Effects of mineral nutrition on health and performance of citrus trees

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Mineral nutrients are essential for plant growth and development, and are important factors in plant-disease interactions. In general, healthy, well-nourished plants resist or tolerate diseases better than weak, malnourished plants. How each nutrient affects a plant's response to disease is unique to each plant-disease complex. The purpose of this article is to briefly summarize some of what we know about plant mineral nutrition and how different nutrients affect citrus diseases, pests and overall tree performance.

Although nutrient-pathogen interactions are not well understood, plant nutrients may affect disease susceptibility by changing internal functions that create a more favorable environment for disease. Pathogen infection alters the plant's physiology, particularly the uptake, transport and use of mineral nutrients. Pathogens may immobilize nutrients in the soil or in infected tissues. They may also interfere with nutrient and water movement or water use in the plant, inducing additional stresses. Such infections can cause root starvation, wilting and plant decline or death, even though the pathogen itself may not be directly harmful.

Still other pathogens may themselves utilize nutrients, which reduces nutrient availability and increases the plant's susceptibility to infection. Soil-borne pathogens commonly infect plant roots, reducing the plant's ability to take up water and nutrients. The resulting nutrient deficiencies may, in turn, lead to secondary infections by other pathogens.

There are at least 13 mineral nutrients that are essential for normal plant growth and development. These nutrients and their general relative abundance and roles in citrus trees are illustrated in Table 1 and Figure 1. Mineral nutrients are often viewed simply as plant food necessary for better plant growth and yield. Although disease resistance is also controlled by genetics, mineral nutrition can have an influence on plant resistance or susceptibility to pathogens and pests. In addition, some disease-resistant genes in plants will only activate via specific environmental stimuli. Mineral nutrition is an environmental factor that can be easily controlled in agricultural systems through fertilizer management.

Table 1. Essential mineral nutrients required by plants, their general abundance relative to nitrogen, and their key function(s)

Nutrient	Chemical symbol	Relative abundance (%)	Function in plant
Nitrogen	N	100	Proteins, amino acids
Phosphorus	P	6	Nucleic acids, ATP
Potassium	K	25	Catalyst, ion transport
Calcium	Ca	12.5	Cell wall component
Magnesium	Mg	8	Part of chlorophyll
Sulfur	S	3	Amino acids
Iron	Fe	0.2	Chlorophyll synthesis
Copper	Cu	0.01	Component of enzymes
Manganese	Mn	0.1	Activates enzymes
Zinc	Zn	0.03	Activates enzymes
Boron	B	0.2	Cell wall component
Molybdenum	Mo	0.0001	Involved in N fixation
Chlorine	Cl	0.3	Photosynthesis reactions

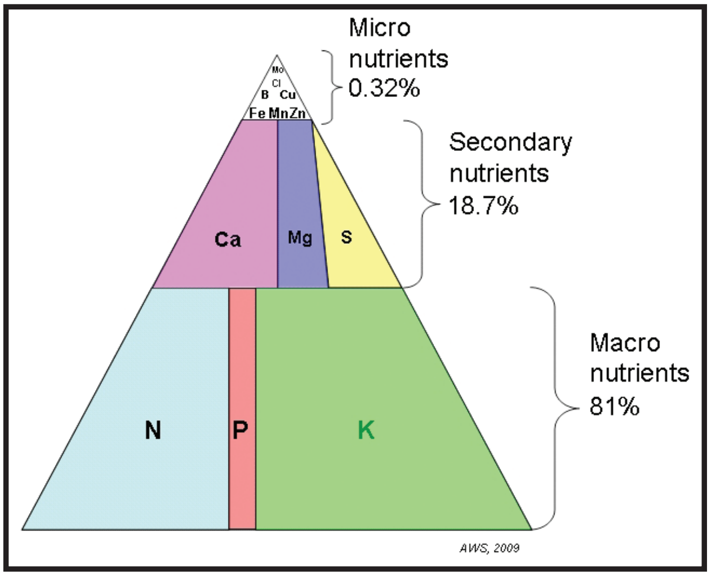

Figure 1. A schematic representation of the relative balance of nutrients for citrus. All of the nutrients are required and must be present in the proper ratios to build a balanced and complete pyramid.

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RESISTANCE MECHANISMS

In order to complement disease and pest control methods, we must understand how mineral nutrients affect disease resistance in plants. Altering how plants respond to attacks by pests or diseases can increase resistance. There are three primary resistance mechanisms that mineral nutrition can affect:

1. Formation of mechanical barriers to resist attack primarily through the development of thicker cell walls.
2. Synthesis of natural defense compounds such as phytoalexins, antioxidants and flavenoids that provide protection against pathogens.
3. Activation of systemic plant defense mechanisms.

Plants with optimal nutritional status have the highest resistance (tolerance) to pests and diseases. Susceptibility increases as nutrient concentrations deviate from this optimum. Since the roles of mineral nutrients are well established in host-disease interaction of many crops, citrus growers should recognize the existence of such interactions and see the possibilities and limitations for disease and pest control by mineral nutrition and fertilizer applications.

Potassium (K) and calcium (Ca) play key roles in forming an effective barrier to infections. Cellulose in plant cell walls requires K for

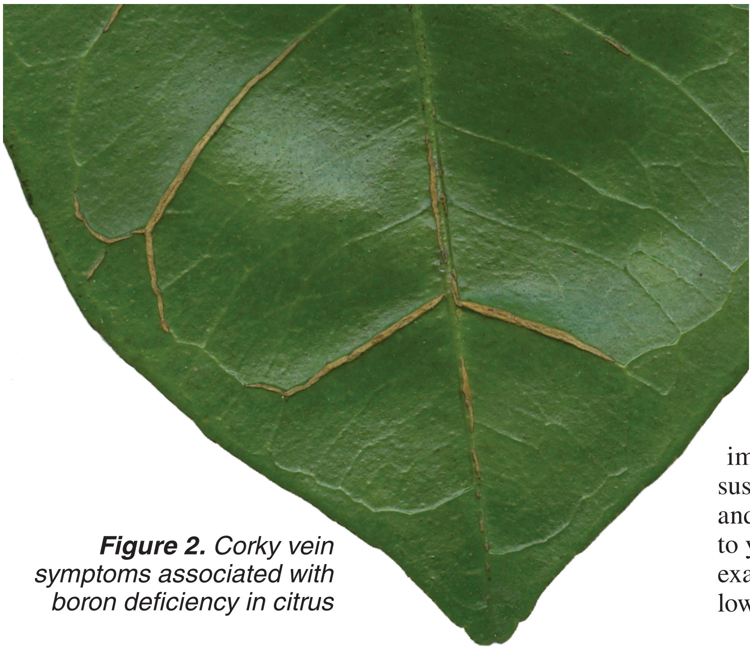

Figure 2. Corky vein symptoms associated with boron deficiency in citrus

synthesis. Thus, K deficiency can cause cell walls to leak cell contents, creating an environment that stimulates fungal growth. When K, Ca and often nitrogen (N) are deficient, plants are more susceptible to bacterial attack. Long-term research with K has shown that sufficient K reduced bacterial and fungal diseases 70 percent of the time and injury from insects and mites 60 percent of the time. Unlike other nutrients, the generalization can be made for K that a sufficient supply usually increases resistance to attack by all pests. K deficiency created by over-application of dolomite or magnesium lowers this resistance. Ca and boron (B) deficiencies also cause mineral imbalances that lower resistance to diseases by creating a more favorable environment for pathogen growth.

A frequent symptom of B deficiency in citrus is the development of "corky" tissue along leaf veins and stems as a result of the irregular (misshapen) cell growth that occurs when B is deficient (Figure 2). These irregular cells are like microscopic wounds through which bacteria can enter. Boron deficiency reduces fruit size and juice quality and causes premature fruit drop and death of terminal growing points on the main stem of citrus trees. Parasites that live on dying tissue or that release toxins to damage or kill host plants thrive in low N situations. While sufficient N increases plant resistance to most bacterial diseases, excessive N can have the opposite effect because rapidly growing high N tissues can have low resistance to attack. In addition, bacteria that depend on living tissue for a food source actually increase with high N.

Mineral nutrition also affects the formation of mechanical barriers in plant tissue. As leaves age, the accumulation of silicon (Si – a non-essential beneficial element) in cell walls helps form a protective barrier to fungal penetration. Excessively high N concentration lowers Si content by growth dilution and increases susceptibility to diseases. Copper (Cu) is a plant nutrient that is widely used as a fungicide. Its action relies on direct application to the plant surface and the infecting fungi. From a nutritional perspective, Cu deficiency leads to impaired production of defensive compounds, accumulation of soluble carbohydrates, and reduced wood development — all of which contribute to reduction in disease resistance. As Cu deficiency develops, twigs start to decline. Weak twigs will bear very small leaves of yellow-green color. Fruit splitting and fruit drop are common on citrus trees showing symptoms of Cu deficiency.

Soil-applied manganese (Mn) can inhibit the growth of certain fungi. Visual factors such as leaf color are important factors in insect and mite pest attraction and susceptibility. Nutritional deficiencies discolor leaf surfaces and may increase susceptibility to pests that are attracted to yellow. The Asian citrus psyllid, *Diaphorina citri*, for example, tends to settle on young leaf surfaces that are yellow in color.

Three primary pest defenses of plants are:

1. Physical surface properties: color, hairs.
2. Mechanical barriers: tough fibers, silicon crystals, wood formation.
3. Chemical/biochemical: content of attractants, toxins, repellants.

Mineral nutrition affects all three defense systems. There is often a correlation between N applications (stimulation of growth) and pest attack. B deficiency reduces the resistance to pest attack in the same way it reduces resistance to fungal infections. B is used in the synthesis of flavenoids and phenolic compounds, which are a part of the plant's biochemical defense system.

A sufficient supply of all nutrients is critical to nutrient management and sustainability of citrus trees. Similar principles govern the effect of both micronutrients and macronutrients on disease resistance: Any nutritional deficiency hinders plant metabolism and results in a weakened plant, which lowers disease resistance. For instance, the lack of one small ounce of molybdenum (Mo) per acre can lower disease resistance by impeding the production of nitrate reductase. This enzyme contains two molecules of Mo, and is required in the conversion of nitrates to proteins. This example also illustrates the importance of balanced nutrition – no nutrient functions in isolation from the others.

CONCLUSION

In conclusion, all essential nutrients are critical for the proper metabolic functioning of citrus trees. A balance between macronutrients and micronutrients is needed to optimize yield of high quality fruit and maintain trees healthy and tolerant to pests, diseases and other stresses.

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