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suspect that we've missed some important cooperators along the way. But from the above one can begin to appreciate that the state's golf courses do, indeed, serve an integral role in the business of figuring out what's needed for turf disease identification and control.

We shouldn't lose sight of the fact that these sites not only have provided a research site, they've also played an important extension role, too. Most of these have been observed by other superintendents in informal or formal settings. The information is a basis for much of the disease control recommendations. And Camelot and Oconomowoc have served as the hosts for the Turfgrass Field Days for the past two summers.

We hope the proposed turf research station becomes a reality someday. It would save a lot of travel time; we could conduct different types of research than we can now—and it should be safer than dodging golf balls, too! But I suspect that some work would still remain on these very special kinds of "University Research Stations.

It's an impressive list of cooperators. We appreciate it!

Biological Control of Soilborne Plant Disease

By Dr. Jennifer L. Parke

In the plant pathologist's black bag are several strategies for controlling plant disease. These include traditional methods of chemical control (fungicides, fumigants), the use of disease-resistant plant varieties, sanitation to limit disease spread, and modification of cultural practices to create an environment less conducive to disease. Although each strategy is useful, there are occasions when none of these methods is effective or economically feasible in solving disease problems. For instance, fungicides are expensive, often require multiple applications, present some degree of environmental hazard, and with repeated use can result in development of pathogen populations which are resistant to the fungicide. It is in these situations that an alternative control strategy such as biological control should be considered.

Biological control uses living organisms, or metabolites produced by living organisms, to combat plant pathogenic fungi, bacteria, viruses, or nematodes. This process occurs naturally in many soils; just as plant species compete with one another for light, nutrients, and water, so do microorganisms compete for nutrients, oxygen, and microsites. Microorganisms have evolved complex "weaponry" for this competition, including antibiotics and special chelating molecules that bind certain soil nutrients very tightly to prevent their utilization by other microorganisms. In fact, the field of medicine has exploited this intense natural competition among soil microorganisms in the use of antibiotics to fight human pathogens; streptomycin, produced by the soil microorganism **Streptomyces**, is one example. Microorganisms can also act as predators or parasites, digesting or invading propagules of plant pathogens, decreasing their viability and their potential to cause disease.

The competition between soil microorganisms is most intense in the area immediately surrounding plant roots called the rhizosphere ("rhizo" = root), because it is here that most of the sugars and organic acids they use for food are leaked from roots to the soil. Each microorganism is vigorously competing for this limited source of nutrients to the extent that plant roots are densely covered by fungi and bacteria, many of which are actually beneficial to plant growth. Because of this intense competition it is unusual that a single pathogenic organism can gain a strong enough "foothold" to cause disease; it is rare to see root disease epidemics in soils which support a large and diverse rhizosphere population of microorganisms. However, in soils in which microbial populations are low, either because the soil is sandy, low in organic matter, or treated with a biocide, this depleted rhizosphere population is less able to prevent an aggressive pathogen from dominating the root zone.

Biological control makes use of microbial antagonism, either by restoring a large and diverse rhizosphere population by cultural means, or by finding and adding back one or more strains of microorganisms which antagonize a particular pathogen. In some cases, antagonistic bacteria have been mass-produced, then added as a seed coating, much as the nitrogen-fixing bacterium **Rhizobium** is added to alfalfa, pea, and bean seed to improve plant growth. Other modes of application include adding microorganisms to soil as a drench, as a dry powder, or as pellets. Biological control agents reproduce in the rhizosphere, and give protection against plant pathogens approaching the root. Biological control has been successful in controlling a variety of root diseases including **Sclerotinia** root rot of lettuce, **Phytophthora** root rot of avocadoes, crown gall of woody plant species and many others. One of the best examples is the biological control of the take-all disease of wheat caused by the fungus **Gauemannomyces graminis** var. **tritici**, for which antagonistic bacteria are applied to wheat seed at the time of planting to reduce disease. Since wheat and turf grasses are closely related and share numerous diseases in common (**Pythium, Rhizoctonia, Fusarium**), one would expect biological control of wheat diseases to have successful application to many turf diseases. Because this is a new and rapidly developing field of research, biological control agents should become available commercially within the next five years.

One classic approach in biological control of soilborne plant pathogens is to identify, characterize, and utilize disease suppressive soils. Suppressive soils can arise in an area where disease was once prevalent but where it has subsided with continued monoculture of the crop. The suppressiveness is generally associated with the build-up of a microbial population which is antagonistic to plant pathogens. If a suppressive soil is steamed to eliminate its living microorganisms, the soil loses its ability to deter plant pathogens. Once a suppressive soil is found it can be used as a source for microbial antagonists which can be tested individually for their effectiveness in reducing the growth, survival, or disease-causing ability of the pathogen in lab, greenhouse, and field trials.

The field of genetic engineering has increased the potential for achieving biological control. Within the next several years it should be possible to genetically modify microorganisms to increase their effectiveness as biological control agents; an organism could thus be modified to incorporate the attributes of a good root colonist and rhizosphere competitor along with having the capability to grow rapidly, tolerate environmental extremes and produce antibiotics to limit specific soilborne plant pathogens. Even though the technology for this is currently available, we need to learn much more about which organisms to modify, and in what way.

Biological control of turf diseases is just beginning to be explored. In many ways turf is ideally suited for biological control; because turf is a perennial, a desirable rhizosphere microflora, once established, could be maintained indefinitely and may not require repeated applications of biological control agents. The high intensity horticulture used for turf production and maintenance makes the application of biological control agents eminently feasible. The use of biological control organisms would probably be a safer alternative than application of toxic chemicals, a consideration very important because of the public's exposure to turf in their home gardens, parks, schools, and golf courses. Most important, perhaps, is the opportunity to maximize the effectiveness of biological control in turf by carefully controlling the environment in which these organisms are expected to perform; more than for any food crop, it is possible to adjust soil conditions in turf by altering the frequency and duration of irrigation, applying soil fertilizers, maintaining soil pH, spot-treating confined areas, and so on. In view of the increasing importance of biological control as a strategy for decreasing disease in agriculture as a whole, additional research is certainly warranted to examine the potential benefits of this strategy as it applies to turf.

Editor's Note: Born in Washington state and raised in California, Dr. Jennifer Parke moved to Madison in July of 1984 to assume a position as Assistant Professor of Plant Pathology at the University of Wisconsin. She received a B.A. degree from California — Santa Cruz in 1975 and a Ph.D. degree from Oregon State University in 1982. After completing her studies in Corvallis and prior to coming to Wisconsin, she received a Fulbright postdoctoral fellowship to work at the CSIRO Division of Soils in Adelaide, South Australia.

She specializes in the ecology and biocontrol of soilborne plant pathogens.