The Interaction Between Plant Nutrition and Disease: Focus on Verticillium

By Brad Geary and Doug Jacobson

A review of the influence plant nutrition can have on plant disease susceptibility using the soil-borne fungal disease *Verticillium* as a case study example.

Most of us know that human health and disease prevention is directly tied to nutrition. Scurvy, for example, is a disease resulting from a lack of vitamin C that causes gum disease and other ailments. Humans can eliminate scurvy by consuming vitamin C in their diets. Plants are also dependent on nutrition for growth and disease reduction. Unlike humans, plants primarily obtain their nutrients from a small area of soil surrounding their roots. Proper nutrition clearly improves plant health, but not all plant diseases are cured by nutrition. However optimal plant nutrition can help reduce the US$5 billion lost annually to crop diseases in the world. Balanced plant nutrition is an effective and affordable way to minimize or prevent plant disease.

All plants are dependent on mineral nutrients for their growth and overall health and quality. Fourteen mineral nutrients are considered essential, with N, P, and K being considered primary, due to the quantity found within the plant and the large amount needed for proper plant growth. A number of other nutrients (e.g., Ca, Mg, Mn, Fe, B, etc.) also influence plant growth and disease interactions. The relationships and mechanisms by which plant nutrients and diseases interact are varied and complex. A particular disease might inhibit the plant's ability to absorb an essential nutrient, while the absorption of a particular nutrient might allow the plant to escape the effects of a particular disease.

Proper plant nutrition is essential to resisting disease. If an otherwise healthy plant is deficient in any of the nutrients required for proper growth, its susceptibility to disease increases. Proper plant nutrition can inhibit the pathogen's ability to infect the plant. One of the advantages to reducing disease with nutrients is that—to a certain degree—growers can control the supply of nutrients available and their timing to the plant. This topic is complex and readers are urged to consult the references at the end of this article for more information on specific crops and nutrients.

Due to their importance and quantity needed, N, P, and K are often the first nutrients to be depleted in the soil and are regularly supplemented through fertilizer applications. These three nutrients play a key role in plant development and health. Nutrient-deficient plants are less likely to tolerate stress and are more susceptible to disease; likewise, plants grown with an excessive supply of these elements may be subject to increased disease and to lower plant quality and development (Univ. California, 1992).

Nitrogen is essential for the production of amino acids, proteins, enzymes, hormones, phytoalexins (antibiotics), and other cellular components, as well serving an essential role in photosynthesis and growth. Phosphorus within a plant is primarily used for energy transfer and protein metabolism. Potassium, unlike N and P, does not become part of any plant material, but remains unattached as a regulator of plant growth through activation of at least 60 different enzymes in meristematic tissues, among other essential roles.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; B = boron; Fe = iron; Mn = manganese. IPNI Project USA-UT8

Plant Nutrition and Verticillium

Verticillium is a destructive soil-borne fungal disease influenced by mineral nutrition. The fungus enters plant roots and begins to clog the vascular system, resulting in the characteristic wilt associated with the disease. There are very few chemical treatments available to eliminate *Verticillium*, so agronomic and field cultural practices are very important. Soil fertility and mineral nutrition affect *Verticillium* virulence by reducing the inoculum density of spores in the soil and by influencing the host plant's resistance to the pathogen.

Jack Kelly Clark Univ. of California

Vascular discoloration in cotton stem resulting from Verticillium infection.

Howard F. Schwartz, Colorado State Univ.,

Brad Geary, Brigham Young Univ.

Cliff Snyder/IPNI Photo

Symptoms of Verticillium wilt infection in sunflower (top), potato (middle) and cotton (bottom) plants.

Verticillium wilt affects over 300 host plants in many plant families. Verticillium wilt on lettuce is a serious problem that has resulted in complete crop failure in some areas. Peppers, tomatoes, and potatoes are well known examples of vegetables that can be severely damaged by *Verticillium*. Unfortunately, populations of *Verticillium* remain in the soil for several years, limiting when lettuce, or other crops, can be planted again. Control options are limited to fumigation or switching to crops that are not *Verticillium* hosts. Recent research has shown that Verticillium damage can be greatly reduced with the proper balance of mineral nutrients within the susceptible plants.

A number of studies have found that N management can decrease Verticillium wilt severity in many crops, including lettuce, cotton, eggplant, olive, and potato. Plants primarily take up N as ammonium (NH_4^+) and nitrate (NO_3^-). Verticillium wilt generally decreases when N is supplied as NH_4^+, rather than in the NO_3^- form, which has shown an increase in disease severity of Verticillium wilt in eggplants (Elmer, 2000). Although the exact mechanisms by which NH_4^+ decreases Verticillium wilt is unknown, it is postulated that the acidification of the rhizosphere due to the extrusion of H^+ ions to balance the charge created by NH_4^+ uptake has a detrimental effect on the pathogen. Evidence supporting H^+ ions influence on *Verticillium* comes from a study where lettuce was grown under low pH conditions, high H^+ ions, and Verticillium wilt was not as severe (Subbarao, 2012).

An adequate Mn supply has been shown to decrease the severity of Verticillium wilt and other plant diseases. Plant tissues low in Mn are more susceptible to fungal diseases such as *Verticillium*, while tissues with adequate Mn concentrations successfully resist many fungal infections. Manganese availability works in tandem with the form of N present and soil acidity to decrease *Verticillium* severity. Higher Mn uptake is generally found in low pH soils, where more of the N may also be N present in the NH_4^+ form due to slower nitrification.

Phosphorus deficiency in soils severely limits plant yield, but research on P and *Verticillium* indicates that it does not have as great an influence as other nutrients. In preliminary studies, an increase in P fertilization of cotton, independent of other nutrients, resulted in an increase in *Verticillium* severity. Clearly, reducing P inputs may a cause P deficiency in plants, limit plant growth, and allow disease to take advantage of a weakened plant, but excessive soil P concentrations may encourage diseases like *Verticillium*. It is important to analyze soil and plant tissues to maintain optimal P concentrations and maintain good plant health.

Potassium uptake is typically greater than for any other nutrient. It is now commonly accepted that ensuring an adequate K supply generally decreases many plant diseases. This is true for *Verticillium*, where increased K fertilization corresponds to a decrease in wilt severity. For example, when cotton is heavily infested with *Verticillium*, an associated deficiency of K is commonly found. Pistachio and potato also show decreases in *Verticillium* severity with increased rates of K fertilization. This relationship between K and plant disease should be used to encourage proper plant nutrition and not excessive K fertilization rates.

Despite the complex relationships between plant nutrition and plant disease, proper nutrition is an essential component to disease resistance. Clearly there are no guaranteed solutions

concerning disease mitigation through plant nutrition, but proper nutrition is one certain way that growers can combat plant disease. Keep in mind that too much of any nutrient can be detrimental to plant growth and that balanced nutrition is essential for optimal crop growth and development. BC

Dr. Geary is a Professor in the Plant and Wildlife Sciences Dept., Brigham Young University, Provo, Utah; E-mail: brad_geary@byu.edu. Mr. Jacobson is a Graduate Student at the Plant and Wildlife Sciences Dept., Brigham Young University.

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Further Reading

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IPNI Appoints Potassium Program Director

The International Plant Nutrition Institute (IPNI) has appointed Dr. T. Scott Murrell as Director of its new Potassium Program.

For the past 20 years, Dr. Murrell has worked for IPNI (2007 to present) and its predecessor the Potash & Phosphate Institute (PPI; 1996 to 2007) as IPNI Director of the North America Program and PPI Regional Director of the Northcentral U.S. Program, respectively. Most recently, Dr. Murrell's focus within the IPNI North American Program has been on the improvement of nutrient management within corn-soybean cropping systems, data management for soil testing and crop nutrient uptake, and soil potassium assessment. Dr. Murrell will continue his work with data management as that is an integral component of potassium plant nutrition and management.

"All IPNI scientists' activities include agronomic programs that address potassium, nitrogen, phosphorus, and other plant nutrients as part of the Institute's regional and global tactical plans," explained IPNI President Dr. Terry L. Roberts. "Our addition of a Potassium Program Director completes our team of Directors that will have primary and global focus on each of the major nutrients." BC

Dr. T. Scott Murrell, Director of the IPNI Potassium Program.

Crop Nutrient Deficiency Photo Contest Entries Due December 6, 2016

Photo by Hari Gowthem G.

Calcium deficiency in wheat.

There is still time to beat the deadline for submitting entries to the annual IPNI photo contest for plant nutrient deficiencies.

Our list of prizes is as follows:

- US$250 First Prize for best overall photo
- US$150 First Prize Awards and US$100 Second Prize Awards within each of the four plant nutrient categories (Nitrogen, Phosphorus, Potassium, and Other Nutrients).
- In addition, the grand prize winners and first place winners will receive the most recent copy of our USB image collection. For details on the collection, please see http://ipni.info/NUTRIENTIMAGECOLLECTION

Entries can only be submitted electronically to the contest website: www.ipni.net/photocontest.

Winners will be notified and announced in early 2017. Look for results posted on ipni.net. BC