PART I of this paper, "Compost-Induced Suppression of Turf Grass Diseases" (June, 2002), provided historical perspective on the use of organic amendments in turf grass management and the introduction of composts to control turf grass diseases. Topdressing amendments, root zone amendments and turf covers — all utilizing compost — were discussed as well. Part II looks at the use of compost extracts and teas on turfgrass. It then offers insights into the mechanisms of disease suppression with composted amendments and the impact of various types of compost on microbial communities.

Compost Extracts/Compost Teas

Aqueous compost extracts (or compost teas) have seen increasing use in turf grass applications in recent years. However, to our knowledge, little published research exists concerning the use of such teas for turf grass applications (see sidebar). All of our available information comes from work done on agricultural systems.

Over the past ten years, numerous studies have shown the potential for aqueous compost extracts to control fungal diseases on a variety of crops. Currently relatively little is known about the mechanisms by which compost extracts control plant diseases. Efficacy of extracts appears to vary depending on the target pathogen. For pathogens such as those causing powdery mildews of the Poaceae (e.g., *Erysiphe graminis*), induced plant resistance appears to be the main mode of action. Induced plant resistance, also called induced systemic resistance, occurs when microorganisms cause the plant to turn on or strengthen its natural defenses against disease. Recent studies suggest that induced plant resistance may also function in the suppression of other foliar pathogens. However, one researcher noted that induced resistance was not the major mode of action of extracts against Oomycete pathogens. Disease reductions in these pathosystems were observed as early as three hours from the time of application, whereas postapplication times of at least 24 hours are generally required to induce host plant resistance. Instead, extracts directly affected these pathogens by suppressing sporangia and oospore germination.

Extracts are generally prepared by mixing one volume of compost with five to ten volumes of water. After soaking at ambient temperatures for anywhere from three to 14 days, the solids are removed and the extract applied as a foliar spray or a soil drench.

The suppressive properties of many compost extracts studied to date have been attributed to microbiological properties. Although previous research indicated that more than one mechanism could be responsible for control of the various diseases studied, the precise nature of these mechanisms is unknown. A German researcher, N. Ketterer, believed that the suppressive activity of compost extracts to some necrotrophic pathogens was dependent on adequate microbial population levels, a specific microbial community composition, and the presence of pathogen suppressive microbial metabolites in

Microbial Mechanics Of Compost-Induced Disease Suppression

This second part of a report on suppression of turf grass diseases using compost looks at extracts and teas, benefits of immature versus mature composts, and the microbiological communities involved. Part II

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extracts. This has been verified by others. Although individual microbial strains recovered from extracts were highly suppressive to various plant pathogens, those compost extracts with the highest microbial populations (~10^9 CFU/ml) did not necessarily give rise to the most suppressive extracts.

Studies in our laboratory have examined the suppressive nature of compost extracts to Pythium diseases and have focused on the mechanisms by which compost extracts suppress specific Pythium diseases, including Pythium root rot of creeping bentgrass caused by P. graminicola. Both the extraction time and extraction temperature affect the suppressiveness of the final extract. The suppressive activity of compost extracts is maximized with a four to seven day extraction time. This corresponds to the period of maximum microbial population development and increased levels of microbial activity. Extraction times beyond 14 days dramatically reduce the overall activity of the extract.

Furthermore, extraction temperatures above 65° to 70°F also reduce the activity of the extract. Applications of different compost extracts, prepared by "brewing" for four days at 65°F and applying 5 to 6 gal/1000 sq. ft. to creeping bentgrass/annual bluegrass golf turf, resulted in different levels of Pythium root rot suppression. Extracts prepared from different composts varied in their disease suppressive properties. Extracts prepared from a 50:50 mix of chicken manure compost and cow manure compost induced significantly more Pythium root rot suppression than extracts prepared from a leaf compost and significantly less disease was seen on plots treated with the chicken/cow extract than on untreated plots.

Only a limited number of composts have produced extracts with significant levels of turf grass disease suppression. In those composts, the microbial components of the extract, when isolated, suspended in water and applied to turf, are capable of providing a high level of disease control in laboratory studies. Interestingly, individual microbial strains from nonsuppressive extracts also will provide a high level of disease control, even though the original compost also was not suppressive (e.g., yard trimmings composts). Clearly, nonsuppressive composts harbor microorganisms that have the potential to control diseases, however their population levels are apparently not sufficient to provide a high level of disease suppression. The brewing process for the preparation of extracts provides a means of selecting organisms with disease control potential, regardless of whether the original composts are highly suppressive or not. These microbes then may be used as compost inoculants or developed in their own right into biological disease control preparations.

Mechanisms Of Disease Suppression With Composted Amendments

Despite the fact that many composts can suppress turfgrass diseases, some types of composts are not suppressive. Additionally, batches of the same compost may vary considerably in disease suppressiveness. Recent work in our laboratory has focused on the microbial properties of composts and compost-amended soils and the relationships of these properties to the suppression of Pythium diseases of creeping bentgrass. Some consistently suppressive compost materials tested to date have been those prepared from brewery sludge, turkey litter, or from some batches of municipal biosolids. All batches of brewery compost and a few batches of certain municipal biosolids composts, when allowed to age for a suitable period of time (one to three years), have been highly suppressive. Furthermore, these materials contain relatively high populations of heterotrophic bacteria, actinomycetes and fungi. These populations can be eliminated by heating, but can be partially restored by incubating sterilized compost with small amounts of nonsterile material. Loss of microbial populations is accompanied by a loss of suppressiveness, whereas restoration of those populations results in a reestablishment of suppressive properties. On the other hand, immature (one to three months) composts prepared from these materials and still undergoing thermophilic decomposition are not suppressive to Pythium graminicola.

With the exception of some antagonist-fortified composts, composts prepared from yard and lawn trimmings also are not suppressive to Pythium diseases or any other turfgrass disease examined to date. This is most likely due to the fact that there is very little available carbon to support microbial activities. Even though antagonistic microbes are present in these composts, they are not present in sufficiently large populations to provide any disease control.

Turkey litter and other poultry manure composts are consistently suppressive to a wider range of diseases than are brewery and municipal biosolids composts in field experiments. The former composts contain relatively low populations of bacteria, actinomycetes and fungi and have low levels of microbial activity. However, populations of microorganisms in soils receiving poultry composts are frequently greater than those found in soils receiving applications of composts that harbor much higher populations of microbes.

Preliminary results from our studies suggest that the suppression of Pythium diseases of creeping bentgrass by poultry manure composts is largely a result of the stimulatory effects on soil microbial communities whereas suppression by brewery sludge and municipal biosolids composts is mediated by microbial communities associated with the mature composted material. Additional evidence to support the latter conclusion is based on relationships between microbial activity and Pythium suppression.

From examining a number of suppressive and nonsuppressive composts, a direct and inverse relationship was established between microbial activity in each compost and disease severity. These results also corroborate those of others in which direct relationships were observed between the amount of microbial activity and suppression of Pythium diseases of other crops. We have further found that a high frequency of microbes possessing Pythium-suppressive properties can be readily recovered from turf grass soils amended with suppressive composts.

At least for Pythium diseases, disease control with compost amendments is dependent on microbial properties of the amendment, and soil microbial responses following application of the amendment. We have found that the microbiological properties of Pythium-suppressive.
composts differ substantially from one another and that even though measurements of compost microbial populations or activity may be predictive of Pythium suppression in some composts, these measurements may not be predictive, in all cases, of the expected level of disease suppression. This is particularly true for turkey litter and perhaps other poultry composts where, although compost microbial populations and activity are relatively low, Pythium suppression may result from the stimulation of soil microbial activity. It is not yet clear whether these same relationships are true for other turf grass pathogens and diseases.

**Microbial Communities And Disease Suppression**

In studies with various types of composted amendments, evidence is growing for the involvement of microbial consortia and not just a single organism in disease suppression. When mature composts are added to soils, a large microbial community accompanies the amendment. The occupation of the mature composted substrate by microbes well adapted to that substrate makes it unlikely that other large microbial community changes could occur as a result of native soil microorganisms colonizing the substrate. In contrast, immature composts and those prepared from poultry manures, all of which contain low levels of microbial biomass and activity, may serve as substrates for microorganisms already present in soil, since less competition from compost-inhabiting microbes would allow colonization and succession by other soilborne microbial species.

Soil microbial populations and activities have been shown to increase following compost amendments. Although little attention has been given to compost age or maturity in these studies, the type of material composted appears to affect microbial enzymatic activities. Furthermore, little attention has been given to the activities and fate of the compost-derived communities as compared with the soil-derived communities in compost-amended soils.

The current and emerging evidence from both field and laboratory experiments on disease suppression by compost amendments suggests that organic material availability and quality, coupled with microbial community dynamics in amended soils, is critical to the understanding of how diseases are suppressed in compost-amended soils. Critical gaps in our understanding of disease suppression with composted soil amendments lie in our limited knowledge of the biochemical changes in organic amendments during decomposition in soils, and our limited understanding of the effects of such amendments on soil microbial community structure, diversity and dynamics.

**Disease Suppressive Activity Of Compost Microbes**

Composts provide some of the richest sources of disease suppressive microorganisms in nature. In our experience, high frequencies of microbes with biological control potential are commonly recovered from composts (Table 1). Many of these microbes can be recovered from suppressive as well as nonsuppressive composts. In some cases these organisms, when applied individually, are capable of providing a level of disease control comparable to that of the original compost amendment. Many of these microorganisms could potentially provide the basis for the development of microbial-based fungicides for turf grasses or for microbial compost in-construction mixes will continue to grow. In particular, industrial and municipal residuals are being viewed as potentially important sources of organic amendments. The management and recycling of municipal and industrial residuals are among the greatest challenges facing the U.S. and the global community. Composting is emerging as one of the more desirable biotechnologies for managing these types of residuals and converting them into a valuable resource that can be used effectively as a biological alternative for the control of turf grass diseases.

One of the greatest obstacles to the widespread use of compost amendments for turf grass disease control has been the inconsistent performance from site to site, batch to batch, and year to year. Much of the unpredictable nature of compost amendments can be attributed to our overall lack of understanding of the microbiology of these materials. This understanding is critical for determining the suppressive properties of and microbial responses to amendments when incorporated into turf grass soils or when applied as topdressings. Increased research in this area will eventually make compost amendment use more predictable and manipulable.

An important consideration in the use of organic amendments in turf grass disease control is the compatibility with other management inputs such as fungicide, insecticide, and herbicide applications. No information is currently available on the compatibilities of organic amendments or other microbial components of organic amendments with pesticide applications.

Although much remains to be understood about the efficient use of organic amendments in turf grass management, it is clear that the benefits of such amendments far outweigh any negative aspects of their use. As we enter a new era of disease control in turf, organic amendments will likely be key elements for sustainable maintenance of turfgrass quality and overall turf grass health.

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**Table 1. Frequency of microbial antagonists from different composts as compared to turf grass and nonturf grass soils**

<table>
<thead>
<tr>
<th>Compost</th>
<th>% Microbes With Biocontrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonturf grass soil</td>
<td>40.6</td>
</tr>
<tr>
<td>Turf grass soil (high maintenance)</td>
<td>41.3</td>
</tr>
<tr>
<td>Turf grass soil (low maintenance)</td>
<td>45.6</td>
</tr>
<tr>
<td>Chicken manure compost</td>
<td>68.4</td>
</tr>
<tr>
<td>Food waste compost</td>
<td>68.8</td>
</tr>
<tr>
<td>Brewery sludge compost</td>
<td>86.4</td>
</tr>
<tr>
<td>Yard waste compost</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Represents bacteria recovered from the various substrates that were suppressive to Pythium blight of creeping bentgrass caused by Pythium aphanidermatum; *High maintenance sites are exclusively from golf course putting greens; *Low maintenance sites are from cemeteries, home lawns, and parks that receive no external fertilizer or pesticide applications.

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