RUTGERS UNIVERSITY
New Jersey Agricultural Experiment Station

THE SOIL PROFILE

A newsletter for information on issues relating to soils and plant nutrition in New Jersey

Volume 29 2024

Mineral Nutrition and Plant Disease, A Reference for Crop Health

A valuable reference titled *Mineral Nutrition and Plant Disease* was published by the American Phytopathological Society (APS, St. Paul, Minnesota). The second edition of this 488-page book is an expanded update. The first edition published in 2007 was a best-seller for APS Press. The book (edited by Datnoff, Elmer and Rodrigues, 2023) includes chapters on every essential mineral nutrient and their role in plant nutrition and physiology. It also includes chapters on beneficial elements silicon, aluminum, selenium, and rare earth elements. My involvement was to coauthor the chapter on manganese nutrition.

The information in this book, when properly translated into practice, can reduce demand for pesticides. The purpose of this issue of *The Soil Profile* newsletter is to introduce growers to this reference on mineral nutrition as a holistic approach for protecting plants from disease. This edition will focus on the major plant nutrients: N, P, K, Ca, Mg, and S. The next edition of this newsletter will focus on the micronutrients.

The convergence of three factors can lead to plant disease: susceptible host, presence of pathogenic organism, and a conducive environment. The objective of the grower should be to create a healthy soil environment with the right balance of minerals such that the environment is favorable to the crop but unfavorable for the pathogen. Soil health should also consider pH, soil physical condition, organic matter content, and the collective assembly of microorganisms known as the soil microbiome, all of which may influence mineral nutrition.

A recent soil fertility test is a starting point that can provide some guidance towards soil health. First growers should look at the soil pH level to see if is on target for the crop of interest or if it needs adjustment. The soil test can also access fertility levels for P and K and the balance of Ca to Mg. The Rutgers Soil Test Lab report also indicates if micronutrients B, Cu, Fe, Mn, and Zn levels are Low, Adequate, or High. Micronutrient fertility levels should also factor soil pH into the interpretation.

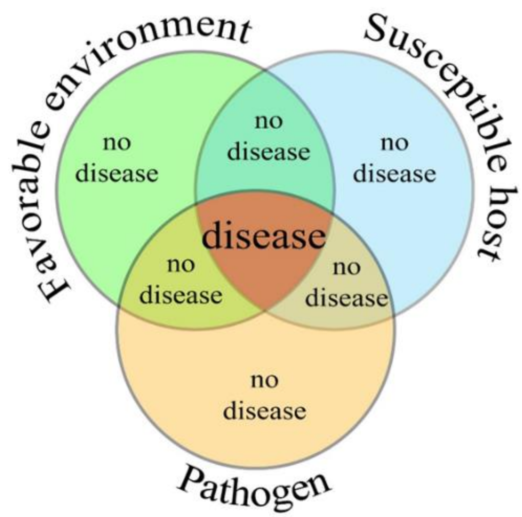

Fig. 1. Protection of plant health should begin with an appreciation for the foundational concept of the disease triangle.

Traditional soil fertility tests generally do not provide information about soil N availability and does not provide the complete list of micronutrients or beneficial elements. Also, soil test interpretations and recommendations are based on calibration research that tends to focus more on crop yield and less attention is given plant disease prevention.

Plant tissue analysis is another diagnostic tool that is complementary to soil testing. It is an especially important tool for accessing the nutritional status of perennial crops which carryover an internal pool of mineral nutrients from seasons to season.

Building on this background, several examples will be given on how information in this book *Mineral Nutrition and Plant Disease*, may be used to protect against plant disease.

Nitrogen Nutrition

Nitrogen impacts crop health status more than any other mineral nutrient. The supply of N, too little or too much, influences susceptibility to diseases. Also, the growth stage of the plant at the time the N is applied can be a factor. But it is not just the amount and timing of N supply, it is also the chemical form.

The two major chemical forms of N are ammonium or nitrate. When soil organic matter decomposes, the soluble N first appears as ammonium. This ammonium, with the action of nitrifying bacteria, converts over to the nitrate form. The nitrification reaction releases acidity into the soil.

Both forms of N are easily assimilated by most plant species. When the N is taken up by roots as ammonium, the soil close to the root surface (rhizosphere) is acidified and the soil pH is lowered. In contrast, when the N is instead taken up in the nitrate form, the rhizosphere pH is increased (Fig 2).

The form of N assimilated by the plant and the associated changes in soil pH can in many ways influence the susceptibility of plants to diseases. For example, changing soil pH can influence the solubility of micronutrients which then may have an impact of certain diseases.

Some diseases are suppressed by the ammonium form of N and others are suppressed by nitrate nutrition.

As an example, field research conducted at Rutgers NJAES found that fertilizing Kentucky bluegrass with an ammonium-based fertilizer, such as ammonium sulfate, is very effective at suppressing summer patch disease. But if the turf is instead supplied with N fertilizer in the form nitrate, it increased disease severity (Fig 3).

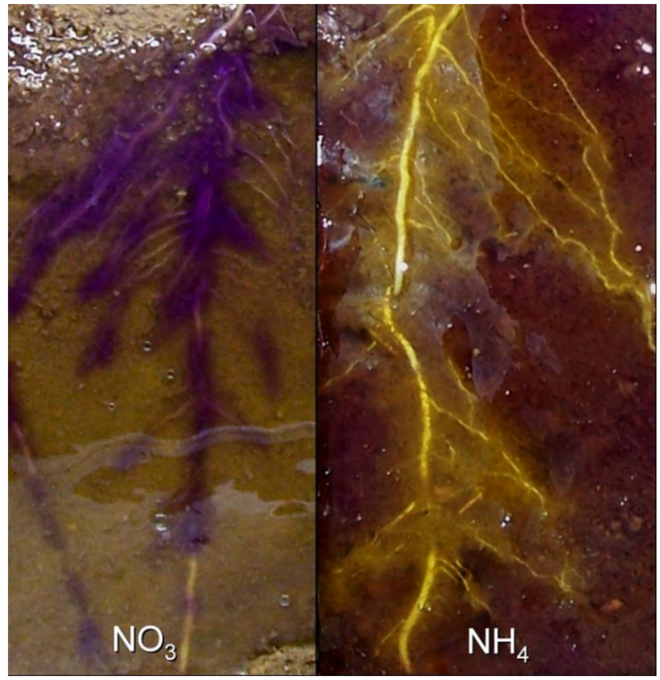

Fig. 2. Bromocresol purple, a pH indicator, added to soil turns purple at high pH in association with uptake of nitrate. Or it turns yellow at low pH with the uptake of N as ammonium.

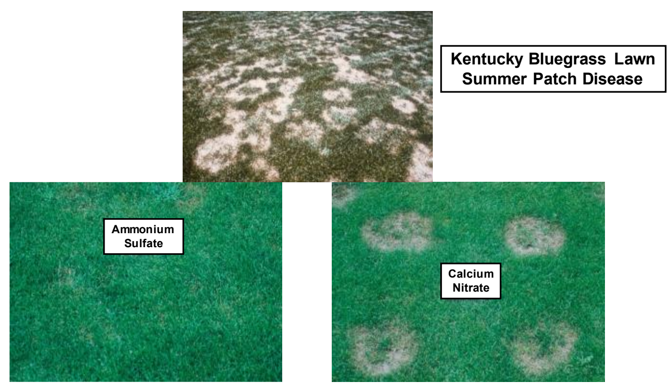

Fig. 3. Ammonium nutrition suppresses summer patch disease on Kentucky bluegrass.

Typically established grasses take up ammonium-N very rapidly and before much of it can be converted over to nitrate. Thus, when turf fertilizer is supplied as ammonium sulfate, most of the N uptake is in the form of ammonium.

This N source effect on summer patch disease development as illustrated above is just one example of how information in this book can lead to better management of mineral nutrition for disease suppression. An extensive table in the book *Mineral Nutrition and Plant Disease* outlines how N supply and ammonium versus nitrate can influence diseases on numerous crops. This information can be used to select the best N source for a specific crop.

Phosphorus Nutrition

Phosphorus is one the three major plant nutrients often included in fertilizer blends. Over half of New Jersey soils analyzed at the Rutgers Soil Test Laboratory have soil test P levels above optimum. Some crops exhibit growth responses to P fertilizer even on soils that have high soil test P levels.

The chapter on P nutrition reports from the literature on numerous crops. There are 44 cases of where P fertilizer deceased disease and 30 cases of where excess P was associated with increased disease.

Mycorrhizal fungi which infect the roots of most species of plants plays an important role in uptake of P from soil. This symbiotic association with plant roots is generally regarded as beneficial to plant health.

Nutrition is a functional approach to plant health and a balance nutrient supply is an important consideration. Because excessive P applications can degrade water quality, growers are urged to be cautious about oversupply of this nutrient.

Potassium Nutrition

Potassium is another major nutrient that can have much influence on susceptibility of plants to disease. Both K and N can have a large influence on plant health and are accumulated by crops in similar amounts. A balanced supply of N and K to plants is another important consideration. The chapter on K nutrition has a table covering six pages of bacterial and fungal diseases influenced by nutritional status. Reported effects in the literature shows 125 diseases where K decreased and 28 where K had the effect of increasing disease.

It is apparent that K nutrition often can influence susceptibility to disease. The chapter on K concludes: "Balanced nutrition is an important factor for plant resistance against disease. Application of K to deficient soils usually increases host resistance to disease, but in some cases no effect or the opposite effect has been reported."

Regarding balance, as previously mentioned, this is where soil testing and plant tissue analysis can be a helpful guide.

Another consideration with potassium fertilization is the chemical source. Potassium chloride is the most common potassium fertilizer. Potassium sulfate and other chemical types of potassium fertilizers are also sometimes applied. Chloride and sulfate are also important nutrients that may influence plant susceptibility to disease.

Calcium (Ca) Nutrition

Calcium mineral nutrition has a protective effect against the development of many plant diseases. The chapter on Ca suggests that it is among the most important nutrients in the management of plant health. There are extensive references to literature reporting "that the application of Ca to soils, foliage, and fruit reduced the incidence and severity of several disease of economically important crop species". They conclude that "applications of Ca for the control of plant disease would be well suited for certain crops permitting a potential reduction in the use of fungicides and improving crop quality and yields."

Within plants much of the Ca is deposited in cell wall and the middle lamella where it functions to increase structural integrity and increase resistance to invasive pathogens. Calcium bridges in cell tissue blocks accessibility of enzymes produced by pathogens that cause tissue softening and decay.

It is not possible to give one simple recommendation on how to use Ca nutrition to protect crops. Each crop disease or physiological disorder has special requirements for Ca nutrition and recommended methods of treatment. Applications of Ca to soil is effective for some crops whereas on other crops foliar sprays or treatment of the fruit per or post-harvest is the more effective approach. The timing or growth stage of Ca sprays is also an important factor.

Another consideration is that Ca is relatively immobile within plants. Soil moisture, irrigation, temperature, humidity, and sunlight intensity can influence transpiration and Ca transport within the plant and affect tissue accumulation. In general, Ca tends to move into leaves more easily than into fruit tissue.

The plant nutrition objective with Ca is to manage crop production practices to enhance greater uptake of Ca into fruit tissue. Because developing fruits tend to transpire less moisture than leaves, the challenge is to enhance Ca uptake into the fruit.

Soil testing can be a starting point to inform growers about the Ca status of the soil/crop system. For many crops that perform well in the range of pH 6.5 to 6.8, soil Ca should occupy about 65 to 70% of the cation exchange sites on soil colloids. In terms of nutritional balance, it is important to note that excessive application of K or Mg fertilizers to soil can suppress Ca uptake. Another reason Ca should be the dominate cation is that Ca more than any other nutrient improves soil physical conditions which contributes to soil and crop health.

Fig. 4. Blossom end rot is a physiological disorder that affects the fruit of peppers, tomato, and watermelon.

The blossom end rot disorder is associated with a deficiency of Ca in the affected tissue which becomes sunken and dark. It may be prevented by using production practices that are effective at getting more Ca into the developing fruit. Ensuring that there is an adequate Ca supply in the soil is a starting point with consideration that soil moisture and environmental factors also influence Ca uptake into the fruit.

Apples are often treated with Ca post-harvest to slow decay. The reduction in decay maybe explained by the role of Ca on stabilizing or strengthening cells walls of the fruit tissue.

Clubroot, a disease on cabbage and broccoli, can be effectively controlled by applying calcium carbonate limestone and raising the soil pH to 6.8 to 7.0. When applying limestone at higher rates growers should be aware that the high soil pH levels could induce deficiencies of boron, iron, manganese, or zinc.

Magnesium (Mg) Nutrition

Magnesium is involved in numerous plant physiological functions. It is a central component of the chlorophyll molecule which makes plants green. Many metabolic pathways and enzymes require Mg to function. It is also involved in stabilizing DNA and ribosome function.

While recognizing the many vital functions of Mg in plants, it may seem surprising that there are fewer reports of Mg minimizing plant disease development than other major nutrients. The reviewed literature in the book reports 23 diseases where Mg decreased and 18 where Mg had the effect of increasing plant disease.

Magnesium has a protective effect against bacterial soft rot of potato. But in the case of bacterial leaf spot of pepper and tomato, increasing tissue concentrations of Mg is associated with increasing disease. Soils rich with Ca and Mg together are suppressive of clubroot disease.

An interesting sidenote in the chapter on Mg is that this mineral is also very important to human health. This is a concern because in recent decades there has been a decline in Mg content of some foods. Low dietary Mg intake is associated with cardiovascular diseases, arrhythmia, and muscle dysfunction. Moreover, in grazing livestock, a deficiency of Mg in forage plants can lead to grass Tenay, a metabolic disease which can be fatal.

As previously mentioned, soil testing is a starting point to achieving a balance for Ca and Mg status in the soil/crop system. For many crops that perform well in the range of pH 6.5 to 6.8, soil Ca should occupy about 65 to 70% of the cation ion exchange sites and Mg should occupy about 10 to 15%. A fertile soil should also have about 3 to 5% exchangeable K. With these cation occupation targets on exchange sites, crops will more likely be provided with a good balance of these three essential cations, all of which play a role in plant health. A Mg excess in the plant is not generally harmful except that it competes for uptake of Ca and K.

Magnesium is a divalent cation that like Ca is typically supplied to soil as limestone. Dolomite liming materials contain about 13% Mg and 21% Ca. Calcite liming materials contain about 40% Ca and very little Mg depending on product and purity. Thus, the type of limestone selected and applied for the purposes of adjusting soil pH can have a major influence on the supply of Ca and Mg in soil and the availability of these nutrients to plants. Thus, it is important to follow soil test guidelines for selection of an appropriate liming material.

Sulfur (S) Nutrition

The amount of S uptake is similar to P uptake by crops. Brassicas and leguminous crops typically have higher S requirements than other plants. Sulfur is used to make proteins, vitamins, and flavor compounds, and it provides disease protection.

Elemental S has been recognized for over a century as an effective fungicide to protect crops from diseases. The mode of action of elemental S is not well understood. It is probably more than a plant nutrition effect. Plants uptake and use S in the form of sulfate. When elemental S is applied to soil it takes time for microbial activity to convert it over to plant available sulfate.

Plants well supplied with sulfate are more resistant to disease and environmental stress by a process referred to as sulfur-induced-resistance, SIR. Over the last several decades there has been a decline in freely available S from the atmosphere with the implementation of clean air standards. This has made crops more vulnerable to S deficiency and increased the susceptibility of plants to pathogens. The chapter in *Mineral Nutrition and Plant Disease* lists numerous crops, from apples to wheat, where diseases are affected or protected based on S nutrition status.

Deficiency symptoms of sulfur are typically exhibited as yellow or pale green leaves and slow growth. Sulfur deficiency is sometimes mistaken for a shortage of N. Both nutrients have critical roles in synthesis of protein and chlorophyll and in photosynthesis. Although the deficiency symptoms are similar, S deficiency is expressed most clearly on younger leaves whereas N deficiency is most prominent on older leaves. Increased susceptibility to diseases and environmental stresses are also suggestive of S deficiency.

Soil testing and plant tissue analysis may be used to diagnose crop S status (Refer Rutgers NJAES Extension Fact Sheet available on web). However, testing has limitations as predictors of S deficiency. Other agronomic and soil factors should be considered to access the need for sulfur fertilization.

Soils with high levels of organic matter are better at suppling S to crops. Soils with a recent history of manure or compost application are less likely to need S fertilizer. The risk of S deficiency is greatest on sandy soils with low organic matter content. Because S tends to leach, deep rooted crops have better access to S in the lower soil profile. Soils with compacted layers limiting root growth make crops more vulnerable to S deficiency. Deep tillage can be used to break up soil compaction and improve root access to S stored in the subsoil.

Soil fertility programs that utilize manures and compost generally supply ample amounts of S. The availability of organic forms of S to plants is enhanced with the help of microbial activity in warm moist soil.

Some commercial fertilizers used to supply one or more of the major plant nutrients also contain various amounts of S. Careful selection of a fertilizer to supply NPK or other nutrients may at the same time satisfy the need for S fertilization.

Since enhanced S nutrition often induces resistance to certain plant diseases, it is better to ensure an ample supply of this vital nutrient as it may offset the need for pesticides. Based on the chapter in *Mineral Nutrition and Plant Disease* one may conclude that soil fertility recommendations for S "should go beyond the usual considerations of growth and yield. They should be designed to optimize functions of S for induced plant disease resistance and crop quality."

Translation of Nutrition into Practice

New Jersey, known as the Garden State, cultivates hundreds of different crop species across many soil types and climatic regions. Mineral nutrition is one of many aspects among a collection of good cultural practices to produce healthy crops. Besides mineral nutrition, the goal of plant protection should employ crop rotation, building soil health and organic matter content with cover crops, improving soil physical conditions with or without tillage, planting of pest resistant varieties, good sanitation, along with other integrated pest management practices with the objective of reducing the demand for pesticides.

When plants are under attack from a pathogen, there may be an increased demand for a given nutrient. In general, mineral nutrition is a more cost-effective approach to disease management in comparison to the spraying of pesticides.

One cannot expect growers to read *Mineral Nutrition and Plant Disease* from cover to cover to implement nutritional practices to protect crop against diseases. But this book should be in the reference library of County Agent Extension offices. When crop producers are troubled by a particular disease this book can be consulted by looking up in the index the crop or the name of the disease or crop disorder for ideas about how plant nutrition and soil fertility may be fine-tuned to protect crop health.

For example, tomato growers plagued by blossom end rot can look up in the index and find that turning to page 142 there is information about this disorder. Or turfgrass managers troubled by summer patch disease can find on page 51 and page 327 information on how selective fertilizer practice for lawns can effectively prevent this disease on Kentucky bluegrass. Or looking up stalk rot on corn plants in the index leads to information on how this disease may be impacted by supply of N, P, K, and certain micronutrients.

The major nutrients (N, P, K, Ca, Mg, and S) were discussed in this issue of The Soil Profile newsletter. An important message to remember about nutrients is that supplying more is not necessarily beneficial to plant health. It is most apparent from the chapters on N and Mg that excess applications of certain nutrients can encourage plant diseases. The chapter on K, Ca and S suggests a supply below optimum presents the greater risks for plant disease. Also, for any given nutrient, it is not just fertilizer applications to consider but the cultural practices that influence solubility or availability of the nutrients already in the soil.

Another consideration is that when fertilizers are applied to supply any given nutrient, they are nearly always accompanied by other nutrients or ions that may also influence plant health. Just to give one quick example, K fertilizer is often applied as potassium chloride. The anion that accompanies the K fertilizer is also an essential nutrient with physiological influence. Identification of nutritional approaches to disease management is arguably a more functional and sustainable in practice than simple reliance on the spraying pesticides. Repeated us of the same fungicide is known to enable pathogens to develop resistance to a specific chemistry. To slow development of resistance, plant pathologists often advise for the "rotation of chemistries". But where optimum plant nutrition can offset the demand to use pesticides, there is in general a significant cost savings to the grower. And the efficacy of the pesticide is extended to times when they are most needed.

Healthy soils and plant nutrition have long been a foundational approach of organic farming. *Mineral Nutrition and Plant Disease* is a book that has useful information for all farmers.

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