ACID SOILS: HOW DO THEY INTERACT WITH ROOT DISEASES?

Soil Acidification Series

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Introduction

Soil pH can have an influence on the outcome of root diseases caused by soilborne pathogens, but it depends on the pathogen. Cereal growers in the Pacific Northwest (PNW) have been experiencing an increase in soil acidity (lower pH) primarily due to a long history of ammonium fertilizer use.

In eastern Washington and northern Idaho, soil acidification tends to be worse in areas that are annually cropped, do not include nitrogen-fixing legumes in the crop rotation, and in areas that were historically forested. Forested soils tend to have a lower pH buffering capacity, making them more prone to shifts in soil pH. These same areas also typically include more forage and seed grass production and seldom include legumes in rotation, meaning that there is more intensive nitrogen application to the soil.

In addition, direct seeding can result in a stratification of soil pH in which the top few inches of soil are more acidic. This is because acidification caused by fertilizer application in the top soil layers is not diluted by mixing with the more alkaline soil below the fertilizer zone. However, the contribution of this stratification on management of soil acidity in direct-seed systems has not been evaluated.

Soil pH and Root Diseases

How does soil pH affect diseases? Plant disease is the outcome of three interacting components: the pathogen, the plant, and the environment. Soil pH, a component of the environment, influences both the pathogen and the host. Root diseases are caused by microscopic soilborne fungi. These organisms form a network of tiny threads, which can grow through the soil and infect plant roots.

Fungi absorb food as simple molecules from organic matter or living plants. These molecules must be transported across the membrane from the outside to the inside of the cell. The fungus expends energy and uses a proton pump to transport many of these molecules across the membrane by maintaining a proton (H^+) gradient.

The external pH (proton concentration) can affect its ability to take up food, but in general, only extremes of pH (greater than 7 or less than 5) impact the growth of most fungi. Put another way, at the pH of most agriculture soils, the growth of most fungi is not pH limited. However, pH may influence the availability of trace nutrients, such as iron, zinc, or manganese, in the same way as its availability to plants is affected. Thus, fungi must work harder to get these less available nutrients.

Soil pH also affects the host plant. If the pH is too extreme, the plant will be stressed and may be less resistant to attack by the pathogen. Soil pH may affect the composition of the root exudates, which attract soilborne pathogens. Soil pH will also affect the availability of nutrients to the plant. Some of these nutrients may be needed for strong cell walls and resistance to fungi. Finally, pH may affect the microbial populations that hold the pathogens in check. In general, fungi are more adapted to acid conditions, and bacteria are favored more by neutral pH.

Disease Examples

The following is a summary of some diseases in the PNW that may be influenced by acid soils. Much of this evidence is based on research done in the PNW over 20 years ago, but some was conducted in other areas of the world.

The research also addressed the type of nitrogen (N) fertilizer—ammonium vs. nitrate. When plant roots take up the positively charged ammonium ion (NH_4^+), they balance the charge by excreting hydrogen ions (H^+), making the pH lower in the root zone. When plants take up a negatively charged nitrate ion (NO_3^-), they balance the charge by excreting hydroxide (OH^-), making the root zone more alkaline.

Take-all (*Gaeumannomyces graminis* var. *tritici*). Although widespread, take-all generally is not a serious problem in dryland wheat production, except in irrigated, continuous wheat or in the high rainfall areas of western Washington. It can be easily controlled with one year of a broadleaf, non-host crop such as pea, lentil, chickpea, or canola.

With take-all, the evidence is strong that it is more severe in alkaline than in acid soils, and that disease is reduced when ammonium forms of N are applied, as opposed to nitrate forms, an effect related to pH of the rhizosphere. The disease is greatly reduced when the rhizosphere pH is below 6.6, but the correlation with bulk soil pH was poor (Smiley, 1974).

The rhizosphere pH for wheat supplied with ammonium nitrogen was 5.5, compared to 7.5 for plants supplied with nitrate. The best control occurred with ammonium sulfate, and the addition of lime negated the control.

Rhizoctonia Bare Patch and Root Rot *(Rhizoctonia solani* AG-8, *R. oryzae*, and *Waitea circinata*). There is not much information on the effect of N or pH on Rhizoctonia root rots of cereals, and the results are mixed. There is no literature on the effect of pH on *R. oryzae*, which is widespread in eastern Washington.

Work by Smiley et al. (1996) in the late 1980s in Pendleton found that N application and timing of application had no effect on bare patch. They used ammonium sulfate at planting and ammonium nitrate at late tillering stages. However, in a 3-year study in a wheat-fallow system, the application of N at some rates increased the incidence of Rhizoctonia root rot. They applied zero, 40, or 80 lb/acre and found more disease at 40 lb/acre, compared to 80 lb/acre. But in a long-term cropping systems study in Australia (Macnish 1988), N application had no effect on Rhizoctonia root rot, even though ammonium reduced soil pH at all sites. The take-home message seems to be conflicting information with no rule of thumb. The effect of fertilizer type and soil pH do not appear to be major for this disease.

Pythium Seedling and Root Rot (*Pythium* spp.) *Pythium* diseases are caused by a complex of species with varying levels of virulence. These fungus-like organisms are widespread and more prevalent in the higher precipitation areas (greater than 16 inches). *Pythium* spp. have a wide host range, attacking the roots of both cereals and broadleaf crops.

Pythium attacks young seedlings and can rot seeds before they emerge, especially in the case of broadleaf crops like pea, lentil, chickpea, and canola. They can also stunt cereal crops and reduce yield by nibbling away at the roots, reducing root hairs and root branching, which negatively impacts the plant's ability to take up water and nutrients.

The above-ground symptoms are not dramatic, and growers often do not realize they have a *Pythium* problem. *Pythium* spp. prefer cool, wet soils in the spring, and can be managed by seed treatments to protect seeds and seedlings.

Pythium is another disease on which there is not much literature on pH effects in the field. In one greenhouse study with natural field soil, the pH was adjusted to a range from 4.3 to 7.6 with sulfuric acid or lime (Fukui et al. 1994). The optimum disease activity was from pH 5.0 to 5.5. There was a slight decline in disease from pH 5.5 to 6.5, but above pH 6.5, the disease activity dropped significantly. In one soil where the pH was decreased to 4.3, disease also declined significantly.

The take-home message on *Pythium* and pH is probably similar to *Rhizoctonia*—in the pH ranges of most of our soils, *Pythium* is not limited. But the finding that activity decreased in the very low pH soils should be further investigated, particularly for field crops that are known to be the most sensitive to low pH, such as occurs with legume crops.

Fusarium Foot Rot or Crown Rot (*Fusarium pseudograminearum* and *F. culmorum*). This pathogen attacks the roots and lower stem of the plant, resulting in a brown discoloration. The pathogen cuts the supply of water and nutrients to the upper stem. Most growers are well aware that this disease is favored by increased nitrogen fertilization and drought stress.

The effect of the type of nitrogen on this disease is well known, based on work done by Papendick and Cook (1973) in the early 1970s. Applications of ammonium forms of nitrogen (NH_4) increase disease severity and incidence, while nitrate nitrogen (NO_3) fertilizers decrease the disease.

Fusarium wilt diseases, such as those in legume crops, are strongly influenced by soil pH and are suppressed by alkaline soils and nitrate fertilizers. However, the evidence that Fusarium crown rot is influenced by pH is much weaker. A study by Smiley et al. (1996) found a correlation between crown rot and nitrogen application, and the disease was inversely proportional to soil pH, at least in the range measured (4.3 to 5.3).

This evidence is only suggestive of soil pH having an impact on Fusarium crown rot since with decreasing soil pH, there was also an increasing rate of nitrogen application, leading to greater plant stress and a higher incidence of disease.

Cephalosporium Stripe (*Cephalosporium gramineum*). This is a disease where soil pH has a dramatic influence. This pathogen causes yellow stripes that run the entire length of the leaves, whiteheads, and reduces yield (Figure 1). Later in the season, whiteheads are formed because of blockage of the vascular system in the stem (Figure 2).

Figure 1. Wheat showing symptoms of Cephalosporium stripe. Photo courtesy of T.D. Murray.

Figure 2. Wheat showing whiteheads, a symptom of Cephalosporium stripe. A blockage of the plant's vascular system cause heads to prematurely turn. Compare to healthy plots on either side. Photo courtesy of T.D. Murray.

Cephalosporium stripe is a disease of winter wheat, but there is variation in susceptibility among current wheat varieties, with some varieties being more tolerant than others. The disease is more pronounced in areas with higher precipitation, but it occurs in all rainfall zones. It is also more damaging in acid soils with high moisture.

This soilborne vascular pathogen produces single-celled spores that infect roots wounded by winter freezing and soil heaving. A series of studies at WSU showed that the germination of spores is not affected by pH, but the production of spores on wheat straw buried in the soil was greater at acid pH (Specht and Murray 1989; Stiles and Murray 1996; Murray and Walter 1991; Murray 1988; Murray et al. 1992).

Disease increased 5-fold when soil pH decreased from 7.5 to 4.5. The isolation of the pathogen from crown roots was less at pH 6.7 to 7.2, than at pH 4.7 to 5.9. Liming the soil to increase soil pH from 5.1–5.3 to greater than 6.0 decreased this disease two out of four years, and there was a significant correlation between soil pH and infected stems. Of all the diseases that may be increased under acid soil conditions, this is the one that growers should be watching.

Eyespot of Wheat (*Tapesia yallundae* and *T. acuformis* [= *Oculimacula yallundae* and *O. acuformis*]). Also known as strawbreaker foot rot, this pathogen attacks the bases of the stem and causes lodging. Both spring and fall sown cereals can be affected by this disease, although it is more prevalent and damaging in winter cereals due to more favorable environmental conditions.

Only one study has been done on the effect of N and pH on this disease, with trends similar to that of Fusarium crown rot. In this study by Smiley et al. (1996) on winter wheat in a wheat-fallow system, eyespot incidence increased 2 to 3 fold when 160 lb/acre of N was applied, compared to the non-fertilized plot. The increased incidence can be explained by the enhanced canopy growth, similar to planting early which is well known to favor eyespot foot rot of wheat.

Like Fusarium crown rot, the impact of soil pH versus increased N application cannot be differentiated by currently known research.

Conclusions

Diseases caused by soilborne pathogens of wheat and barley can be classified into two groups— those that are influenced greatly by pH or type of nitrogen fertilizer and those that are not. The first group includes take-all and Cephalosporium stripe.

Those pathogens that are not influenced by soil pH or too little data exist to definitively suggest that pH has an impact include the root rotting pathogens *Fusarium*, *Pythium*, *Rhizoctonia*, and stem base pathogen *Tapesia* (= *Oculimacula*).

Of all the diseases influenced by pH, Cephalosporium stripe, a vascular disease, shows the strongest trend toward greater incidence and severity in acid soils. Liming the soil will decrease the severity of this disease.

When much of the research was conducted in the inland PNW 20 years ago, a pH in the low 5s was considered acid, but we now have many soils with an even lower pH. Future research is necessary to further explore the impact of commercial lime application on Cephalosporium stripe and other diseases, and to more closely examine the impact of soil pH on other important cereal pathogens.

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