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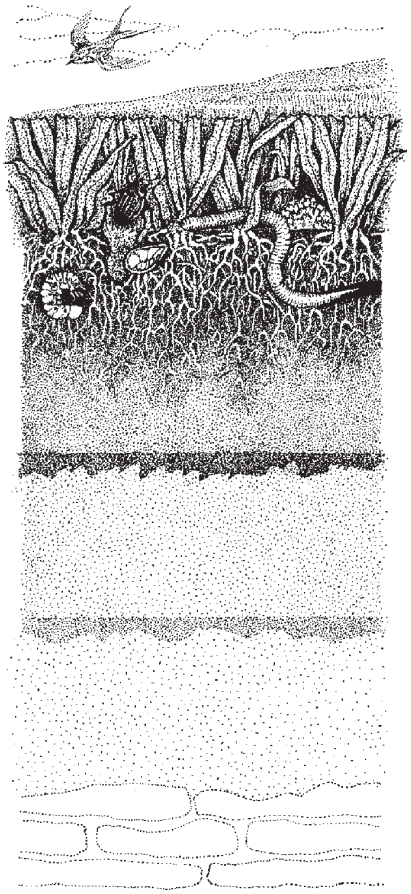

# The Development of Microbial Fungicides for Turfgrass Disease Management

In a previous edition of *CUTT* (Vol.1, No.1), I considered some of the general approaches to biological control and the use of materials containing complex mixtures of microorganisms, such as composts and organic fertilizers, for the biological control of turfgrass diseases. In this article, I wish to consider the use of preparations of individual microorganisms as microbial fungicides for turfgrass disease control. Although no microbial fungicides are currently available for turf, products are likely to be labelled in the next few years. ■

## Properties of Microbial Fungicides

Microbial fungicides consist of living preparations of microorganisms that have inhibitory properties toward plant pathogens. These organisms can act in a number of ways to inhibit plant pathogens. They may act as fungal parasites, compete with the pathogen for nutrients or alter the plant such that it is less susceptible to infection. For example, just as many of our medically important antibiotics come from soil microorganisms, similar microorganisms producing similar kinds of antibiotics are also effective in treating plant infections as well. In the development and use of microbial fungicides, we try to take advantage of the beneficial microorganisms commonly found in nature by isolating them from the environment (usually from soils or plant tissues), increasing their populations artificially, culturally or genetically improving their activity in the laboratory, and then reintroducing them back into the environment as an inoculant.

Unlike traditional synthetic chemical fungicides, microbial fungicides need more careful consideration of various aspects of their storage and application. Of particular importance is the shelf life of microbial fungicides since the organisms present in such products may not be able to remain viable for extended periods of time. One also needs to consider that, for any microbial-based fungicide to be effective, the organism(s) present in such a product must be able to establish itself in turfgrass plantings and must remain active throughout the period when disease pressure is greatest. Additionally, the organisms present in these types of products must be compatible with other agrichemicals used in management systems. For example, while bacterial preparations may generally be tolerant of most other chemical fungicides

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## Microbial Fungicides

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used in management programs, fungal preparations are not.

Through the past couple of decades, it has become apparent that the use of microbial fungicides is fraught with limitations, primarily due to the fact that we are trying to manipulate a living organism instead of a synthetic chemical. However, through continued evaluation in agronomic and horticultural systems, it has become evident that microbial fungicides have a very important place in commercial plant production and realistically offer important alternatives to plant health management. They can provide levels of disease control that, in many cases, facilitate reduced applications of fungicides and, in a few cases, eliminate the need for fungicide applications altogether. In addition, microbial fungicides are a potentially important tool in managing fungicide resistance among pathogen populations. Resistance is becoming more of a problem with many of the newer systemic fungicides on the market today. Furthermore, the success of sustainable plant production is largely dependent on the integration of biological and other non-chemical means of control into disease management strategies. Recent developments in Integrated Pest Management (IPM) are a direct result of the awareness of the importance of biological controls in holistic approaches to plant health management.

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### The Development and Use of Microbial Fungicides in the United States

Several requirements must be met before the successful development of a commercially viable microbial fungicide can take place. The product must be 1) needed in the marketplace; 2) technically feasible to produce; 3) economically feasible to produce; 4) competitively attractive with conventional fungicides; 5) acceptable to environmentalists and regulatory agencies; and 6) compatible with activities and interests of the company developing the product. Certainly, the turf industry and its clientele as well as the agrichemical and pharmaceutical industries can satisfy all of these criteria. When one considers the volumes of fungicides being utilized for turfgrass disease control, the economic feasibility of microbial fungicide development seems quite attractive. For example, the development of microbial fungicides in the United States is estimated to take approximately 2-3 years at a cost of less than $500,000 while chemical fungicides are estimated at approximately 10-15 years at a cost exceeding $80 million. Current costs of applying one of the more recent microbial fungicides, DAGGER G®, is estimated at approximately $9.50 per acre. If these figures can be used as a general standard with which to base future product economics, microbial fungicides will be extremely attractive if the product is used by a large portion of the turfgrass industry.

Since the 1920's, when interest in biological control of plant diseases first arose, there have been only five commercial biological controls targeted for plant diseases put into the marketplace in the United States. Four of those, QUANTUM-4000® (Gustafson Chemical Co., Dallas, TX, USA), a preparation of the bacterium *Bacillus subtilis;* DAGGER G® (Ecogen, Inc., Langehorne, PA, USA), a preparation of the bacterium *Pseudomonas fluorescens;* BINAB-T® (U.S. distributor unknown), a preparation of the fungus *Trichoderma harzianum;* and most recently a preparation of the fungus *Gliocladium virens* (unknown trade name but developed by W.R. Grace) are targeted for fungal pathogens. A fifth, GALLTROL-A® (AgBioChem, Inc., Orinda, CA, USA), a preparation of the bacterium *Agrobacterium radiobacter,* is effective against one specific bacterial disease. Likewise, there are only a few commercial products available in Europe and the Middle East. Unfortunately, none of these materials are labelled for turf disease control at this time. However, in the last few years, there has been intense interest among the traditional chemical pesticide producers in developing microbial fungicides for turf. Similarly, research here at Cornell is being directed toward the discovery and utilization of microbial antagonists for turfgrass disease control. Since our knowledge of the types, nature, and ecology of microbial antagonists active against turfgrass pathogens is rapidly increasing, it is likely that in the next three to five years, microbial turfgrass fungicides will begin appearing on the market.

### Microbial Fungicides for Turf

Although biological control of turfgrass diseases is still very much in its infancy, there have been promising studies using preparations of individual organisms as tools for managing fungal diseases (Table 1). Although limited in scope, these studies indicate the potential of soil and plant associated microorganisms to suppress turfgrass diseases. Additionally, our research at Cornell has shown that individual microorganisms, when applied at the proper time and in an appropriate manner, can establish in bentgrass putting greens and can be as effective as some of the

newest chemical fungicides in controlling turfgrass diseases (Table 2). The future use of these antagonists in microbial fungicides will come only from a better understanding of how antagonists function and how they interact with other turfgrass management inputs. Recent developments in molecular biology have tremendously increased our abilities to answer some of these questions. As a result, we are now gaining a better understanding of how antagonists can be manipulated to get the most out of them in the tasks they are being asked to perform. For example, antagonist technology has developed to such a level that we now have the potential to introduce and establish antagonists on specific plant parts or in specific ecosystems, the techniques to identify genes conferring biological control activity, and the ability to understand their interactions with the environment. Undoubtedly, advances in antagonist molecular biology have been one of the principal reasons that biological control of fungal plant pathogens has become more of a reality today than just a few years ago. Future developments of microbial fungicides for turf will come only from this type of understanding of antagonist biology.

**Table 1. Known Examples of Research on the Biological Control of Turfgrass Diseases**

| Disease *(pathogen)* | Antagonists | Location | Reference |
|---|---|---|---|
| **Brown Patch** *(Rhizoctonia solani)* | *Rhizoctonia* spp. | Ontario Canada | Burpee & Goulty, 1984 |
| | *Laetisaria* spp. | N. Carolina | Sutker & Lucas, 1987 |
| | Complete mixtures | New York | Nelson & Craft, 1989 |
| **Dollar Spot** *(Sclerotinia homoeocarpa)* | *Enterobacter* spp. | New York | Nelson & Craft, 1990 |
| | *Fusarium* spp. | Ontario Canada | Goodman & Burpee, 1989 |
| | Complex mixtures | New York | Nelson & Craft, 1989 |
| **Gray Snow Mold** *(Typhula* spp.) | *Typhula* spp. | Ontario Canada | Burpee, *et al.,* 1987 |
| | | | Lawton & Burpee, 1990 |
| | *Trichoderma* spp. | Massachusetts | Harder & Troll, 1973 |
| **Pythium Blight** *(Pythium aphanidermatum)* | *Enterobacter* spp. | New York | Nelson & Craft, 1989 |
| | Various bacteria | New York | Nelson & Craft, 1991 |
| | | Ohio | O'Leary, *et al.,* 1988 |
| | | Illinois | Wilkinson & Avenius, 1984 |
| | Complex mixtures | New York | Nelson & Craft, 1989 |
| | *Trichoderma* spp. | Ohio | O'Leary, *et al.,* 1988 |
| **Red Thread** *(Laetisaria fuciformis)* | Complex mixtures | New York | Nelson & Craft, 1989 |
| **Southern Blight** *(Sclerotium rolfsii)* | *Trichoderma* spp. | N. Carolina | Punja, *et al.,* 1982 |
| **Take-All Patch** *(Gaeumannomyces graminis* var. *avenae)* | *Pseudomonas* spp. | Colorado | Wong & Baker, 1984, '85 |
| | *Gaeuman.* spp. | Australia | Wong & Siviour, 1979 |
| | *Phialophora* spp. | | |
| | Complex mixtures | | |

## Future Perspectives

Because microbial pesticides are relatively new to the marketplace, it is not yet clear, particularly in the United States, whether they will compete well with chemical fungicides and be acceptable to environmentalists and regulatory agencies. Although it is encouraging that more and more biological control products are becoming available, time will tell whether biological fungicides turn out to be effective enough to either replace or augment traditional fungicides. It is critical that some of these initial products consistently perform as well as or better than conventional fungicides if the future of microbial fungicides is to be successful. Biological control is on the verge of a new era of discovery and commercialization. One must believe that the benefits of biological controls, once realized, will overcome any limitations currently impeding development and ultimately change the way in which disease control is approached.

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**Table 2. Comparison of Biological and Chemical Suppression of Dollar Spot on Creeping Bentgrass with *Enterobacter cloacae* (EcCT-501) and the Fungicide Propiconazole**

| Treatment | Rating 1 (30 dpi)[1] | | Rating 2 (23 dpi) | |
|---|---|---|---|---|
| | Spots per Plot | %Control | Spots per Plot | %Control |
| Untreated | 3.4 a | 0.0 | 19.8 a | 0.0 |
| Propiconazole[2] | 1.4 c | 58.8 | 0.6 b | 97.0 |
| *E. cloacae* (EcCT-501)[3] | 2.2 b | 35.3 | 8.6 b | 56.5 |
| Autoclaved cornmeal (carrier)[4] | 3.6 a | 0.0 | 21.0 a | 0.0 |

[1] Rating 1 (June 26, 1989) 30 days after first application. Rating 2 (July 19) 23 days after second application. dpi = days post-inolucaltion.
[2] Propiconazole (BANNER®) applied at the rate of 174 mg a.i./$m^2$ as a fungicide check.
[3] Cornmeal/sand preparations of EcCT-501 applied at monthly intervals. Recoverable populations at the time of application were approx. $10^9$ cells/g dry wt. thatch.
[4] Cornmeal/sand mixture consisted of 70% fine sand and 30% cornmeal (v/v) and was used as a carrier for *E. cloacae.*

*Numbers followed by the same letter are not significantly different (P = 0.05) according to the LSD test.*