Soil-Pest Relationships

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Soil is essential for the production of healthy nursery stock. It provides physical support for roots and supplies mineral nutrients and water necessary for growth. The soil is also the environment in which plant roots interact with soilborne insects and pathogens. Therefore, an understanding of how soil properties affect both plant and pest health is critical for making effective pest management decisions.

Soil is a living, dynamic body composed of mineral solids, air, water, and organic matter (including living organisms). Although soil characteristics vary greatly throughout the United States, certain basic soil properties are important in mediating soil-pest relationships. Some properties, such as soil texture, are relatively fixed. Other properties, however, can be modified to favor plant health over that of injurious insects and pathogens. Knowing your site along with its associated soil properties can go a long way in determining which disease and pest management practices will be most appropriate. The most relevant soil properties are discussed below.

Texture

Soil texture (percentages of sand, silt, and clay) is one of the most important properties in soil-pest relationships because it directly affects a number of other soil characteristics crucial for plant growth including nutrient availability, gas exchange, and soil moisture levels. In general, sandy loams or loamy sands are recommended for nursery production because they are more resistant to compaction and provide enough pore space for adequate drainage and air infiltration. Coarse-textured soils are also more workable across a wider range of soil moisture levels and resist large clod formation, thus making soil management easier. For example, fumigants infiltrate farther in sandy soils with large pore spaces and few soil aggregates (clods).

Fine-textured soils are more prone to compaction and susceptible to poor drainage. Both conditions inhibit root growth and result in plant stress that can increase susceptibility to root pathogens. Damping-off and root rot are frequently more severe in clay soils because of these conditions. Fine-textured soils may slow seedling emergence, thereby increasing the amount of time that seedlings are in contact with pathogenic fungi. Garden symphylans (*Scutigerella immaculata*) also tend to be more problematic in heavier soils.

Coarse-textured soils, on the other hand, are more favorable for nematodes, which require larger pore spaces to move easily. For example, the root lesion nematode (*Pratylenchus penetrans*) and *Xiphinema bakeri*, the cause of corky root disease, are both more severe in sandy soils. Root feeding insects, such as the black vine weevil (*Otiorhynchus sulcatus*), strawberry root weevil (*Otiorhynchus ovatus*), and pales weevil (*Hylobius pales*) similarly prefer coarse-textured soils.

Moisture

Soil moisture is another important property that mediates soil-pest relationships. Water is essential for life and its presence directly affects both plant and pest health. Because the amount of water in a soil is inversely related to the amount of soil aeration, maintaining the proper balance of water and air is key to plant health. If too much water is present for an extended period of time, roots can suffocate. However, too little water can lead to drought stress. In either case, roots can sustain damage and become more susceptible to insect and pathogen attack.

Although local climatic conditions and water tables strongly influence soil moisture, appropriate drainage tile placement and the installation of an irrigation system can help mitigate the effects of standing water or a dry nursery site. Soil moisture conditions may also need to be managed for effective pest control. Fumigant efficacy is dependent on soil moisture during and after fumigation, and excess water can lead to pesticide leaching or uneven pesticide distribution in nursery fields.

Two classic examples of disease favored by excess water are damping-off and root rot caused by *Pythium* and *Phytophthora* species. Both pathogen genera produce motile spores that swim to host plant roots when soil moisture is abundant. Certain insects such as the European crane fly (*Tipula paludosa*) and fungus gnats (*Bradysia* and *Lycoriella* spp.) also prefer moist conditions.

Other disease and pest problems are favored by low soil moisture. Damping-off caused by *Rhizoctonia solani* and *Fusarium* species can be more severe under dry conditions. Drought stress may increase plant susceptibility to root rot caused by *Cylindrocladium* species. Similarly, charcoal root rot of pine, caused by *Macrophomina phaseolina*, is much more severe in hot, dry soils. Drought also predisposes hosts to stem diseases such as Phomopsis canker on Douglas-fir, Diplodia shoot blight and canker on pine, and Cytospora canker on hardwoods.

Temperature

Soil temperature affects the rate of seed germination, plant growth, and the development and survival of soil pests. The predominant factors that influence soil temperature are local climatic conditions, soil characteristics, and the amount of vegetative cover shielding the soil from incoming solar radiation. Several nursery practices, however, may be used to moderate soil temperature extremes. In summer, irrigation and mulching can be used to cool nursery soils. Mulching also works to keep the soil warmer during cold weather by reducing heat loss. In areas that receive adequate sun, soil solarization with clear plastic has proven effective in reducing insect and pathogen populations.

Warm soil temperatures are favorable for the development of a number of diseases including charcoal root rot and Fusarium root rot. Warm, moist conditions also increase infection by *Cylindrocladium* species, which cause root rot in a number of ornamentals. In some situations, excessive soil temperatures predispose seedlings to infection. In the case of Fusarium hypocotyl/root rot on Douglas-fir seedlings, symptoms often appear with the first onset of hot summer weather when roots are unable to supply adequate amounts of water to actively growing seedlings. Warm soil temperatures may also be crucial for biological control efficacy. *Heterorhabditis marelatus*, an insect-feeding nematode, requires consistent soil temperatures above 10 ºC (50 °F) to be effective against black vine root weevil.

Cool soil temperatures slow seed germination, seedling growth, and woody tissue development. These conditions prolong the amount of time that seedling tissues remain succulent, and therefore susceptible to infection by damping-off pathogens. Cooler soil temperatures also slow pest development and may reduce the number of generations that occur each year. Garden symphylans take 5 months to complete their life cycle at 10 ºC (50 °F), but require less than 2 months at 25 °C (77 °F). In addition, cold soil temperatures restrict the geographic range of certain insects and pathogens. The root pathogens *Phytophthora cinnamomi* and *Sclerotium rolfsii* are both limited by low soil temperatures and do not survive where soils regularly freeze.

Soil Reaction (pH)

Soil pH is a measure of the acidity or alkalinity of the soil. In general, slightly acid soils (pH 5 to 6) are recommended for optimal seedling growth of both hardwoods and conifers. Micronutrients such as iron and manganese become more available in slightly acid soils, but others such as aluminum may become toxic as pH levels decrease. Soil acidity is generally modified through the addition of soil amendments. Liming serves to increase pH and make soils more alkaline. Soil sulfur is commonly used to quickly lower pH, thus promoting soil acidity.

The severity of several diseases may be significantly reduced by soil acidification. Black root rot, caused by *Thielaviopsis basicola*, has been suppressed in soils with a pH less than 5.2. Losses from damping-off caused by *Fusarium*, *Phytophthora*, *Pythium*, and *Rhizoctonia* species have also been reduced by keeping soil pH low. Some acid-tolerant pathogens such as *Cylindrocladium,* however, may actually increase disease severity if the soil is acidified. Aluminum sulfate, a common soil amendment to lower soil pH, has shown some efficacy in reducing disease severity because several soilborne pathogens are sensitive to aluminum and increased soil acidity. However, caution must be used because high aluminum levels can be toxic to plants.

Symptoms of iron, manganese, and zinc deficiency are common on certain plant species grown in soils with a high pH. Pin oak and river birch seedlings, for example, are often chlorotic in alkaline soils. Treatment options are determined after a nutrient analysis of the affected plants and include soil acidification or fertilization with the appropriate nutrient.

Relatively little information exists about the effect of soil pH on nursery insect pests. However, the pH range of most nursery soils is unlikely to limit insect pests known to occur in nurseries.

Nutrients

Optimal plant nutrition is an important component of plant health because it helps maintain plant defenses. As with water, too little or too much of any nutrient can negatively affect plant health and increase susceptibility to insect and pathogen attack. The best strategy is to maintain a balanced fertilization program without promoting excessive growth.

The three main constituents of most fertilizers—nitrogen, phosphorous, and potassium—have been shown to affect disease incidence and severity. Nitrogen is the most studied nutrient and is essential in many physiological processes for growth and disease resistance. Excess nitrogen can lead to succulent growth and delayed tissue maturity, thereby making plants more susceptible to fungal infection. Damping-off, for instance, is frequently more severe after heavy nitrogen fertilization. In contrast, phosphorous decreases the severity of damping-off in conifers by *Fusarium oxysporum*. Phosphorous accelerates tissue maturity, thus increasing resistance to several plant pathogens, particularly those that attack young tissues. Phosphorous also helps with new root generation, which may assist seedlings in outgrowing root damage. Although potassium assists root growth, increased potassium levels in Monterey pine have been associated with greater susceptibility to Phytophthora root rot. Where fusiform rust (*Cronartium fusiforme*) is prevalent, high concentrations of all three nutrients are associated with increased susceptibility and damage.

With the exception of calcium, little work has been done on the effect of other nutrients in mediating soil-pest relationships. Calcium amendments such as gypsum, calcium chloride, and calcium carbonate have reduced infection by *Phytophthora* species in seedlings of fruit trees and ornamentals. It is thought to function by strengthening plant cell walls, thus increasing resistance to infection, and by directly interfering with pathogen biology.

Relatively little research has been conducted on the effect of plant nutrition on root insects of nursery crops. About the only generalization that can be made is that most root feeding insects tend to have long generation times (root weevils 1 to 2 years, cicada up to 17 years, white grubs 2 to 4 years) because the availability of nitrogen in roots is low.

Organic Matter

A significant proportion of research in the last few decades has focused on the role of organic matter (OM) in the management of soilborne diseases. Organic matter benefits the soil by increasing water holding capacity, soil aeration, and nutrient availability. However, the addition of too much carbon by incorporating amendments such as sawdust or bark mulch directly into the soil can result in temporary nitrogen deficiencies. Three strategies of OM management (bare fallow, specific OM amendments, and suppressive soils) have emerged in the past few decades and show promise for pathogen management. The first, bare fallow, is a relatively simple strategy for the reduction of certain soilborne pathogen populations. The latter two strategies, however, are more complicated and will likely require additional research to realize their full potential.

Periodic bare fallow treatments (every third year) have proven effective in reducing pathogen populations in bareroot conifer nurseries. This strategy works by removing the host and by decreasing the amount of OM in the soil, thereby eliminating or decreasing the food base for soilborne pathogens. Soils without vegetative cover also experience greater temperature and moisture extremes that may contribute to pathogen mortality. Significant reductions in soilborne pathogens such as *Pythium*, *Fusarium*, and *Cylindrocarpon* species have been observed and in several cases bare fallow has been as effective as fumigation in reducing pathogen populations. However, bare fallow is less likely to work as well for certain soilborne pathogens, such as *Cylindrocladium* species or *Macrophomina phaseolina*, which produce resistant structures that survive for years in the soil.

Incorporation of specific OM amendments, such as compost or green cover crops, has shown promise in reducing soilborne pathogen populations in nursery soils. Plants in the cabbage (Brassicaceae), onion (Alliaceae), and grass (Poaceae) families have received particular attention because of their ability to produce compounds that are directly toxic to soilborne pathogens. Perhaps the best known example is the use of *Brassica* species as a soil amendment to produce isothiocyanates and other fungitoxic compounds. Although some trials have been promising, overall the results have been inconsistent and much more research needs to be conducted before this method gains acceptance. To further complicate matters, populations of *Fusarium* species have often increased dramatically after OM amendment. Nevertheless, not all isolates of *Fusarium* are pathogenic and it is unknown what effect these population surges have on disease severity.

Suppressive soils are those in which disease incidence or severity is minimal despite the presence of the pathogen and susceptible plant host. Suppressiveness is often a function of the soil microbial community, although the soil's physical and chemical attributes may play a role. The functionality of suppressive soils is maintained through a variety of means, including crop rotation and the addition of OM amendments, in an effort to increase resident soil microbial diversity or to enhance the presence of microbes that are antagonistic to soilborne pathogens. Some microbes identified from suppressive soils compete with soilborne pathogens for resources or directly affect pathogen growth. Others, such as nonpathogenic *Fusarium oxysporum* isolates, have induced systemic resistance in crop plants. Research to date has focused primarily on agronomic and fruit crops, but the knowledge gained from these systems will assist interested nurseries in the development of healthy soils with greater microbial diversity.

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