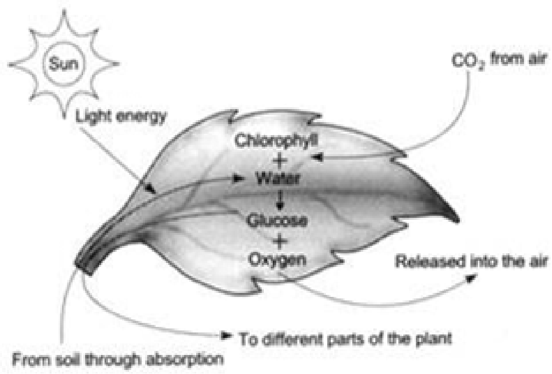
PLANT NUTRITION

Plants meet their nutritional needs for growth by absorbing soil nutrients, water, and carbon dioxide, in addition to the required sunlight. Main modes of nutrition in plants and animals are:

1. Autotrophic nutrition
2. Heterotrophic nutrition (Animal Nutrition)



A summary of nutrition in green plants

AUTOTROPHIC NUTRITION

The term 'autotroph' is derived from two Greek words—autos (self) and trophe (nutrition). In autotrophic nutrition, an organism makes its own food from simple raw materials.

Introduction

Plants are unique organisms that can absorb nutrients and water through their root system, as well as carbon dioxide from the atmosphere. Soil quality and climate are the major determinants of plant distribution and growth. The combination of soil nutrients, water, and carbon dioxide, along with sunlight, allows plants to grow. In order to develop into mature, fruit-bearing plants, many requirements must be met and events must be coordinated. Take for example the Cucurbitaceae family of plants that were the first cultivated in Mesoamerica, although several species are native to North America. The family includes many edible species, such as squash and pumpkin, as well as inedible gourds . First, seeds must germinate under the right conditions in the soil; therefore, temperature, moisture, and soil quality are important factors that play a role in germination and seedling development. Soil quality and climate are significant to plant distribution and growth. Second, the young seedling will eventually grow into a mature plant with the roots absorbing nutrients and water from the soil. At the same time, the above ground parts of the plant will absorb carbon dioxide from the atmosphere and use energy from sunlight to produce organic compounds through photosynthesis. Finally, the fruit are grown and matured and the cycle begins all over again with the new seeds. There is a complex dynamic between plants and soils that ultimately determines the outcome and viability of plant life.

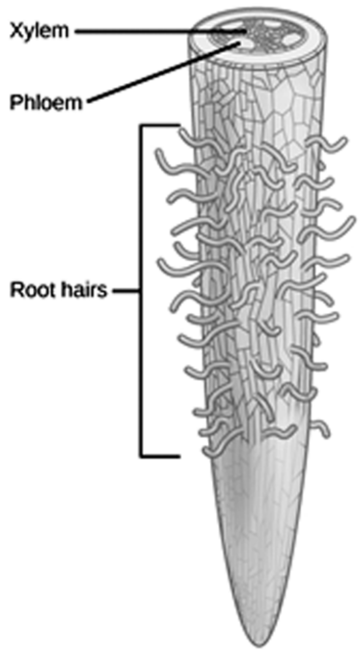
The Chemical Composition of Plants

Plants are composed of water, carbon-containing organics, and non-carbon-containing inorganic substances such as potassium and nitrogen.

Water

Since plants require nutrients in the form of elements such as carbon and potassium, it is important to understand the chemical composition of plants. The majority of volume in a plant cell is water; it typically comprises 80 to 90 percent of the plant's total weight.

Soil is the water source for land plants. It can be an abundant source of water even if it appears dry. Plant roots absorb water from the soil through root hairs and transport it up to the leaves through the xylem. As water vapor is lost from the leaves, the process of transpiration and the polarity of water molecules (which enables them to form hydrogen bonds) draws more water from the roots up through the plant to the leaves . Plants need water to support cell structure, for metabolic functions, to carry nutrients, and for photosynthesis.



Water absorption by the roots

Nutrients

Plant cells need essential substances, collectively called nutrients, to sustain life. Plant nutrients may be composed of either organic or inorganic compounds. An organic compound is a chemical compound that contains carbon, such as carbon dioxide obtained from the atmosphere. Carbon that was obtained from atmospheric CO2 composes the majority of the dry mass within most plants. An inorganic compound does not contain carbon and is not part of, or produced by, a living organism. Inorganic substances (which form the majority of the soil substance) are commonly called minerals: those required by plants include nitrogen (N) and potassium (K), for structure and regulation.

Essential Nutrients

Approximately 20 macronutrients and micronutrients are deemed essential nutrients to support all the biochemical needs of plants. Plants require only light, water, and about 20 elements to support all their biochemical needs. These 20 elements are called essential nutrients. For an element to be regarded as essential, three criteria are required:

- a plant cannot complete its life cycle without the element
- no other element can perform the function of the element
- the element is directly involved in plant nutrition

Macronutrients and Micronutrients

The essential elements can be divided into macronutrients and micronutrients . Nutrients that plants require in larger amounts are called macronutrients. About half of the essential elements are considered macronutrients: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. The first of these macronutrients, carbon (C), is required to form carbohydrates, proteins, nucleic acids, and many other compounds; it is, therefore, present in all macromolecules. On average, the dry weight (excluding water) of a cell is 50 percent carbon, making it a key part of plant biomolecules.

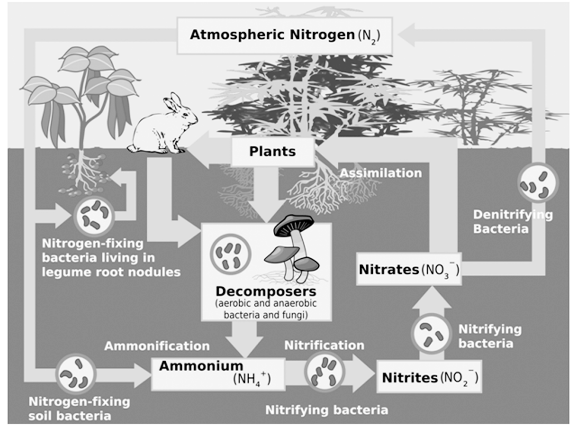
Essential Elements for Plant Growth	
Macronutrients	**Micronutrients**
Carbon (C)	Iron (Fe)
Hydrogen (H)	Manganese (Mn)
Oxygen (O)	Boron (B)
Nitrogen (N)	Molybdenum (Mo)
Phosphorus (P)	Copper (Cu)
Potassium (K)	Zinc (Zn)
Calcium (Ca)	Chlorine (Cl)
Magnesium (Mg)	Nickel (Ni)
Sulfur (S)	Cobalt (Co)
	Sodium (S)
	Silicon (Si)

Essential elements required by plants

The next-most-abundant element in plant cells is nitrogen (N); it is part of proteins and nucleic acids. Nitrogen is also used in the synthesis of some vitamins. Hydrogen and oxygen are macronutrients that are part of many organic compounds and also form water. Oxygen is necessary for cellular respiration; plants use oxygen to store energy in the form of ATP. Phosphorus (P), another macromolecule, is necessary to synthesize nucleic acids and phospholipids. As part of ATP, phosphorus enables food energy to be converted into chemical energy through oxidative phosphorylation. Light energy is converted into chemical energy during photophosphorylation in photosynthesis; and into chemical energy to be extracted during respiration. Sulfur is part of certain amino acids, such as cysteine and methionine, and is present in several coenzymes. Sulfur also plays a role in photosynthesis as part of the electron transport chain where hydrogen gradients are key in the conversion of light energy into ATP. Potassium (K) is important because of its role in regulating stomatal opening and closing. As the openings for gas exchange, stomata help maintain a healthy water balance; a potassium ion pump supports this process. Magnesium (Mg) and calcium (Ca) are also important macronutrients. The role of calcium is twofold: to regulate nutrient transport and to support many enzyme functions. Magnesium is important to the photosynthetic process. These minerals, along with the micronutrients, also contribute to the plant’s ionic balance. In addition to macronutrients, organisms require various elements in small amounts. These micronutrients, or trace elements, are present in very small quantities. The seven main micronutrients include boron, chlorine, manganese, iron, zinc, copper, and molybdenum. Boron (B) is believed to be involved in carbohydrate transport in plants; it also assists in metabolic regulation. Boron deficiency will often result in bud dieback. Chlorine (Cl) is necessary for osmosis and ionic balance; it also plays a role in photosynthesis. Copper (Cu) is a component of some enzymes. Symptoms of copper deficiency include browning of leaf tips and chlorosis (yellowing of the leaves). Iron (Fe) is essential for chlorophyll synthesis, which is why an iron deficiency results in chlorosis. Manganese (Mn) activates some important enzymes involved in chlorophyll formation. Manganese-deficient plants will develop chlorosis between the veins of its leaves. The availability of manganese is partially dependent on soil pH. Molybdenum (Mo) is essential to plant health as it is used by plants to reduce nitrates into usable forms. Some plants use it for nitrogen fixation; thus, it may need to be added to some soils before seeding legumes. Zinc (Zn) participates in chlorophyll formation and also activates many enzymes. Symptoms of zinc deficiency include chlorosis and stunted growth. Deficiencies in any of these nutrients, particularly the macronutrients, can adversely affect plant growth . Depending on the specific nutrient, a lack can cause stunted growth, slow growth, or chlorosis. Extreme deficiencies may result in leaves showing signs of cell death.

Nitrogen Fixation: Root and Bacteria Interactions

Plants cannot extract the necessary nitrogen from soil, so they form symbiotic relationships with rhizobia that can fix it as ammonia. Nitrogen is an important macronutrient because it is part of nucleic acids and proteins. Atmospheric nitrogen, which is the diatomic molecule N2, or dinitrogen, is the largest pool of nitrogen in terrestrial ecosystems. However, plants cannot take advantage of this nitrogen because they do not have the necessary enzymes to convert it into biologically useful forms. However, nitrogen can be "fixed." It can be converted to ammonia (NH3) through biological, physical, or chemical processes. Biological nitrogen fixation (BNF), the conversion of atmospheric nitrogen (N2) into ammonia (NH3), is exclusively carried out by prokaryotes, such as soil bacteria or cyanobacteria. Biological processes contribute 65 percent of the nitrogen used in agriculture. The most important source of BNF is the symbiotic interaction between soil bacteria and legume plants, including many crops important to humans. The NH3 resulting from fixation can be transported into plant tissue and incorporated into amino acids, which are then made into plant proteins. Some legume seeds, such as soybeans and peanuts, contain high levels of protein and are among the most important agricultural sources of protein in the world.



Nitrogen cycle

Soil bacteria, collectively called rhizobia, symbiotically interact with legume roots to form specialized structures called nodules in which nitrogen fixation takes place. This process entails the reduction of atmospheric nitrogen to ammonia by means of the enzyme nitrogenase. Therefore, using rhizobia is a natural and environmentally-friendly way to fertilize plants as opposed to chemical fertilization that uses a non-renewable resource, such as natural gas. Through symbiotic nitrogen fixation, the plant benefits from using an endless source of nitrogen from the atmosphere. The process simultaneously contributes to soil fertility because the plant root system leaves behind some of the biologically-available nitrogen. As in any symbiosis, both organisms benefit from the interaction: the plant obtains ammonia and bacteria obtain carbon compounds generated through photosynthesis, as well as a protected niche in which to grow.

Nutrients from Other Sources

Many species of plants are unable to make their food via photosynthesis and must acquire nutrients in a variety of additional ways. Some plants cannot produce their own food and must obtain their nutrition from outside sources. This may occur with plants that are parasitic or saprophytic: ingesting and utilizing dead matter as a food source. In other cases, plants may be mutualistic symbionts, epiphytes, or insectivorous.

Plant Parasites

A parasitic plant depends on its host for survival. Some parasitic plants have no leaves. An example of this is the dodder, which has a weak, cylindrical stem that coils around the host and forms suckers . From these suckers, cells invade the host stem and grow to connect with the vascular bundles of the host. The parasitic plant obtains water and nutrients through these connections. The plant is a total parasite (a holoparasite) because it is completely dependent on its host. Other parasitic plants, called hemiparasites, are fully photosynthetic and only use the host for water and minerals. There are about 4,100 species of parasitic plants.

Saprophytes

A saprophyte is a plant that does not have chlorophyll, obtaining its food from dead matter, similar to bacteria and fungi. (Note that fungi are often called saprophytes, which is incorrect, because fungi are not plants). Plants such as these use enzymes to convert organic food materials into simpler forms from which they can absorb nutrients . Most saprophytes do not directly digest dead matter. Instead, they parasitize mycorrhizae or other fungi that digest dead matter, ultimately obtaining photosynthate from a fungus that derived photosynthate from its host. Saprophytic plants are uncommon with only a few, described species.

Symbionts

A symbiont is a plant in a symbiotic relationship with other organisms, such as mycorrhizae (with fungi) or nodule formation. Root nodules occur on plant roots (primarily Fabaceae) that associate with symbiotic, nitrogen-fixing bacteria. Under nitrogen-limiting conditions, capable plants form a symbiotic relationship with a host-specific strain of bacteria known as rhizobia. Within legume nodules, nitrogen gas from the atmosphere is converted into ammonia, which is then assimilated into amino acids (the building blocks of proteins), nucleotides (the building blocks of DNA and RNA, as well as the important energy molecule ATP), and other cellular constituents such as vitamins, flavones, and hormones. Fungi also form symbiotic associations with cyanobacteria and green algae; the resulting symbiotic organism is called a lichen. Lichens can sometimes be seen as colorful growths on the surface of rocks and trees . The algal partner (phyco- or photobiont) makes food autotrophically, some of which it shares with the fungus; the fungal partner (mycobiont) absorbs water and minerals from the environment, which are made available to the green alga. If one partner was separated from the other, they would both die.

Epiphytes

An epiphyte is a plant that grows on other plants, but is not dependent upon the other plant for nutrition; it is non-parasitic. The epiphyte derives its moisture and nutrients from the air, rain, and sometimes from debris accumulating around it instead of from the structure to which it is fastened. Epiphytes have two types of roots: clinging aerial roots (which absorb nutrients from humus that accumulates in the crevices of trees) and aerial roots (which absorb moisture from the atmosphere).

Insectivorous Plants

Carnivorous plants are a specialized group of plants that grow in wet, boggy, acidic soils. These bogs are typically comprised of peat soils which are low in the mineral salts and other nutrients vital for the plants survival. One of the most critical plant nutrients is nitrogen which is usually taken up by plants as nitrates. Nitrogen is a nutrient that is easily leached out of even ordinary soils. For this reason the plants that live in these soils have evolved into carnivorous plants that capture and digest insects as a means of obtaining nitrates. There are two major categories of the Carnivorous Plants, one with the active traps and other with the passive traps. The active traps are those with spiny hinged leaves and tend to move really fast, where passive traps are plants having leaves shaped like a vase.

Venus Flytrap

Venus Flytrap scientifically known as Dionaea muscipla is the most famous kind of Active Carnivorous plants. It is the relative of Sundew plant. The insects are attracted to these plants for nectar found on its blade like leaves. As soon as an insect touches the tiny hair present inside the leaves the fringe of spiny hair found around the leaves snap shut trapping the prey inside. Then the leaves release some digestive enzymes and absorb essential nutrients.

Sundew Plant

These plant species belong to genus Drodera. Sundew plants have hundreds of tentacles all over its leaves that produce a shiny sticky substance that is often confused with the dew, as sunlight like makes them glitter. The insects are tricked by these fake dew drops and get stuck to the leaves. The poor prey is then enclosed within the tentacles and digestive enzymes start their work. In some cases, bugs reside on these plants, these bugs eat up the insects that get trapped and serve the plants with their waste products.

Pitcher Plant

Pitcher plants come in two varieties that are, Tropical pitchers and North American pitchers. Tropical pitcher plants are also known as Monkey Cups and belong to the genus Nepenthes. As the name suggests the plants are shaped like pitchers and are brightly colored. The bright colors and nectar of the plant helps to draw its prey's attention. The inside of the pitcher shaped leaves are covered with slippery waxy scales that make its prey slip at the bottom of the pitcher where digestive fluids are present.

The North American Pitcher plants belong to the genus Sarracenia. Inside the pitcher at the bottom water is present; the trapped insects drown in this water and are then digested by the enzymes that are released in it.

Bladderworts

Bladderworts are also known as Utricularia and are aquatic plants. It comprise of tiny sacs that resemble a bladder, located on the leaves and the stems of the plant. The size of these bladder like sacs ranges from 2mm to 4mm. The tiny sacs have a thin flap like membrane that acts like a door, this mechanism is also known as "trap door". There are tiny bristly hairs found surrounding the door. The plant is slightly oval in shape which forms a vacuum that helps trap insects triggering its hair. The prey is then digested with the help of enzymes that are excreted inside the sac.

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