ROOT HEALTH MANAGEMENT: AN INTEGRATED APPROACH

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Plants are more vigorous and yield more when grown in fumigated than in natural soil because the roots are healthier. The suggestion that fumigation does something beneficial for plant growth in addition to reduction in pressure from root pathogens cannot be supported by experimental data. Instead, results continue to accumulate to support the explanation that, with healthier roots, or simply more roots that are healthy, more growth factors are made for the tops and the plants with a greater absorptive capacity are better able to take advantage of fertilizer and water available in the soil.

In his justification for the use of soil pasteurization by steam-air mixtures to control soilborne plant pathogens of bedding and container-grown plants, the late K.F. Baker used to say "don't fight 'em; eliminate 'em." Soil fumigation is similar to soil pasteurization in that, rather than fight the soilborne pathogens, we eliminate 95-99 or even 99.9% of them, at least temporarily. Without methyl bromide or other soil treatment with the ability to eliminate the inoculum of soilborne plant pathogens, we usually must find ways to protect roots while they grow in soil infested with pathogens.

This session will be used to discuss root health achieved and maintained using a combination of strategies that include but do not depend entirely on elimination of the pathogens. The examples will be mainly from our personal experience and research on vegetable crops in the Midwest and cereal crops in the Pacific Northwest. With both of these kinds of crops, methyl bromide has never been a viable option for root health management. It should be kept in mind, however, that virtually all crops grown without benefit of adequate crop rotation, and many when grown as part of a crop rotation, respond more or less the same to soil fumigation for the simple reason that all crops are subject to damage from their soilborne plant pathogens. It should also be kept in mind that the 90-95% of U.S. cropland planted each year is not fumigated or treated chemically in any other way for pathogen control.

This summary, which will serve as the basis for our discussion session, is divided into four sections. The first is a list of principles that may seem obvious but need to be stated nevertheless as a guide to any system aimed at root health management without benefit of a fumigant such as methyl bromide. In our second paper, we provide a very brief review of the emerging and promising approach to biological control of soilborne pathogens using antagonists introduced with the planting material, e.g. with seeds or transplants. The third and fourth papers in this series review our personal experience, respectively, with root health management for vegetables in the Midwest and cereals in the Pacific Northwest.

Principles

Some reduction in the inoculum density or inoculum potential (power of the pathogen to cause disease) of soilborne pathogens, even if only modest, is essential as the first step towards root health management.

This can include any of several methods or practices, depending on the region, soil type, and pathogen complex, including: start the crop with pathogen-free planting material; temporarily avoid fields with known or suspected heavy infestations of soilborne pathogens; allow time for natural decline in inoculum or inoculum potential provided by crop rotation or plant-free period, however, limited; use soil solarization in areas with sufficient intensity and duration of sunshine; create a condition of temporary anaerobiosis by short-term flooding.

The severity of root diseases can be limited to a significant extent by management of the microenvironment of the soil or rhizosphere where the pathogens are active.

This can be accomplished by practices that improve soil drainage; raise or lower the soil or rhizosphere pH, depending on whether the pathogen complex is favored by high or low pH; and practices that affect soil temperature or soil water potential, to produce an environment relatively less favorable for growth and competitive ability of the pathogen than for its natural enemies (antagonists).

Significant root protection can be achieved by microbial biocontrol agents in the rhizosphere, either fostered as naturally occurring (resident) antagonists by cultural practices or as antagonists introduced with the planting material.

Soils can be rendered inhospitable to the growth and survival of some soilborne pathogens by the addition of composts or other organic materials properly processed. The increased predation, antibiosis, and competition accompanying the increased microbial activity of soil can be lethal to some plant parasitic nematodes and cause untimely germination/lysis of the survival structures of some fungal pathogens. More often, this enhanced antagonism limits the prepenetration phases of pathogen growth in the rhizosphere.

There is also a growing body of evidence to indicate that the repeated exposure of the soil microbiota to roots of the same crop enriches not only for root pathogens of that crop, but also, or eventually, for nonpathogens adapted to those roots, some of which are antagonists with ability to suppress activity of pathogens. These antagonists, naturally present as residents, account for examples of pathogen-suppressive soils. These same or similar antagonists formulated and applied with seeds or transplants at the time of planting, offer another means to achieve biological control of root-infecting pathogens (see next section).

Significant root protection can be achieved with narrow-spectrum fungicides targeted to specific pathogens or complexes of pathogens and applied on or with the planting material or directly to the soil.

Selective fungicides such as metalaxyl, difenconozole, triadimefon, propiconazole, imazalil, and others, applied singly or as mixtures, can be useful against soilborne pathogens provided the chemical is suitably applied so as to be taken up by roots (in the case of systemics) or otherwise placed to come into contact with the dormant or active inoculum of the pathogen. Pathogens can be controlled in soil with fungicide drenches, deep band applications, root-dips, and seed treatments, as examples. Success also has been reported with a water-soluble formulation of a chemical applied as a mixture with the fertilizer solution.

Useful genetic variation in tolerance or resistance exists in plants for virtually any biological or environment plant stress factor, including plant stress caused by soilborne pathogens, and should be exploited through variety development as a contribution to root health management over the long-term.

Resistance has been found to most if not all vascular pathogens such as *Verticillium dahliae* and the formae speciales of *Fusarium oxysporium*. Resistance has also be found to certain plant parasitic nematodes, e.g., root knot and cyst nematodes, with newer plant breeding technologies offering still more options for management of plant parasitic nematodes through host plant resistance. Useful resistance continues to be found in wild relatives of crop plants, and the availability of rDNA methods opens unlimited opportunities to access traits and genes heretofore not available to plant breeders. This approach is obviously long-term, but progress can be accelerated.