BOTANY, PLANT PHYSIOLOGY AND PLANT GROWTH
Lesson 9: PLANT NUTRITION

Segment One – Nutrient Listing

Plants need 17 elements for normal growth. Carbon, oxygen, and hydrogen are found in air and water. Nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur are found in the soil. The above nine elements are used in relatively large amounts by the plant and are called macronutrients. There are eight other elements that are used in much smaller amounts and are called micronutrients or trace elements. The micronutrients, which are found in the soil, are listed in the table below. All 17 elements, both macronutrients and micronutrients, are essential for plant growth.

MACRONUTRIENTS		
Found in air and water	carbon	C
	oxygen	O
	hydrogen	H
Primary Elements	nitrogen	N
	phosphorus	P
	potassium	K
Secondary Elements	calcium	Ca
	magnesium	Mg
	sulfur	S
MICRONUTRIENTS	iron	Fe
	manganese	Mn
	copper	Cu
	zinc	Zn
	boron	B
	molybdenum	Mo
	chlorine	Cl
	cobalt	Co

The terms primary, secondary, and micronutrients actually refer to the amount of these elements needed by the plants rather than their relative importance. All 17 elements are essential; this is an important concept when learning plant nutrition. The term "essential" means if even ONE nutrient is missing, you have a critical situation. The plant will stop growing, and will die eventually. Think of all 17 elements as a chain of 17 links; if you lose one link in the chain, it has no power.

Seldom do you need to be concerned about the supply of carbon, oxygen, and hydrogen, even though large amounts of each are used in plant growth and development. About 94% of the dry weight of a healthy plant is composed of carbon, oxygen, and hydrogen. This large percentage is attributed to the amount of carbohydrates manufactured by the plant. Although the air around us usually provides all the oxygen and carbon needed by plants, carbon as carbon dioxide may become a limiting factor in a greenhouse in winter. The plant uses carbon dioxide in photosynthesis and if the supply is limited, growth can be greatly retarded especially in enclosed areas such as greenhouses.

Water supplies the plant with hydrogen as well as being another excellent source of oxygen. In addition, many of the secondary and micronutrients are sometimes supplied by certain water sources. Water may also be a source of certain elements that are detrimental to plant growth such as sodium, which can be toxic to plants when present in rather small amounts. For this reason, you should familiarize yourself with the chemical analysis of your water source.

Segment Two - How Plants Absorb Nutrients

Most of the nutrients that a plant needs are dissolved in water and then absorbed from the soil by roots. Ninety-eight percent of these plant nutrients are absorbed from the soil solution and only about 2% are actually extracted from the soil particles by the root. Most of the nutrient elements are absorbed as charged ions or pieces of molecules (which are the smallest particle of a substance that can exist and still retain the characteristics of the substance). Ions may be positively charged cations or negatively charged anions. Positive and negative are equally paired so that there is no overall charge. For example, nitrogen may be absorbed as nitrate ($N0_3$-) which is an anion with one negative charge. The potassium ion (K+) is a cation with one positive charge. Potassium nitrate ($KN0_3$) would be one nitrate ion and one potassium ion. However, calcium nitrate ($Ca(N0_3)_2$) would have two nitrate ions and one calcium ion because the calcium cation has two positive charges.

The balance of ions in the soil is very important. Just as ions of the opposite charge attract each other, ions of similar charges compete for chemical interactions and reactions in the environment. Some ions are more active than others or can compete better. For example, both calcium (Ca++) and magnesium (Mg++) are cations with two charges; however, magnesium is more active. If both are in competition to be absorbed, the magnesium will be absorbed. This explains why the results of a soil test may indicate that while there is sufficient calcium in the soil the plant may still exhibit a calcium deficiency because of an excess of the more active magnesium. What may be expressed as a deficiency in one micro nutrient may really be caused by an excess of another.

In order for the ions to be easily absorbed, they must first be dissolved in the soil solution. Some combinations of ions are easily dissolved, such as potassium nitrate. When other ions combine, they may precipitate or fall out of the solution and thus become unavailable to the plant. Many of the micro nutrients form complex combinations with phosphorous and calcium and precipitate out of the soil solution so the nutrients cannot be easily taken up by the plant. The pH, which is a measurement of acidity or alkalinity, greatly affects these chemical reactions. If the soil pH is extremely high (alkaline), many of the micro nutrients precipitate out of the solution and are unavailable to the plant. When the soil pH is extremely low (acidic), some of the micro nutrients become extremely soluble and ion levels may become high enough to injure the plant. The effect of pH varies with the ion, the types of ions in the soil, and the type of soil. Therefore, not only is the amount of the nutrient important, but also the soil pH. The water and oxygen in the soil must also be in available form. Since nutrients are taken up with water, there must be sufficient water for the plant to absorb. Water is taken into the plant both passively and actively. Water that is taken in passively requires no energy output by the plant. It flows through the plant due to differences in concentration between the soil solution, the cells, and also the atmosphere. Water that is actively absorbed requires energy from the plant. If there is no oxygen available, sugar cannot be burned to produce energy and therefore the nutrients cannot be absorbed.

Anything that lowers or prevents the production of sugars in the leaves can lower nutrient absorption. If the plant is under stress, due to low light or extremes in temperature, nutrient deficiency problems may develop. The stage of growth or how actively the plant is growing may also affect the amount of nutrients absorbed. Many plants go into a rest or dormancy during part of the year. During this period, few nutrients are absorbed. Plants may also absorb different nutrients just as flower buds begin to develop.

Nutrients transported from the root to the cell by the vascular system move into the cell across a cell membrane. There are three different ways this happens. First, an entire molecule or ion pair may move through the membrane. If the cell is using energy or active transport to absorb the ions, then only one of the ions of the pair is pulled into the cell. The other will follow to keep the number of positive and negative charges even. Most anions (negative ions) are actively absorbed.

The second way of keeping the charges inside the cell balanced and absorbing a new ion is to exchange one charged ion for another of the same charge. The hydrogen ion (H^+) is often released from the cell so that the cell can absorb another positive ion such as the potassium ion (K^+). Since this is a simple exchange (or passive), absorption energy may not be required. Cations or positive ions may be passively absorbed by this method.

Both of the methods mentioned above may be passive or active. However, the third method, the carrier system, is always active absorption, requiring energy. Scientists have discovered that within the cell membrane there are specialized chemicals that act

as carriers. The carrier, through chemical changes, attracts an ion outside the cell membrane and releases it inside the cell. Once the ion is inside the cell, it is attached to other ions so that it does not move out of the cell. Complex chemical reactions are involved in the entire process. Although nutrients can be absorbed passively, research has shown that active absorption must take place if the plant is to grow and be healthy. The factors we discussed earlier about absorption by the root are also true for absorption by the cell. Here is a quick review of some of the factors that affect nutrient absorption: type of ion, pH, solubility of ion pairs, water, soil oxygen, sugar supply, plant stress and temperature.

Foliar Absorption: A Special Case

Under normal growing conditions, plants absorb most nutrients, except carbon, hydrogen and oxygen, from the soil. However, leaves can also absorb some nutrients if a dilute solution is sprayed on them. The factors that affect absorption by the cell are still important because the nutrient must enter the cell to be used by the plant. Care must be taken that the concentration of the nutrient solution is not too high or the leaf will be injured. Also, the leaf is covered by a thin layer of wax called the cuticle that the nutrient must get around or through before it can enter the cell.

Segment Three – Nutrient Summaries

MACRONUTRIENTS

NITROGEN (N)

Nitrogen Function in Plants:

- Produces vegetative growth
- Gives dark green color to plants
- Increases yields of foliage, fruits and seeds
- Increases protein quantity of food crops

Nitrogen Deficiency Symptoms:

- Yellowing (chlorosis) of vegetative growth
- Slow and dwarfed growth
- Symptoms appear first on older growth
- Poor root system

Nitrogen Sources:

- Organic matter in soil
- Animal manures
- Legumes
- Commercial fertilizers

Nitrogen Movement in Soil:

- In the ammonium form, nitrogen moves very little after it is absorbed by the clay particle.
- In the nitrate form, nitrogen moves with soil moisture; consequently, nitrate nitrogen will be more apt to leach on sandy soils than in heavier clays and clay loams since water movement will be greater.

PHOSPHORUS (P)

Phosphorus Function in Plants:

- Stimulates early root formation
- Gives rapid and vigorous start to plants
- Hastens maturity
- Stimulates blooming and aids in fruit and seed formation
- Improves winter hardiness

Phosphorus Deficiency Symptoms:

- Stunted growth and weak root system
- Delayed maturity
- Low yield of flowers, fruit and seed
- Purpling of leaves, stems and branches in plants

Phosphorus Sources:

- Native soil phosphorus
- Animal manures
- Decomposing plant residues
- Rock phosphate
- Commercial fertilizers

Phosphorus Movement in Soil:

- Phosphorus moves very little from its point of application

POTASSIUM (K)

Potassium Function in Plants:

- Imparts increased vigor and disease resistance
- Produces strong, stiff stalks
- Improves quality of fruit and seed
- Essential to the formation and transfer of starches and sugars
- Imparts winter hardiness in plants

Potassium Deficiency Symptoms:

- Reduced growth
- Shortened internodes
- Marginal burn or scorch
- Necrotic (dead) spots on the leaf
- Reduction of lateral breaks and tendency to wilt readily.

Potassium Sources:

- Native soil potassium
- Animal manures
- Decomposing plant residues
- Commercial fertilizers

Potassium Movement in Soil:

- Potassium will move very little in heavy-textured clays and clay loams. It will move with soil moisture in lighter-textured sands and sandy loams.

MAGNESIUM (Mg)

Magnesium Function in Plants:

- Magnesium is present in chlorophyll, the green pigment in plants. It aids in the formation of certain phosphorus compounds. It acts as the "catalyst" or "activator" for certain plant processes.

Magnesium Deficiency Symptoms: *Mg is commonly deficient in foliage plants because it is leached out and not replaced.*

- Reduction in growth
- Marginal chlorosis
- Interveinal chlorosis (yellow between the veins) in some species

Magnesium Sources:

- If an increase in pH is also desired, use dolomitic limestone (dolomite). When you do not want to raise pH, use magnesium sulfate (Epsom salts) or magnesium oxide.

Magnesium Movement in Soil:

- Leaches from soil.

CALCIUM (Ca)

Calcium Function in plants:

- Ca is important in pH control and is rarely deficient if the correct pH is maintained.
- Calcium is a part of a compound in the cell wall. Adequate calcium in the plant improves plant vigor and is necessary for growth of new plant parts.

Calcium Deficiency Symptoms:

- Inhibition of bud growth
- Death of root tips
- Cupping of maturing leaves
- Weak growth
- Blossom end rot of many fruits
- Pits on root vegetables

Calcium Sources

- Calcium is supplied primarily in the form of limestone. It can also be supplied as gypsum or other calcium-containing materials. Some mixed fertilizers will contain calcium.

Calcium Movement in Soil:

- Moderately leachable in soil

SULFUR (S)

Sulfur Function in plants:

- Sulfur is present in certain plant proteins. It affects cell division and formation.

Sulfur Symptoms of Deficiency:

- S is often a carrier of impurity in fertilizers and rarely deficient. It may also be absorbed from the air and is a by-product of combustion. Symptoms are a general yellowing of the affected leaves or the entire plant.

Sulfur Sources:

- Sulfur can be supplied as elemental sulfur, gypsum (calcium sulfate), iron sulfate, aluminum sulfate or sulfuric acid. Keep in mind that iron sulfate, aluminum sulfate or sulfuric acid will all lower soil pH. Sulfur is present in adequate quantities in many fertilizers.

Sulfur Movement in Soil:

- Leachable

MICRONUTRIENTS

Please remember, all 17 elements are essential - if even ONE nutrient is missing, you have a critical situation. The plant will stop growing and will die eventually. Think of all 17 elements as a chain of 17 links; if you lose one link in the chain, it has no power, even if that link is a micronutrient, or "trace" mineral. The term "trace" means that the elements are required in very small amounts; it does not imply that the importance is minimal.

Sufficient micronutrients are nearly always present in Minnesota soils, but may or may not be present in soilless media typically used to produce container grown plants.

Today we'll discuss only one micronutrient, iron.

IRON (Fe)

Iron Function in Plants:

- Chlorophyll synthesis

Iron Symptoms of Deficiency: *The most important deficiency symptom to the professional nurseryman is iron deficiency, especially in areas where alkaline soils tend to be extremely low in available iron.*

- Interveinal chlorosis, primarily on young tissue. The symptoms of iron chlorosis are progressive, starting with a gradual loss of green color, then turning to a yellow with the veins remaining green. In extreme cases the younger leaves may turn almost white. The color change is due to loss of chlorophyll as iron is needed in the production of this green chemical compound.

Iron Sources:

- Iron can be supplied as iron sulfate (copperas) or as iron chelate; the type of chelate needed depends upon the soil pH.

OTHER MICRONUTRIENTS

The other micronutrients are boron (B), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), chlorine (Cl), and cobalt (Co).

Micronutrients can be supplied individually as a specific compound or they can be applied as a mixture of the salts or chelated forms.

CAUTION:
Excessive amounts of micronutrients can kill plants. Be sure to follow recommendation of manufacturers or contact your County Extension Agent.

09_PlantNutrition_Reading.pdf