TECHNICAL PAPER

PLANT NUTRITION AND DEFICIENCIES

RX GREEN TECHNOLOGIES

PLANT NUTRITION ESSENTIAL ELEMENTS

Plants require light, water, minerals, oxygen, carbon dioxide, and a suitable temperature to grow. These absolute growth requirements must be available within appropriate ranges and in balance with others for optimum growth to occur.

A total of 17 elements are known to be required for plants to grow and reproduce normally. The elements are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), chlorine (Cl) and nickel (Ni).

The atmosphere provides C and O, and H is provided by water. Together, these three elements are combined into simple organic compounds during the process of photosynthesis. The other 14 elements are supplied mostly from the soil including native soil fertility, residual lime and fertilizer, or from current lime and fertilizer applications. Other less important sources of plant nutrients are well water (Ca, Mg, S, Fe) and the atmospheric deposition (S and N).

The macronutrients (N, P, K, Ca, Mg, S) are those found in comparatively high concentrations in plants and are measured in percent (%). Micronutrients (Fe, B, Mn, Cu, Zn, Mo, Cl) are present in comparatively minute concentrations in plants and are measured in parts per million (ppm).

ROLES OF ESSENTIAL ELEMENTS IN PLANT GROWTH

Each of the essential elements has at least one specifically defined role in plant growth so that plants fail to grow and reproduce normally in the absence of that element. However, most of the essential elements have several functions in the plant. A basic summary of some of these functions follows:

CARBON: from carbon dioxide (CO_2) in the atmosphere, is assimilated by plants in the photosynthetic process. It is a component of organic compounds such as sugars, proteins, and organic acids. These compounds are used in structural components, enzymatic reactions, and genetic material, among others. The process of respiration degrades organic compounds to provide energy for various plant metabolic processes.

OXYGEN: derived from CO_2, also is a part of organic compounds such as simple sugars. Atmospheric oxygen is necessary for all oxygen-requiring reactions in plants including nutrient uptake by roots.

HYDROGEN: derived from water (H_2O) also is incorporated into organic compounds in the photosynthetic process. Hydrogen ions are involved in electrochemical reactions and maintain electrical charge balances across all membranes.

PHOSPHORUS: used in several energy transfer compounds in plants. A very important function for P is its role in nucleic acids, the building blocks for the genetic code material in plant cells.

POTASSIUM: plays a major role as an activator in many enzymatic reactions in the plant. Many enzymes responsible for cellular reactions require K as a co-factor. Another role for K in plants occurs in special leaf cells called guard cells found around the stomata. By regulating the turgor pressure in the guard cells, the degree of opening of the stomata is controlled and thus the level of gas and water vapor exchange through the stomata is regulated. Turgor is largely controlled by K movement in and out of guard cells.

NITROGEN: found in many compounds including chlorophyll (the green pigment in plants), amino acids, proteins, and nucleic acids. A large part of the plant body is composed of N-containing compounds.

SULFUR: a component of sulfur-containing amino acids such as methionine. Sulfur also is contained in the sulfhydryl group of certain enzymes.

CALCIUM: a component of calcium pectate, a constituent of cell walls. In addition, Ca is a co-factor of certain enzymatic reactions. Recently, it has been determined that Ca is involved in the intimate regulation of cell processes mediated by a molecule called calmodulin.

MANGANESE: functions in several enzymatic reactions that involve the energy compound adenosine triphosphate (ATP). Manganese also activates several enzymes and is involved in the processes of the electron transport system in photosynthesis.

COPPER: a constituent of a protein, plastocyanin, involved in electron transport in chloroplasts, and copper is part of several enzymes, called oxidases. Zinc is involved in the activation of several enzymes in the plant and is required for the synthesis of indoleacetic acid, a plant growth regulator.

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MOLYBDENUM: a constituent of two enzymes involved in N metabolism. The most important of these is nitrate reductase, the enzyme involved in the reduction of nitrate-N to ammoniacal-N.

CHLORINE: plays a possible role in photosynthesis and might function as a counter ion for K fluxes involved in cell turgor.

NICKEL: now recognized by plant scientists as an essential element for plants. It is involved in the enzyme urease and is a part of several other enzymes involved in plant metabolism.

MOBILITY OF ESSENTIAL ELEMENT WITHIN THE PLANT

Approximately 80% of all nutrients absorbed by roots are translocated to the shoots. When nutrient supply is abundant, they are delivered directly to the shoots often within minutes of absorption. Accordingly, plants may absorb and accumulate essential elements in far greater quantities than are necessary for immediate use. These accumulated elements are available for use later in the plant life cycle when demands are high for fruit production and/or when nutrient supply from the soil is restricted. The ability of an element to move from one plant part to another is called mobility and the process is known as retranslocation. The mobility of the essential elements in plants is shown in the table below.

Table 1. Mobility of essential elements in plants. Mobility reflects the ability of an element to be relocated within the plant under deficient supply.

HIGH	INTERMEDIATE	LOW
Nitrogen (NO_3^- or NH_4^+)	Iron	Calcium
Phosphorus	Manganese	Boron
Potassium	Zinc	
Magnesium	Copper	
Sulfur	Molybdenum	
Chlorine Nickel		

The mobility of an element influences the location where deficiency symptoms (see the following section) are likely to be observed on the plant. For example, Mg deficiency symptoms occur on the oldest, generally lower leaves, because Mg is retranslocated to the younger leaves of the plant. Conversely, Ca deficiencies occur at the growing point or in storage organs like roots and fruits because Ca, being immobile, is not retranslocated to these sites during Ca stress conditions.

NUTRIENT DEFICIENCY SYMPTOMS

Vegetable plants exhibit deficiency symptoms that are characteristic for each element, and are, therefore useful for diagnostic purposes. However, in many cases, the symptoms may be masked by symptoms of other nutritional disorders, those caused by unfavorable environment, or stress caused by plant pests. In these situations, plant tissue analysis provides useful information to complement and confirm visual diagnosis. Nutritional disorders of vegetables rarely occur in well managed crops. The general symptoms associated with deficiencies and excesses of the essential elements follow:

NITROGEN: absorbed as NH_4+ and NO_3-. It is a mobile element in the plant and deficiency symptoms therefore show up first on the lower leaves. Symptoms consist of a general yellowing (chlorosis) of the leaves. On tomatoes, there might be some red coloration to the petioles and leaf veins. If the problem persists, lower leaves will drop from the plant.

Healthy plant leaves contain between 2.0 and 5.0% N on a dry weight basis. Deficiencies of N show up most often where errors are made in fertilizer management resulting in insufficient N supply to the crops. More often in commercial vegetable production, there is a problem from excess N application. Plants receiving excess N usually are lush and tender with larger and darker-green leaves. Excess N (especially in warm and sunny conditions) can lead to "bullish" tomato plants. These plants produce thick, leathery leaves that curl under in dramatic fashion producing compact growth.

PHOSPHORUS: typically absorbed as H_2PO_4- by an active (energy-requiring) process. P is very mobile in the plant. Deficiencies therefore show up on the older leaves of the plant because P is translocated out of these leaves to satisfy the needs of new growth. P deficiency shows up as stunting and a reddish coloration resulting from enhanced display of anthocyanin color pigments. Deficient leaves will have only about 0.1% P in the dry matter. Normal, most-recently matured leaves of most vegetables, will contain 0.25 to 0.6% P on a dry weight basis. Excess P in the root zone can result in reduced plant growth probably as a result of P retarding the uptake of Zn, Fe, and Cu.

POTASSIUM: absorbed in large quantities by an active uptake process. Once in the plant, K is very mobile and is transported to young tissues rapidly. Deficiency symptoms for K show up first on lower leaves as flecking or mottling on the leaf margins. Prolonged deficiency results in necrosis along the leaf margins and the plants can become slightly wilted. Deficient plant leaves usually contain less than 1.5% K. Deficiencies of K lead to blotchy ripening of tomatoes where fruits fail to produce normal red color in some areas on the fruit.

CALCIUM: unlike most elements, is absorbed and transported by a passive mechanism. The transpiration process of plants is important in the transport of Ca. Once in the plant, Ca moves toward areas of high transpiration rate, such as rapidly expanding leaves.

Most of the uptake of Ca occurs in a region on the root just behind the root tip. This has practical importance for vegetable culture because it means that growers must keep healthy root systems with numerous actively growing root tips. Root diseases and nematodes may severely limit Ca uptake by the plant.

Calcium is immobile in the plant, therefore, deficiency symptoms show up first on the new growth. Deficiencies of Ca cause necrosis of new leaves or lead to curled, contorted growth. Examples of this are tipburn of lettuce and cole crops.

Blossom-end rot of tomato also is a calcium-deficiency related disorder. Cells of the tomato fruit deprived of Ca break down causing the well-known dark area on the tomato fruit. Sometimes this breakdown can occur just inside the skin so that small darkened hard spots form on the inside of the tomato while the outside appears normal.

On other occasions, the lesion on the outside of the fruit is sunken or simply consists of a darkening of tissue around the blossom area.

Since Ca movement in the plant is related to transpiration, environmental conditions that affect transpiration also affect Ca movement. Periods of high humidity can lead to tipburn of lettuce because the leaves are not transpiring rapidly enough to move adequate Ca to the leaf extremities.

Calcium concentrations in healthy, most-recently matured leaves will be from about 0.6 to 5.0%. Deficiencies, however, can occur temporarily given certain environmental conditions as previously discussed. Therefore, it is important to consider irrigation in the overall Ca fertilization program.

MAGNESIUM: absorbed by the plant in lower quantities than Ca. Unlike Ca, Mg is highly mobile in the plant and deficiencies first appear on the lower leaves. Deficiency symptoms consist of an interveinal chlorosis, which can lead to necrosis of the affected areas. On tomato leaves, advanced Mg deficiency leads to a mild purpling of the affected areas.

Magnesium is usually found in concentrations of 0.2 to 0.8% in normal leaves. Conditions that lead to deficiency are usually related to poorly designed fertilizer programs that supply too little Mg, or when Ca and/or K compete with Mg for uptake.

SULFUR: absorbed mainly in the form of sulfate (SO_4^{-2}) by a mechanism that is not well understood. Sulfur is somewhat mobile in the plant so deficiency symptoms are fairly evenly distributed on the plant but mostly on the upper leaves. Deficiency symptoms consist of a general yellowing of the leaves. Deficiencies of N and S appear somewhat similar but N deficiency occurs on the lower leaves whereas S deficiency occurs in the upper part of the plant.

Plant leaves usually contain between 0.2 and 0.5% S on a dry weight basis. This range is similar to that for P. Plants can generally tolerate quite high concentrations of S in the growing media. This is one reason for the wide use of Scontaining materials to supply nutrients such as Mg and the micronutrients, and explains why S deficiency is not very common in vegetable crops.

IRON: absorbed by an active process as Fe^{2+} or as iron chelates, which are organic molecules containing iron sequestered within the molecule. Uptake of Fe is highly dependent on the Fe form and adequate uptake depends on the ability of the root to reduce the pH nearby and reduce Fe^{3+} to Fe^{2+} for uptake. Iron chelates are soluble and aid in keeping Fe in solution for uptake. The uptake of the whole chelate molecule is low and usually Fe is removed from the chelate before uptake.

Iron is not mobile in plants and symptoms appear on the new leaves first. Symptoms consist of interveinal chlorosis that may progress to a bleaching and necrosis of the affected leaves. Usually, the chlorosis begins on the lower part of the leaflets and not at the tips. Normal leaves contain 30 to 150 ppm Fe on a dryweight basis.

Conditions that lead to Fe deficiency are inadequate concentrations of Fe in the soil solution or basic soil conditions (pH above 7.0). Fe deficiency is corrected by adding Fe to the fertilizer or by foliar sprays of Fe. Usually one or two sprays of 0.5 ppm Fe solution will correct a temporary Fe deficiency.

MANGANESE: absorbed as Mn^{2+} ions and uptake is affected by other cations such as Ca and Mg. Manganese is relatively immobile in the plant and symptoms of deficiency first appear on the upper leaves.

Deficiency of Mn resembles that of Mg, however Mn deficiency appears on the upper leaves of the plant. Manganese deficiency consists of interveinal chlorosis; however, the chlorosis is more speckled in appearance compared to Mg deficiency. Manganese deficiency also slightly resembles Fe deficiency of tomato however Mn deficiency appears as chlorotic speckling over most of the leaf while Fe deficiency usually appears first on the lower part of the leaflets.

Critical concentrations of Mn in leaves ranges from 20 to 100 ppm for most plants. High levels of Mn can be toxic to plants. Toxicity appears as marginal leaf necrosis in many plants. Concentrations of Mn on the order of 500 to 800 ppm can result in toxicity in many crops. Excess Mn in the soil solution can reduce uptake of Fe by the plant.

Situations that lead to deficiency are mostly related to inadequate Mn supply in the soil solution, from basic soil conditions, or to competition effects of other ions. Toxicity can occur from excess Mn supply especially when plants are in acidic soil. Solubility of Mn in the soil solution is increased by low pH.

ZINC: uptake is thought to be by an active process and can be negatively affected by high concentrations of P in the media. Zinc is not highly mobile in plants. Deficiency of Zn results in young leaves with interveinal chlorosis. Sometimes Zn deficiency will lead to plants with shortened internodes.

Healthy leaves contain about 25 to 150 ppm Zn. High levels of Zn can lead to toxicity where root growth is reduced and leaves are small and chlorotic. Zinc deficiency may occur in cold, wet soils, or in soil with a very high pH where Zn is rendered unavailable to the plant.

COPPER: absorbed by plants in very small quantities. The uptake process appears to be an active process and it is adversely affected by high Zn concentrations. Copper is not highly mobile in plants but some Cu can be translocated from older to newer leaves. The normal level of Cu in plants is on the order of 4 to 20 ppm. Copper deficiency on young leaves leads to chlorosis and some elongation of the leaves. Excess Cu, especially in acidic soil may be toxic to plants.

MOLYBDENUM: absorbed as molybdate (MoO_4^{-2}) and the uptake can be suppressed by sulfate. Normal tissue concentrations of Mo are usually less than 1 ppm.

A deficiency of Mo first appears on leaves that are intermediate in age and older. The leaves become chlorotic and the margins roll. Unlike other micronutrients, Mo deficiency occurs in acidic soil conditions.

BORON: uptake by plants is not well understood. Boron is not mobile in the plant and seems to have many uptake and transport characteristics in common with Ca. Boron deficiency affects the young growing points first, e.g., buds, leaf tips and margins, and root tips. Buds develop necrotic areas and leaf tips become chlorotic and eventually die. Tomato leaves and stems become brittle.

Healthy leaves contain 20 to 100 ppm B; levels higher than 150 ppm may lead to toxicity. Cole crops, beets, and celery have rather high B requirements, otherwise only small amounts of B are needed by plants and supplying excessive B from fertilizer or from foliar sprays can lead to toxicity.

CHLORINE: supplied for plant nutrition as the chloride ion and is required in very small amounts for normal plant growth. Chloride is involved in photosynthesis and functions as a counter-ion in maintaining turgor pressure in cells. Chlorine deficiency symptoms are not common but include wilting. The chloride ion is very common in the environment and is often found as a constituent in fertilizers; therefore, deficiency symptoms are rare. High concentrations of chloride in the nutrient solution can be toxic to plants in hydroponic culture.

NICKEL: required in small amounts by plants, 0.5 to 5.0 ppm Ni. Nickel is common in soil, and truly deficient soils have not be found. Deficiency symptoms include chlorosis similar to that of iron deficiency. Nickel deficiency also can be similar to zinc deficiency. These similarities in deficiencies make it difficult to diagnose true Ni deficiency in plants. A buildup of urea in leaf tips may occur in Ni-deficient plants.

The information contained within was an excerpt copied from a paper and research done by University of Florida agricultural program. Please see the link for more detailed information. http://edis.ifas.ufl.edu/ep081

These deficiency symptoms are common with all plant species.