EDITORIAL

Plant Pathogens in Soils

Substantial advances have been made in enhancing the ability of plants to combat enemies that attack above ground. But comparable progress has not been achieved in safeguarding plants against the biological warfare that rages in the soil. Nematodes and microorganisms attack the roots of plants, limiting the effectiveness of fertilizers and lowering the yields of many crops. Although the damage they do to some high-value crops such as strawberries is currently controlled by fumigation of the soil with methyl bromide, use of that chemical will be terminated as a result of the Montreal protocol.

Soilborne pathogens can be partially controlled by crop rotation and tillage. However, rotation is often not economically feasible, and tillage leads to soil erosion. No-till agriculture minimizes the loss of soil but often results in more severe attack by pathogens.

Control of plants' many enemies in the soil will not be achieved quickly or easily. The complex nature of the underground war changes as surrounding conditions vary. Nevertheless, there is reason to expect important accomplishments in the control of soilborne pathogens. One example is research demonstrating improved control of pathogens that attack the roots of wheat.

A key figure in the research on wheat root pathogens is R. James Cook, a scientist with the U.S. Department of Agriculture's Agricultural Research Service at Washington State University, where he has been active since 1965. Early in his research, Cook made many studies of the effects on wheat yields when soils were fumigated with methyl bromide before seeds were planted. If wheat had previously been grown continuously in the same soil for several years, fumigation resulted in an average increase in yield of 72%. The principal pathogens controlled by the fumigant were fungi.

Cook and his associates have focused on studies of wheat rhizosphere bacteria that act against the pathogenic soilborne fungus *Gaeumannomyces graminis* var. *tritici*, cause of the major root disease of wheat known as "take-all." These beneficial bacteria are associated with a spontaneous decline in take-all that occurs after two or three successive outbreaks of the disease. Studies of this phenomenon at a field site indicated that the rhizosphere bacterium *Pseudomonas fluorescens* 2-79 produced the antibiotic phenazine-1-carboxylate, which accounts for 50 to 90% of take-all suppression by the bacterium. Phenazine was detected in extracts from roots and soil when seeds used to produce the plants were treated with the fluorescent *Pseudomonas* strain that had been isolated from the wheat-monoculture soil. Experiments also showed that the ability to produce the antibiotic conferred survival value against other soil microorganisms. Other strains of *Pseudomonas* produced a different but effective suite of antibiotics. One produced three phenazines; another suppressed take-all by production of 2,4-diacetylphloroglucinol.

A recent article* describes these experiments in more detail and indicates that Cook and his associates are trying to understand how creation and emission of the antibiotics are genetically regulated. Partial information about the gene clusters involved has been obtained. The article also mentions the recent discovery of a *Bacillus* species that has antibiotic activity against every species and strain of the three major root pathogens of wheat, including take-all. This strain can grow at temperatures as low as 10°C. The authors state, "The discovery of this strain and its broad-spectrum effectiveness against wheat root diseases gives but a glimpse of the enormous untapped potential for discovery of strains or traits and their deployment in defense against soilborne plant pathogens." The authors also mention that beneficial soilborne microorganisms can be modified through genetic engineering to improve the effectiveness of their association with plants.

Cook has suggested that the precedent of successfully coating seeds with appropriate antibiotic-producing organisms could be extended to treat the roots of plants such as strawberries during their transplantation. With more than 100 different commercial crops to be protected, this research is only in its beginning phase. The effort required will be great, but the payoff will be enormous in the United States and around the world.

Philip H. Abelson

*R. J. Cook *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **92**, 4197 (1995).