Exercise 6 – The Mineral Nutrition of Plants
Biol 1012, S2008, Lee

Goals
• Observe the effects of mineral deficiencies on plant growth
• Relate the known metabolic needs of minerals with the structural changes seen in deficient plants
• Identify nutrients as mobile vs. non-mobile within the plant body

INTRODUCTION
The external features of plant growth and development are products of internal processes and events that can be traced back to molecules and chemical reactions. For these reasons, the names of several of the molecules that have an important role in plant development will be introduced, even though the major emphasis will be on easily observable external features.

Essentiality
Growth requires an adequate supply of the elements needed to produce new plant tissue. While carbon is obtained from the atmosphere, most elements are available as minerals in the soil. Presently, 17 mineral elements are considered essential for plant growth. The definition of “essentiality” of nutrients has changed over time, to a large degree because of the change in research methods. Earlier, essentiality was determined simply by growing organisms in the absence of the particular nutrient (complete deficiency of micro-nutrients is actually quite difficult to achieve because of contaminants in chemicals, glassware, and water). More recently, research has focused on subcellular components, revealing a number of elements essential for the activity or structure of macromolecules of the cell (e.g. enzymes) that have not been detected through the coarser whole organism studies. Most biologists today define an element as essential if
1) the plant cannot complete its life cycle (form viable seed) in the absence of that element
   -OR-
2) it forms part of any molecule or plays a role in some metabolic function essential in the plant
   (Salisbury and Ross 1992).

Sources
Plants acquire the majority of these elements from the soil solution by absorption through the roots. Some elements may also enter plants via the stomata in gaseous states. Gases may include carbon as CO₂, sulfur as gaseous SO₂, and nitrogen as gaseous NO₂ or NH₃. Other elements such as chlorine may also enter the plant via the atmospheric route carried on dust particles or water droplets. In the case of essential micronutrients (required in relatively small amounts, < 0.1 mg/g dry wt of tissue), the atmospheric pathway could possibly supply all of a plant’s requirements. The required macronutrients (required in relatively large amounts, usually >> 1 mg/g dry wt of tissue) typically cannot be supplied in sufficient quantity through the atmosphere (except for carbon and oxygen).

Deficiency
Low levels or the absence of a particular essential element will result in specific deficiency symptoms in a given plant species. These deficiency symptoms can be useful for determining what roles(s) these elements play in the plant. Colors, organ or tissue shapes, or accumulation of unusual products are examples of symptoms that may be clues. Whether the deficiency symptoms first appear on the youngest or the oldest portions of the plant also can provide clues about the mobility and thus the identity of the elements. Plants can remobilize some elements that are in short supply and transport them to actively growing (younger) regions of the plant. Symptoms that first appear on older
portions of the plant such as fully expanded leaves are indicative of a **mobile element**. Deficiency symptoms that first appear in younger regions of the plant are indicative of a **non-mobile element**. A plant cannot remobilize these elements when they are in short supply and therefore requires a consistent supply of these elements to actively growing regions.

**Hydroponics**

Deficiency symptoms can best be studied using a water culture system (**hydroponics**), where the presence or absence of essential mineral elements can be controlled precisely (at least as precisely as the purity of our chemicals and glassware will allow.) In addition, hydroponics allows the researcher to observe deficiency symptoms that occur in the roots, which cannot be observed easily in soil-grown plants. In natural (or agricultural) growing situations, rarely is a nutrient *completely* absent, but knowing what complete deficiency looks like provides a basis for understanding the role of the nutrient in plant growth and development and provides a comparison for determining deficiencies that are not as severe.


**AFTER** you complete the exercise on the following page, answer the following **questions**:

1. Why are hydroponic systems so useful when studying plant mineral nutrition?

2. Some nutrient deficiency symptoms show up in younger parts of the plants, some in the older, and some throughout. Why is there a difference? (Are there properties of the nutrients or their use in the plant that could explain differences? Are there different demands in younger vs. older plant parts?)

3. Some elements are regarded as beneficial although not essential. What is the difference between these two categories? What might be an example of a beneficial element (look on the internet)?
Demonstrations of plants grown in mineral deficient conditions
Observe plants that have grown in hydroponic solutions completely lacking specific nutrients. Table 1 gives terminology commonly used for plant symptoms. Record your observations in Table 2. Note deficiency symptoms such as chlorosis of leaves and stems, necrosis of leaves, buds, roots, etc. Also note where on the plant deficiency symptoms first appear (the youngest vs. the older leaves, etc.), as this information will be very useful in differentiating among deficiencies of some elements that give similar symptoms. Compare plants in the nutrient deficient treatments with the control treatments grown in the complete medium and in distilled water. Once you have made initial observations, ask your TA for the table of deficiency symptoms so that you can compare your observations with those commonly associated with particular mineral deficiencies. If the symptoms differ, note the nature of these differences. What might explain these differences? We will likely discuss this as a group.

Table 1. Symptom terminology.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>General yellowing of leaf tissue</td>
<td>Chlorosis</td>
</tr>
<tr>
<td>Spotted yellowing of leaf tissue</td>
<td>Chlorotic spots</td>
</tr>
<tr>
<td>Mosaic patterned yellowing of leaf tissue</td>
<td>Mottling</td>
</tr>
<tr>
<td>Yellowing between but not on veins</td>
<td>Interveinal chlorosis</td>
</tr>
<tr>
<td>Complete loss of color of leaf tissue (whitening)</td>
<td>White chlorosis</td>
</tr>
<tr>
<td>Reddening of leaf veins (often visible on leaf underside)</td>
<td>Purple, red, anthocyanin accumulation</td>
</tr>
<tr>
<td>Other discoloration</td>
<td>Yellow-green, deep blue-green</td>
</tr>
<tr>
<td>Curling or twisting of leaves</td>
<td>Epinasty</td>
</tr>
<tr>
<td>Death of plant tissue</td>
<td>Necrosis (necrotic spots, interveinal necrosis)</td>
</tr>
<tr>
<td>Loss of turgidity of leaf or stem</td>
<td>Wilting</td>
</tr>
<tr>
<td>Less growth in stem length than control</td>
<td>Stunting</td>
</tr>
<tr>
<td>Production of roots along stem</td>
<td>Adventitious root formation</td>
</tr>
<tr>
<td>Other symptoms to note (no specific terms):</td>
<td></td>
</tr>
<tr>
<td>• Exaggerated length of stem</td>
<td></td>
</tr>
<tr>
<td>• Thickening of stem or roots</td>
<td></td>
</tr>
<tr>
<td>• Death of meristematic tissue of root or stem</td>
<td></td>
</tr>
<tr>
<td>• Premature loss of leaves or failure of leaves to expand</td>
<td></td>
</tr>
</tbody>
</table>

* Record your observations in Table 2.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
<td></td>
</tr>
<tr>
<td>Distilled water</td>
<td></td>
</tr>
<tr>
<td>-K</td>
<td></td>
</tr>
<tr>
<td>-Ca</td>
<td></td>
</tr>
<tr>
<td>-Mg</td>
<td></td>
</tr>
<tr>
<td>-N</td>
<td></td>
</tr>
<tr>
<td>-P</td>
<td></td>
</tr>
<tr>
<td>-S</td>
<td></td>
</tr>
<tr>
<td>-Fe</td>
<td></td>
</tr>
</tbody>
</table>