Plant Nutrition

Introduction

Plants, just like humans, have a number of nutrient requirements, and exhibit a variety of deficiency symptoms when essential nutrients are missing in their “diet”. Carbon, hydrogen, and oxygen comprise about 98% of the fresh weight of a plant, but several other elements, called the **essential inorganic nutrients**, are needed for plant growth. Six of these: nitrogen, potassium, calcium, phosphorus, magnesium, and sulfur, are required in relatively large amounts and are known as **macronutrients**. The remaining essential inorganic nutrients, including iron, chlorine, copper, manganese, zinc, molybdenum, and boron, are required in very small, or trace amounts (as little as a few parts per million), and are known as **micronutrients**.

Plants can manufacture the bulk nutrients (carbohydrates, proteins and lipids) from inorganic materials, and do not require these substances as a part of their "diets". Their required nutrients are needed to synthesize their cells' needs and to manufacture the bulk nutrients. If plants do not get their needed nutrients, they will have growth problems just like we do.

Deficiencies of one or more of the essential nutrients result in abnormal plant growth and development. Plants suffering from the deficiencies exhibit deficiency symptoms, such as

- A pale green or yellow color, which is known as chlorosis
- Localized death of tissues, called necrosis
- Abnormal anthocyanin formation
- Stunting of growth.

The specific deficiency symptoms depend on the function of the nutrient, and the mobility of the nutrient within the plant. Plants lacking nitrogen or phosphorus often produce anthocyanins in stems and leaves. Necroses at leaf tips and margins are symptoms of potassium deficiency. Magnesium, for example, is required for chlorophyll synthesis, so plants lacking magnesium are chlorotic, or yellowish. Nutrients that are mobile will be translocated from older parts of plants to newer growth, and deficiency symptoms of those nutrients will appear in older growth first. Deficiencies of non-mobile nutrients will appear in new growth. Calcium deficiency is exhibited in new growth. The terminal bud usually dies.

In order to determine which inorganic nutrients or combination of inorganic nutrients a plant needs for growth, plants can be grown in solution cultures, a technique known as hydroponics. When we want to know how one mineral affects plant growth, that element is omitted from the culture solution and a nonessential mineral is substituted so that the relative amounts of the other elements are not altered.

Exercise

Today you will observe the effects of some nutrient deficiencies on plant growth. Tomato (*Lycopersicon esculentum*) seedlings were washed clean of soil, and rinsed in distilled water. They were transferred to the following solution cultures four weeks ago:

1. Solution containing all essential inorganic nutrients
2. Solution lacking nitrogen
3. Solution lacking phosphorus
4. Solution lacking magnesium
5. Solution lacking potassium
6. Solution lacking calcium
7. Solution lacking sulfur
8. Solution lacking iron
9. Distilled water

Examine the experimental (nutrient-deficient) plants and compare them with the control plant. Many of the plants undoubtedly will look abnormal in comparison with the control. Record the deficiency symptoms shown by the treated plants on the chart provided. Use the Key to Plant-Nutrient Deficiency Symptoms, which follows, to help describe the symptoms. As you look at and describe the deficiency symptoms shown by the respective plants, think about and record what functions the missing nutrient normally has in plant growth.

Plant Deficiency Symptoms

Cultures	Observations
Control	
Lacking Nitrogen	
Lacking Phosphorus	
Lacking Magnesium	
Lacking Potassium	
Lacking Calcium	
Lacking Sulfur	
Lacking Iron	
Distilled Water	

Key to Plant Nutrient-Deficiency Symptoms

I. Effects general on whole plant or localized on older, lower leaves..2
  2. Leaves light green. Uniform chlorosis of older leaves, which may die and turn brown. Abnormal production of anthocyanins in stems and leaves. Stems with greatly reduced terminal growth..Nitrogen
  2 Leaves dark green. Stunted growth. Abnormal production of anthocyanins resulting in red and purple colors. Death of older leaves. Stems weak and spindly...……........................……….....Phosphorus

II. Effects mostly localized on older, lower leaves..3
  3. Older leaves chlorotic, initially interveinal, beginning at tips of leaves. Margins and tips of leaves may turn or cup upward. If severe, all leaves become yellow or white. Older leaves may drop off..............….............................Magnesium
  3. Older leaves mottled, with necrosis of leaf tips and margins. Leaves may curl and crinkle. Internodes abnormally short and stems weak, sometimes with brown streak..Potassium

III. Effects localized on new leaves ....…..............................4
  4. Terminal bud dies. Tips and margins of youngest leaves necrotic and then buds. Initially young leaves pale green with hooked tips, as well as being deformed.............Calcium
  4. Terminal bud remains alive...………........5
    5. Leaves light green (never yellow or white), beginning with younger ones. Veins lighter than interveinal areas. Necrotic spots may appear but not common...………....Sulfur
    5. Leaves chlorotic, beginning with younger ones. Veins remain green, except in case of prolonged, extreme deficiency..Iron

Plant Nutrients and their Functions

Macronutrients

Element	Form	Source	% Dry Weight	Function
Carbon	CO_2	Air	45	Major element in organic molecules; photosynthesis
Oxygen	O_2	Air	45	Major element in organic molecules; cellular respiration
Hydrogen	H_2O	Soil	6	Major element in organic molecules
Nitrogen	NO_3^- or NH_3^+	Soil	1.5	Major element in proteins, nucleic acids, and chlorophyll
Potassium	K^+	Soil	1	Principal positive ion inside cells; control of stomatal opening and closing; enzyme activation
Phosphorus	H_2PO_4 or $HPO_4^=$	Soil	0.2	Major element in nucleic acids, phospholipids, and electron carriers in chloroplasts and mitochondria
Calcium	Ca^{++}	Soil	0.5	Component of adhesive compounds in cell walls; important in control of membrane permeability; enzyme activation
Magnesium	Mg^{++}	Soil	0.2	Component of chlorophyll; enzyme activation; ribosome stability
Sulfur	$SO_4^=$	Soil	0.1	Component of proteins and many coenzymes

Micronutrients

Element	Form	Source	% Dry Weight	Function
Iron	Fe^{++} or Fe^{+++}	Soil	0.01	Needed for synthesis of chlorophyll; component of many electron carriers
Chlorine	Cl^-	Soil	0.01	Required for photosynthesis
Manganese	Mn^{++}	Soil	0.005	Required for photosynthesis; enzyme activation
Molybdenum	$MoO_4^=$	Soil	0.00001	Required for nitrogen metabolism
Copper	Cu^{++}	Soil	0.0006	Enzyme activation; component of electron carriers in chloroplasts
Boron	Bo^{---}	Soil	0.002	Involved in sugar transport
Zinc	Zn^{++}	Soil	0.002	Enzyme activation; protein synthesis; hormone synthesis