Soil and Plant Nutrition

Soil contains a living, complex ecosystem

- Plants obtain most of their water and minerals from the upper layers of soil
- Living organisms play an important role in these soil layers
- This complex ecosystem is fragile
- The basic physical properties of soil are
  - Texture
  - Composition

Soil Texture

Sand – silt – clay

soil horizons

topsoil

humus

Soil solution consists of water and dissolved minerals in the pores between soil particles

After a heavy rainfall, water drains from the larger spaces in the soil, but smaller spaces retain water because of its attraction to clay and other particles

The film of loosely bound water is usually available to plants.

Topsoil Composition

A soil's composition refers to its inorganic (mineral) and organic chemical components

Inorganic Components

Cations adhere to negatively charged soil particles; this prevents them from leaching out of the soil through percolating groundwater

During **cation exchange**, cations are displaced from soil particles by other cations

Displaced cations enter the soil solution and can be taken up by plant roots

Negatively charged ions do not bind with soil particles and can be lost from the soil by leaching

Organic Components

Humus builds a crumbly soil that retains water but is still porous

It also increases the soil's capacity to exchange cations and serves as a reservoir of mineral nutrients

Topsoil contains bacteria, fungi, algae, other protists, insects, earthworms, nematodes, and plant roots

These organisms help to decompose organic material and mix the soil

Irrigation

Irrigation is a huge drain on water resources when used for farming in arid regions

- For example, 75% of global freshwater use is devoted to agriculture

The primary source of irrigation water is underground water reserves called aquifers

The depleting of aquifers can result in land subsidence, the settling or sinking of land

Irrigation can lead to salinization, the concentration of salts in soil as water evaporates

Drip irrigation requires less water and reduces salinization

Fertilization

Soils can become depleted of nutrients as plants and the nutrients they contain are harvested

Fertilization replaces mineral nutrients that have been lost from the soil

Commercial fertilizers are enriched in nitrogen (N), phosphorus (P), and potassium (K)

Excess minerals are often leached from the soil and can cause algal blooms in lakes

Organic fertilizers are composed of manure, fishmeal, or compost

They release N, P, and K as they decompose

Controlling Erosion

Topsoil from thousands of acres of farmland is lost to water and wind erosion each year in the United States

Erosion of soil causes loss of nutrients

Erosion can be reduced by

- Planting trees as windbreaks
- Terracing hillside crops
- Cultivating in a contour pattern
- Practicing **no-till agriculture**

Phytoremediation

Some areas are unfit for agriculture because of contamination of soil or groundwater with toxic pollutants

Phytoremediation is a biological, nondestructive technology that reclaims contaminated areas

Plants capable of extracting soil pollutants are grown and are then disposed of safely

Macronutrients and Micronutrients

More than 50 chemical elements have been identified among the inorganic substances in plants, but not all of these are essential to plants

There are 17 **essential elements**, chemical elements required for a plant to complete its life cycle

Researchers use **hydroponic culture** to determine which chemical elements are essential

Nine of the essential elements are called **macronutrients** because plants require them in relatively large amounts

The macronutrients are carbon, oxygen, hydrogen, nitrogen, phosphorus, sulfur, potassium, calcium, and magnesium

The remaining eight are called **micronutrients** because plants need them in very small amounts

The micronutrients are chlorine, iron, manganese, boron, zinc, copper, nickel, and molybdenum

Plants with C_4 and CAM photosynthetic pathways also need sodium

Micronutrients function as cofactors, nonprotein helpers in enzymatic reactions

Soil Bacteria and Plant Nutrition

The layer of soil bound to the plant's roots is the

rhizosphere

The rhizosphere contains bacteria that act as

decomposers and nitrogen-fixers

Rhizobacteria

Free-living **rhizobacteria** thrive in the rhizosphere, and some can enter roots

The rhizosphere has high microbial activity because of sugars, amino acids, and organic acids secreted by roots

Rhizobacteria can play several roles

- Produce hormones that stimulate plant growth
- Produce antibiotics that protect roots from disease
- Absorb toxic metals or make nutrients more available to roots

Bacteria in the Nitrogen Cycle

Nitrogen can be an important limiting nutrient for plant growth

The **nitrogen cycle** transforms nitrogen and nitrogen-containing compounds

Plants can absorb nitrogen as either nitrate-NO_3^- or ammonium-NH_4^+

Most soil nitrogen comes from actions of soil bacteria

Along a legume’s roots are swellings called **nodules**, composed of plant cells “infected” by nitrogen-fixing *Rhizobium* bacteria

Fungi and Plant Nutrition

Mycorrhizae are mutualistic associations of fungi and roots

The fungus benefits from a steady supply of sugar from the host plant

The host plant benefits because the fungus increases the surface area for water uptake and mineral absorption

Mycorrhizal fungi also secrete growth factors that stimulate root growth and branching

Epiphytes, Parasitic Plants, and Carnivorous Plants

Some plants have nutritional adaptations that use other organisms in nonmutualistic ways

Three unusual adaptations are

- Epiphytes
- Parasitic plants
- Carnivorous plants

An **epiphyte** grows on another plant and obtains water and minerals from rain

Parasitic plants absorb sugars and minerals from their living host plant