Plant Nutrition

Photosynthesis is the major source of plant nutrition. Plants also require a number of inorganic molecules. **Macronutrients**
- carbon, hydrogen, oxygen, nitrogen, potassium, calcium, phosphorus, magnesium and sulfur
- each may exceed 1% dry weight of plant

**Micronutrients**
- iron, chlorine, copper, manganese, zinc, molybdenum, and boron
- constitute from less than one, to several hundred, parts per million in most plants

Nutritional requirements assessed in hydroponic cultures

<table>
<thead>
<tr>
<th>Elements</th>
<th>Principal Form in which Element is Absorbed</th>
<th>Approximate Percent of Dry Weight</th>
<th>Examples of Important Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macronutrients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>(CO₂)</td>
<td>44</td>
<td>Major component of organic molecules</td>
</tr>
<tr>
<td>Oxygen</td>
<td>(O₂, H₂O)</td>
<td>44</td>
<td>Major component of organic molecules</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>(H₂O)</td>
<td>6</td>
<td>Major component of organic molecules</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>(NO₃⁻, NH₄⁺)</td>
<td>1–4</td>
<td>Component of amino acids, proteins, nucleotides, nucleic acids, chlorophyll, coenzymes, enzymes</td>
</tr>
<tr>
<td>Potassium</td>
<td>(K⁺)</td>
<td>0.5–6</td>
<td>Protein synthesis, operation of stomata</td>
</tr>
<tr>
<td>Calcium</td>
<td>(Ca²⁺)</td>
<td>0.2–3.5</td>
<td>Component of cell walls, maintenance of membrane structure and permeability, activates some enzymes</td>
</tr>
<tr>
<td><strong>Micronutrients (Concentrations in PPM)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>(Cl⁻)</td>
<td>100–10,000</td>
<td>Osmosis and ionic balance</td>
</tr>
<tr>
<td>Iron</td>
<td>(Fe²⁺, Fe³⁺)</td>
<td>25–300</td>
<td>Chlorophyll synthesis, cytochromes, nitrogenase</td>
</tr>
<tr>
<td>Manganese</td>
<td>(Mn²⁺)</td>
<td>15–800</td>
<td>Activator of certain enzymes</td>
</tr>
<tr>
<td>Zinc</td>
<td>(Zn²⁺)</td>
<td>15–100</td>
<td>Activator of many enzymes, active in formation of chlorophyll</td>
</tr>
<tr>
<td>Boron</td>
<td>(BO₃⁻² or B(OH)⁻)</td>
<td>5–75</td>
<td>Possibly involved in carbohydrate transport, nucleic acid synthesis</td>
</tr>
<tr>
<td>Copper</td>
<td>(Cu²⁺)</td>
<td>4–30</td>
<td>Activator or component of certain enzymes</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>(MoO₄²⁻)</td>
<td>0.1–5</td>
<td>Nitrogen fixation, nitrate reduction</td>
</tr>
</tbody>
</table>
Deficiencies of certain nutrients cause specific diseases.

Complete lack of only one nutrient can result in lack of growth.

**Leybig’s Law of the Minimum**

Although all other nutrients are in abundance, a deficiency of a single nutrient will stop growth.

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**Diagram:**

- **Complete nutrient solution**
  - Transplant
  - Monitor growth

- **Solution lacking one suspected essential nutrient**
  - Abnormal growth

- **Suspected nutrient is not essential**
  - Normal growth

- **Suspected nutrient is essential**
  - Solution lacking one suspected essential nutrient
Under natural circumstances, nutrients come from soil

Plant growth affected by soil composition
Most roots found in topsoil
Topsoil consists of small particles of weathered rock, minerals, decomposing organic materials (humus), and living organisms

About half total soil volume occupied by spaces or pores filled with air or water, depending on environmental conditions

weathering of bedrock releases nutrients slowly - chemical processes make mineral nutrients soluble

In natural conditions, plants remove nutrients from the soil but their death and decomposition returns nutrients to the soil
In agriculture, removal of the crop removes nutrients that the crops have taken from the soil. Agricultural land often becomes nutrient depleted.

Chemical fertilizers can be used to replenish lost nutrients. Commercial fertilizers generally have Nitrogen (N), Phosphorus (P), and Potassium (K) in percentages given on the label:

20:20:20 = 20% N; 20% P; 20% K

They often have other macronutrients and micronutrients also.

Nutrient depletion in soils can be reduced by crop rotation and plowing under of unharvested plant remains.

Large particle soils have large air spaces and little surface area. They have poor ability to hold water and nutrients.

Small particle soils have small air spaces and large surface area. They hold water and nutrients well - sometimes too well.

The best soils have a mixture of particle sizes - “loam”.

Sand 200 - 2000 μm

Silt 2 - 200 μm

Clay < 2 μm
Nitrogen Fixation

Plants need ammonia (NH₃) to build amino acids.
N₂ most common atmospheric form
Plants lack the ability to convert gaseous nitrogen to ammonia.
some bacteria have the ability
A mutualism between legumes and nitrogen-fixing bacteria allow atmospheric N to be captured and made available to the plant.

Nutritional Adaptations of Plants

Carnivorous plants
   obtain nitrogen directly from other organisms
   allows growth in N poor environments
Mycorrhizae
   extend surface area for nutrient uptake
Parasitic plants
   tap into vascular tissue of host plant for nutrients