Physiological Dynamics in Animals & Plants – Lecture 6 – Plant Nutrition

I. The body of a herbaceous plant contains a small percentage of mineral nutrients, a larger percentage of carbon, and is 80-85% water.

A. Water and nutrients come from the soil; carbon is from the air.

B. Wet weight vs. dry weight

C. 95% of the dry weight is organic compounds; the other 5% is inorganic substances.

II. More than 50 elements can be identified by inorganic analysis of plants, but not all inorganics are essential for growth.

A. Inorganic substances required for growth are called essential nutrients.

1. Most plants require 17 essential nutrients.

2. The essential nutrients have been identified by hydroponic culture.

3. Those required in larger amounts are called "macronutrients"; those required in "trace" amounts are called "micronutrients".

a. The nine required macronutrients include CHNOPS; the others are potassium, calcium, and magnesium.

b. Micronutrients are often metals that function as enzyme cofactors.

4. Nutrient deficiencies can be diagnosed and treated by methods like atomic absorption spectrometry; the most common ones are lack of nitrogen, potassium, and/or phosphorous.

III. Mineral nutrients come from the soil.

A. Topsoil = fragmented rock, living organisms, and humus.

B. Rock fragments = sand, silt, and clay

1. Soils with roughly equal amounts = loams

C. Organisms of topsoil include: bacteria, fungi, algae, protists, insects, earthworms, nematodes and plant roots.

D. Humus is decaying organic material.

E. Clay particles are negatively charged and bind cations such as potassium, magnesium, and calcium ions.

1. These ions are removed by secretion of protons from plant roots in a process called cation exchange.

F. Soil may need to be managed for a sustainable agriculture.

1. Minerals like nitrogen, phosphorus, and potassium may need to be replaced with fertilizers.

2. Soil pH may need to be adjusted.

3. Topsoil can be lost to erosion and to over-irrigation.

IV. Even though nitrogen exists in both oxidized and reduced forms in the soil and is 80% of the atmosphere, it is the element that most often limits plant growth.

A. World-wide, the single most common form of malnutrition is protein deficiency.

B. Most of the world's population is vegetarian and must depend on plants for protein; many plants have low protein content and many lack certain amino acids that are essential for animal growth.

C. Nitrogen-fixing bacteria convert N_2 to ammonium ion (NH_4^+).

1. $N_2 + 8\ e^- + 8\ H^+ + 16\ ATP \rightarrow 2\ NH_3 + H_2 + 16\ ADP + 16\ P_i$

D. Ammonifying bacteria convert nitrogen-containing compounds of decaying organic material NH_4^+.

E. Nitrifying bacteria convert NH_4^+ to nitrate ion (NO_3^-).

F. NO_3^- can either be converted to N_2 by denitrifying bacteria or can be absorbed by roots, where it is converted to NH_4^+.

G. Nitrogen fixation requires anaerobic conditions.

1. Oxygen irreversibly inactivates nitrogenase, the nitrogen-fixing enzyme.

2. Free-living nitrogen-fixing bacteria create their own internal anaerobic environments: e.g., cyanobacteria live in heterocysts and lack PSII, *Azotobacter* has high rates of respiration.

3. Many plants have symbiotic bacteria (genus *Rhizobium*) that live in anaerobic nodules on their roots; these plants are called legumes and include – beans, peanuts, soybeans, alfalfa, clover, and peas.

   a. Plants and bacteria co-operate in the synthesis of leghemoglobin, an analog to animal hemoglobin that regulates oxygen levels and release in the nodule in a way that is appropriate for the high respiration rates of *Rhizobium sp*.

   b. Interactions of roots with a species-specific *Rhizobium* lead to nodule formation.

   c. Roots secrete flavenoids that turn on a cluster of bacterial genes called *nod* genes. These genes produce enzymes that catalyze formation of Nod factors that are secreted by the bacterial cells. Nod factors are similar structurally to chitin.

d. Nod factors stimulate the formation of infection threads and proliferation of cortical cells to form the nodule.

4. It may be possible to "genetically engineer" nitrogen fixation.

V. Mycorrhizae are symbiotic associations of roots and fungi that enhance plant nutrition.

A. Fungi increase water and nutrient absorption and secrete growth factors that stimulate roots to grow and branch and antibiotics that protect roots from infection.

B. Ectomycorrhizzae cover the surfaces of roots.

C. Endomycorrhizae grow into the apoplasts of roots and invaginate the plasma membranes of root cells.

1. Branched, knot-like invaginations are called arbuscles.

2. Like root nodules, arbuscles form after activation of *nod* genes.

3. The plant hormone cytokinin can activate *nod* genes.

VI. Some plants are parasitic; others are carnivorous.

A. Epiphytes should not be confused with parasitic plants.