plant growth.

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2. Aluminium Toxicity

- Increased soil acidity causes aluminium compounds to dissolve.
- Aluminium ions are released into the soil solution.

Reaction:

\text{Al₂O₃ + 3H₂SO₄ + 6H₂O → 2Al(OH)₃ + 3SO₄^{2-} + 6H⁺}

- Aluminium ions are **toxic to plants**.
- They damage roots and reduce water absorption, leading to plant death.

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3. Damage to Plant Leaves

- Direct acid rain damages the waxy protective layer of leaves.
- This increases water loss and makes plants more vulnerable to:
  - Diseases
  - Environmental stress

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4. Reduced Crop Yield

- Acid rain affects sensitive crops such as:
  - Soybeans
  - Wheat
  - Peanuts
- In soybeans, acid rain reduces **nitrogen fixation**.
- In wheat and other crops, it interferes with nutrient uptake.
- These effects lead to reduced crop productivity.

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5. Effect on Soil Microorganisms

- Acid rain harms beneficial soil microorganisms.
- These microorganisms are essential for:
  - Nutrient cycling
  - Decomposition of organic matter
- Their reduction further decreases soil fertility and crop yield.