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Enhancing Turfgrass Disease Control with Organic Amendments

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The management of turfgrasses, particularly on golf courses, represents perhaps the highest level of plant management practiced on any agricultural or horticultural commodity known today. Proper turfgrass management involves a number of rather complicated mechanical, physical, chemical, and bio-

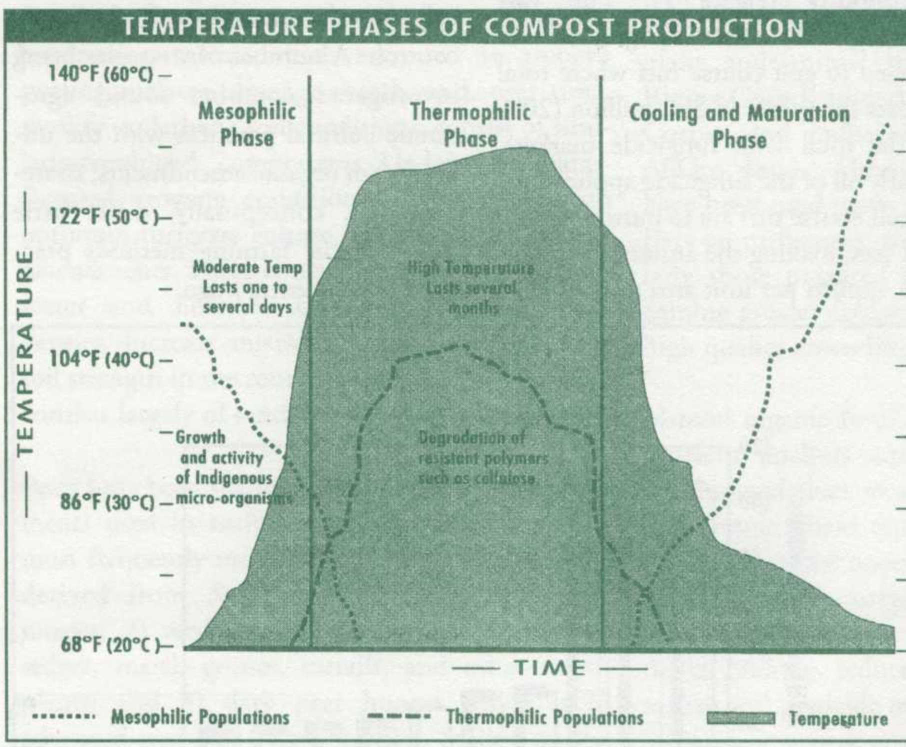

Figure 2.

PHASE I - Initial heating takes place and readily soluble components are degraded.
PHASE II - Cellulose and hemicellulose are degraded under high (thermophilic) conditions. This is accompanied by the release of water, carbon dioxide, ammonia and heat.
PHASE III - Curing and stabilization are accompanied by a drop in temperatures and increased humification of the material. Low temperature (mesophilic) microorganisms, including populations of microbial antagonists, recolonize the compost during this final cooling and maturation phase.

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logical manipulations that are used to achieve the desired goal: a blemish-free carpet of green grass. Because of this high degree of manipulation and the rigorous physical demands placed on turfgrass plants, considerable effort goes toward the maintenance of optimal soil conditions to maximize turfgrass growth and survival, and toward the management of plant stress levels in order to reduce the incidence and severity of pest outbreaks.

Highly maintained turfgrass sites characteristically use vast amounts of inputs in the form of fuel, fertilizers, pesticides, and water for irrigation. The intensity of fungicide use on turfgrasses in the United States is greater than that on any other agricultural commodity (Figure 1). The vast majority of those fungicides are applied to golf course turf where total dollars spent exceed $90 million (20% of the total U.S. fungicide market). Nearly all of the fungicide applications to golf course turf are to putting greens and tees, making the amount of fungicide applied per unit area quite high.

Currently, there are few reliable non-chemical turfgrass disease control strategies, making immediate reductions in fungicide use nearly impossible. Since many high-maintenance turfgrass sites are found in close proximity to surface waters and within critical groundwater recharge areas primarily in and around urban areas, questions have been raised as to the impact of such a land use on water quality, wildlife, and human health, particularly as it relates to pesticide exposures.

In recent years, greater research emphasis has been placed not only on documenting the environmental impacts of pesticide use on turf, but also on developing alternative biologically-based strategies for disease control. A number of strategies being investigated combine sound agronomic cultural practices with the utilization of organic amendments; strategies that, conceptually, differ little from organic farming methods practiced over a century ago.

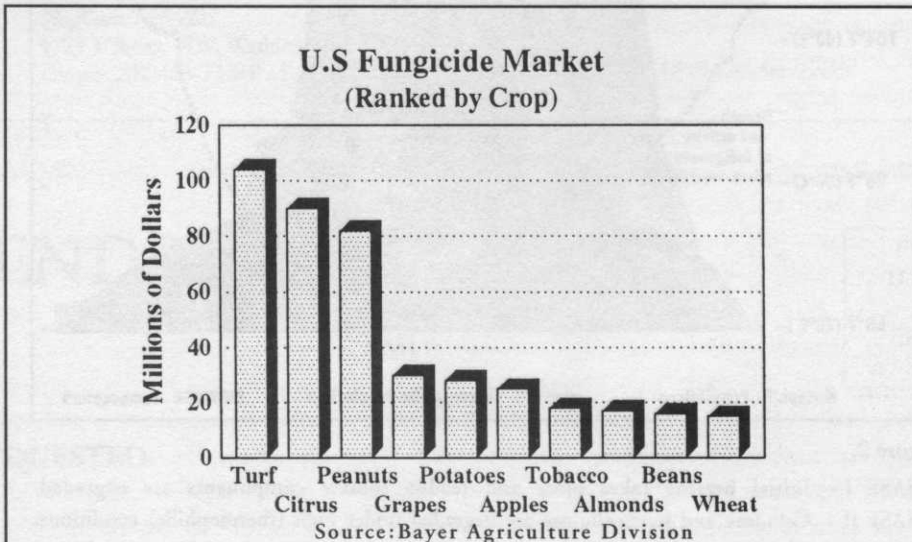


Figure 1.
Dollars spent annually for fungicide applications on various commodities in the United States. More dollars are spent on turfgrass fungicides than on any other plant grown.

The use of organic amendments in turfgrass management

Intensively managed turfgrasses, such as those on golf course putting greens, athletic fields, and other high-traffic areas, have traditionally been grown on soils modified through the addition of both organic and inorganic amendments. This is done to minimize soil compaction and other plant stresses, and to improve plant-soil relationships for the enhancement of turfgrass growth. Today, turf on golf course putting greens is commonly grown on completely artificial growth media similar to those used in the floriculture and nursery industries.

Newly constructed or renovated golf course putting greens are typically built according to specifications outlined by the United States Golf Association. These specifications call for root zone mixes that consist largely of sand mixed with some form of organic matter, usually peat. Similarly, topdressing mixes, which are used to smooth putting surfaces, manage thatch, and, over time, modify underlying soil conditions, consist of similarly-combined components. Under these manufactured growing conditions, a key element to optimum turfgrass culture is high quality organic amendments. These amendments serve to increase water and nutrient retention, decrease bulk density, increase microbial activity, and increase soil strength in the root zone profile that otherwise consists largely of sand.

Peats have been the most common type of amendments used in turfgrass management. The three most frequently used peats include: 1) moss peats derived from *Sphagnum, Hypnum,* and other mosses; 2) reed-sedge peats formed from reeds, sedges, marsh grasses, cattails, and other marsh plants; and 3) dark peat humus which is in advanced stages of decomposition. Studies on the physical properties of these amendments have shown that moss peats generally retain much more water than is suitable for root growth whereas the humus-type peats have other undesirable physical properties. Reed sedge peats, therefore, are the most desirable with respect to their physical properties.

Although the disease-suppressive properties of some peat-amended growing media used in the floriculture and nursery industries are well recognized, little is known of these properties relative to turfgrass culture. Disease suppression has not been observed on golf course putting greens amended with *Sphagnum*-type peats. However, amendment of sand-based putting green profiles with reed-sedge peat has been shown to induce suppressiveness to Pythium root rot of creeping bentgrass caused by *Pythium graminicola.*

Turf management with natural organic fertilizers

In recent years, turfgrass managers have increasingly turned to natural organic fertilizers for use on high maintenance turf. These types of fertilizers are prepared from a variety of organic wastes such as dehydrated sludges (e.g. Milorganite), plant and animal meals (e.g., products from Ringer Corp.), animal manures (e.g. from Sustâne Corp.), and industrial by-products (e.g., from AllGro, Inc.). Although uncomposted materials have been used more commonly as organic fertilizers on turfgrasses, composted materials, particularly those prepared from poultry manures, are gaining greater acceptance as widely available and high quality amendments.

Natural organic fertilizers generally have a higher nutrient analysis and are much more readily decomposed than most highly decomposed peats. As a result, these types of amendments support greater microbial populations and microbial activities important to turfgrass health. Benefits of using such natural organic fertilizers include reduced thatch buildup, reduced soil compaction, reduced nitrate and pesticide movement, increased levels of soil organic matter, and reductions in the incidence and severity of certain turfgrass diseases. It is this latter attribute that offers the greatest potential impact on turfgrass management, providing a cost-effective alternative to traditional fungicide disease control programs.

Natural organic fertilizers were shown as early as the mid to late 1960's, to be suppressive to turfgrass diseases. Natural organic fertilizers prepared from activated sewage sludge were more effective in suppressing dollar spot disease of creeping bentgrass caused by *Sclerotinia homoeocarpa* than were common inorganic nitrogen sources. Reduced dollar spot incidence was greater than could be explained just from the nitrogen applications alone, suggesting that other chemical and/or biological factors might be involved in dollar spot suppression.

In addition to activated sludges, other uncomposted natural organic fertilizers composed of plant and animal meals are also highly suppressive of dollar spot disease, providing greater than 75% disease control. These types of amendments have also been suppressive to other important turfgrass diseases but have had no effects or even increased the severity of others. With these materials, the suppressiveness observed is due, in part, to elevated soil populations of bacteria and fungi, but may also be related to increased water holding capacity or improved nitrogen nutrition.

A considerable amount of frustration has come with the use of natural organic fertilizers in turfgrass management. This has been due to variable turfgrass responses following the application of such amendments, and the sometimes unpredictable behavior of these amendments when incorporated into or applied onto turfgrass soils. Even though a wide variety of natural organic fertilizers give rise to positive plant growth responses and also reduce the incidence and severity of turfgrass diseases, occasionally variable and sometimes negative results are obtained. Among the more consistent and predictable types of amendments for eliciting positive effects on turfgrass plants have been composted materials.

The nature of the composting process

Composting is nothing more than the biological decomposition of organic constituents in wastes and other biological materials under controlled conditions. Composting relies exclusively on microorganisms to decompose the organic matter and, as a result, the process has biological as well as physical limitations. During composting, the environmental parameters (i.e. moisture, temperature, aeration) must be stringently controlled. This is necessary to maintain optimum microbiological conditions to ensure adequate rates of decomposition and to avoid the production of decomposition by-products that may be harmful to plant growth. To maintain proper temperatures, the composting mass must be large enough to be self-insulating but not so large that compaction results in reduced air exchange. The composting mass must be moist enough to support microbial activity but not excessively moist so that air exchange is limited. The particle size of the material must be small enough to provide proper insulation but not too small to limit air exchange.

When all the environmental and physical conditions are optimized, composting should proceed through three distinct phases (**Figure 2, see cover**). During the initial phase lasting from one to several days, depending on the type of starting material, temperatures in the internal portions of the composting mass rise as a result of the growth and activity of the indigenous mesophilic microorganisms associated with the starting organic material. During this self-heating phase, most of the soluble, readily degradable materials are broken down by these naturally-occurring microorganisms, precluding the need for additional inoculum. At this stage of composting, populations of microorganisms increase in magnitude and activity. The entire process is characterized by successions of both mesophilic (moderate-temperature) and thermophilic (high-temperature) microorganisms dominating during various phases of organic matter decomposition. Each microbial community makes an important contribution to the nature of the composted material. Failure to maintain environmental conditions favorable for adequate microbial activity could jeopardize the quality of the final product.

As temperatures increase above 100° F, the mesophilic populations are replaced by thermophilic populations capable of degrading most of the resistant organic materials such as cellulose and hemicellulose. During this stage of decomposition, microbial diversity decreases and only one or a few species of the bacterial genus, *Bacillus,* are active in decomposition processes.

The thermophilic phase may last several months, depending on the cellulose content of the material and the temperatures maintained during this period. Generally, the higher the cellulose content, the longer the thermophilic phase. Temperatures required for thermophilic decomposition range from 95 - 160° F. However, the highest rate of microbial activity and organic matter decomposition occurs at the lower end of the thermophilic range at temperatures of 95 - 135°F.

Increases in temperature above 135° F can be self-limiting to the decomposition process. To overcome these constraints, most composts need to be aerated either through repeated pile inversions or through forced air ventilation. Prior to placing in windrows, many composts are started in aerated vessel systems where temperatures can be regulated precisely and uniform decomposition can be maintained.

Since composting consumes much oxygen, aeration serves to keep the composting mass aerobic instead of anaerobic. Should composts become anaerobic, many toxic microbial metabolites can accumulate resulting in detrimental effects on plants coming in contact with such material. Additionally, undesirable odors are present in uncontrolled anaerobic composts. Most composts produced in a proper aerobic environment should have little or no odor associated with the decomposing mass. Aeration also serves as a means of drying the material making it more suitable for handling and transport.

As the cellulose and hemicellulose components are exhausted, the compost enters a curing or stabilization phase where temperatures decline, decomposition rates decrease and the thermophilic microbial populations are again replaced by mesophilic populations. In general, the longer the curing period, the more diverse is the colonizing mesophilic microbial community. It is this recolonizing mesophilic microbial community that is most important in suppressing turfgrass diseases since large proportions of the recolonizing microbes are antagonists that render the compost Zdisease-suppressive. Unfortunately, there is no reliable way to predict the disease-suppressive properties of composts since the numbers and types of recolonizing microbes are left to chance -- determined largely by the types of microbes present at the composting site.

The organic matter contents and the availability of that organic matter for microbial growth varies considerably from compost to compost. Organic matter content may be as low as 25-30% in composts produced in windrows on soil to as high as 85% for some composts produced in concrete-lined vessel systems. Generally the higher the organic matter content of the compost, the greater the size and activity of its microbial population.

Suppressiveness of compost amendments to turfgrass diseases

Of all the natural organic materials commonly applied to turfgrasses, composted amendments have been among the most consistently effective in reducing the severity of turfgrass diseases. Composts commonly applied to established turfgrasses or used in sod production include those prepared from animal manures (e.g., poultry, cow, and horse manures), municipal biosolids, industrial sludges, leaf and yard wastes (including grass clippings), food residuals, and mixed solid waste (MSW). Results of studies conducted over the past 10-15 years have clearly shown the potential for compost amendments to reduce the severity and incidence of a wide variety of turfgrass diseases, particularly when applied either as a topdressing, a winter cover, a root zone amendment, or as an aqueous extract (compost tea).

Topdressing amendments

Golf course superintendents routinely topdress putting greens with a thin layer of sand, sand/organic matter, or sand/organic matter/soil mixtures. The purpose of topdressing is primarily to smooth putting surfaces and to manage thatch, but also to modify gradually underlying soil properties. Among the goals of amending topdressing mixes with composts are to increase the nutrient and water holding capacities of sand-based growth media and also to convert a relatively biologically-inert material into a biologically-active soil amendment. Yet, most typically, the organic component of a topdressing mix consists of sphagnum peat. Many sphagnum-based mixes contain little or no disease suppressive activity. Numerous studies using container media have verified this property.

Studies have shown that monthly applications of topdressings composed of as little as 20% compost by volume applied at rates of 10 lbs compost/1000 ft^2 are effective in suppressing foliar as well as root diseases of turfgrasses. For example, diseases such as dollar spot, brown patch, Pythium root rot, Typhula blight, and red thread have been effectively reduced following topdressing applications of various composted materials. Reductions in severity of Pythium blight, summer patch (E.B. Nelson, *unpublished observations*) and necrotic ringspot have also been observed in sites receiving periodic applications of composts. The levels of disease control vary widely (Figure 3), ranging from 0-94%, depending on the target disease, the compost feedstock, and the manner and degree to which the material is composted.

While the short-term magnitude of turfgrass disease control using compost-amended topdress-

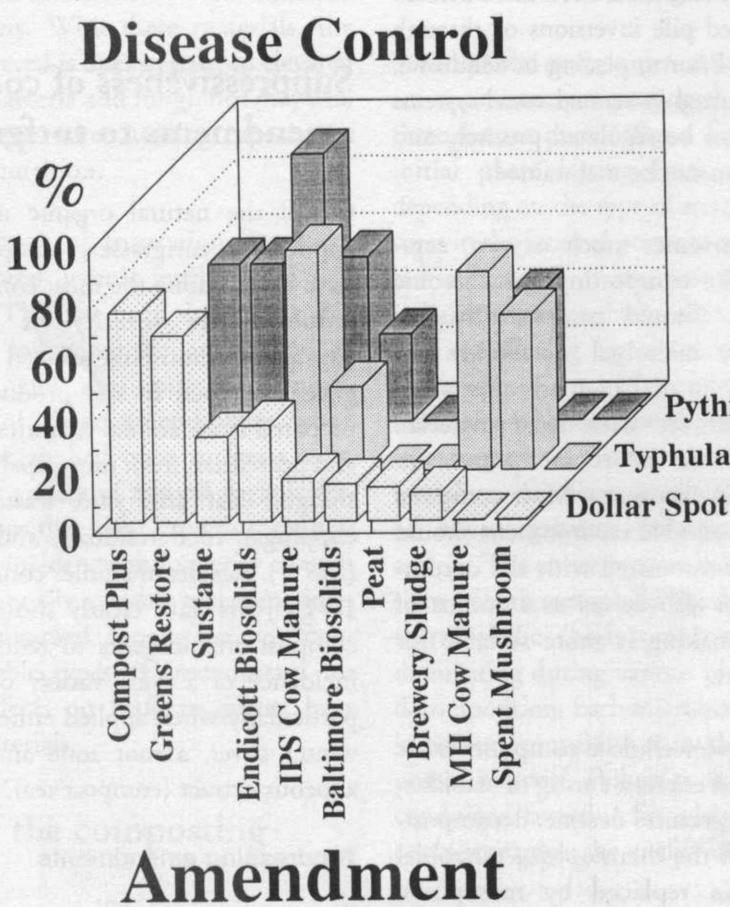


Figure 3. Differential suppression of three turfgrass diseases with composts prepared from different feedstocks.

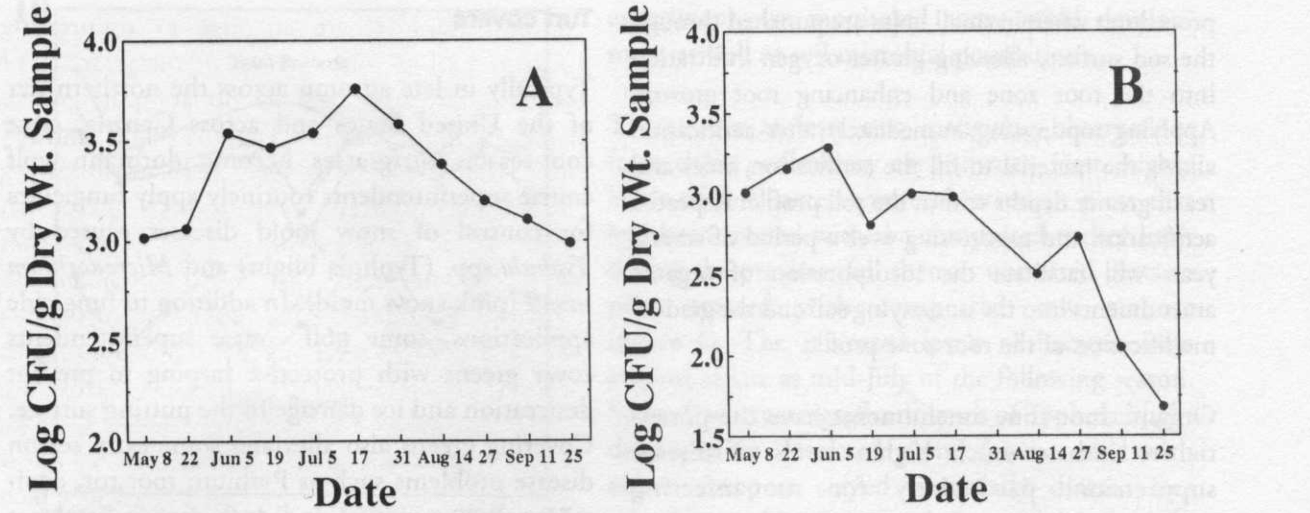


Figure 4. Populations of Pythium species in creeping bentgrass putting greens A) receiving repeated fungicide applications or B) receiving one compost application applied the previous fall at rates of 200 lb/1000 ft^2.

ings may not match that typically achieved with fungicide applications, the longer-term level of control often equals or exceeds that attainable with fungicides. This is, in part, related to the ability of composted topdressing amendments to gradually reduce populations of some pathogens in turfgrass soils (Figure 4), an effect not realized with fungicide applications. The level of turfgrass quality is also greatly enhanced over what one would typically get with fungicide applications. The reasons for this are undoubtedly due to many poorly understood mechanisms of growth enhancement and pest suppression. In some cases, the improved quality following compost applications can be evident years after compost applications cease (Figure 5).

Root-zone amendments

Soil organic amendments have been used for centuries in soil and crop management and have been an integral part of turfgrass management for decades. Aside from preplant soil modification, the addition of soil organic amendments to mature turfgrass stands is somewhat problematic. The difficulties of amending turfgrass soils without damaging plants is largely overcome by aerification

Figure 5. Long-term effects of compost applications on turfgrass quality. Note the enhanced turf quality as indicated by the darker shading of turf previously treated with composts. The last application of composts to these plots was 14 months prior to the photograph.

procedures wherein small holes are punched through the sod surface, allowing greater oxygen infiltration into the root zone and enhancing root growth. Applying topdressing immediately after aerification allows the material to fill the aerification holes and reach greater depths within the soil profile. Repeated aerification and topdressing over a period of several years will facilitate the incorporation of organic amendments into the underlying soil and the gradual modification of the root-zone profile.

Organic root-zone amendments have the potential to induce much higher levels of disease suppression, particularly for root-infecting pathogens, than topdressing amendments since greater quantities of material can be placed in the root zone. Additionally, preplant organic amendments incorporated into root zones such as those used in sand-based golf course putting greens may have dramatic long-term disease control efficacy. In studies conducted at Cornell University, we have found that amending sand-based greens with a municipal biosolids compost, a brewery sludge compost, or a reed sedge peat induces a high level of suppression of Pythium root rot disease. In our studies, these amendments provided complete control 6 months after incorporation and retained their suppressive properties for as long as 4 years.

One of the concerns of using compost amendments in this way, particularly on USGA specification sand-based greens having a perched water table, is that over time, as the organic materials decompose, the smaller particles may clog pores and interfere with the drainage properties of the root zone profile. Also, there has been a perceived phytotoxicity hazard from the byproducts of anaerobic decomposition of organic materials in the perched water table zone of USGA-type golf greens. To date there has been no long-term research to address these issues. However, as a general guideline, organic materials and incorporation rates should be chosen such that the organic matter content of this growing medium does not exceed 3.5%. This will help to maintain more ideal physical properties so that many of the problems mentioned above may be avoided.

Turf covers

Typically in late autumn across the northern tier of the United States and across Canada, once cool-season turfgrasses become dormant, golf course superintendents routinely apply fungicides for control of snow mold diseases caused by *Typhula* spp. (Typhula blight) and *Microdochium nivale* (pink snow mold). In addition to fungicide applications, some golf course superintendents cover greens with protective tarping to prevent desiccation and ice damage to the putting surface. Covering greens also alleviates some early season disease problems such as Pythium root rot, cool-season brown patch, and anthracnose basal rot since protected turf comes out of dormancy in a less-stressed condition and is not as predisposed to diseases as uncovered turf. Results of preliminary studies have indicated that a dormant application of certain composts to golf course putting greens in the late autumn appears to be a promising substitute for artificial turf covers, allowing golf course superintendents to protect greens not only from winter damage, but also from snow mold damage.

The insulating properties of the compost, combined with its dark heat-absorbing properties, will help to retain soil heat and at the same time, absorb additional heat on sunny winter days. Additionally, the compost will harbor many different microbes and also stimulate the activity of native soil microbes. The activity of each group can potentially provide a significant level of disease control. The elevated temperatures under a compost cover should provide conditions for microbial activity, even during the winter months. Collectively, these conditions should discourage the development of snow mold diseases and reduce the risk of winter turfgrass damage.

In our studies, plots were treated with either a turkey litter (Sustāne®) or a cow manure compost in late November at rates of 200 lb/1000 ft^2. This rate corresponded to an application depth of approximately $^1/_2$ inch. Excess compost that was not incorporated into the turfgrass canopy over the winter was removed from the greens in late March the following spring. During the course of the

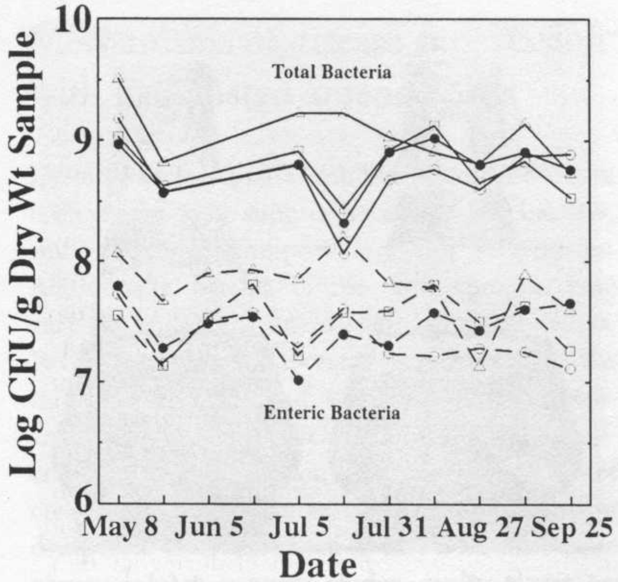
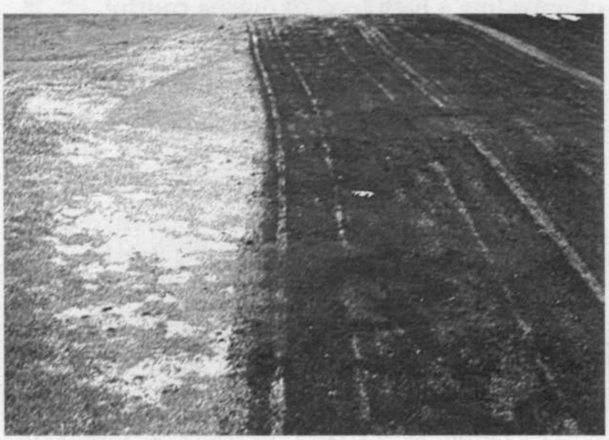
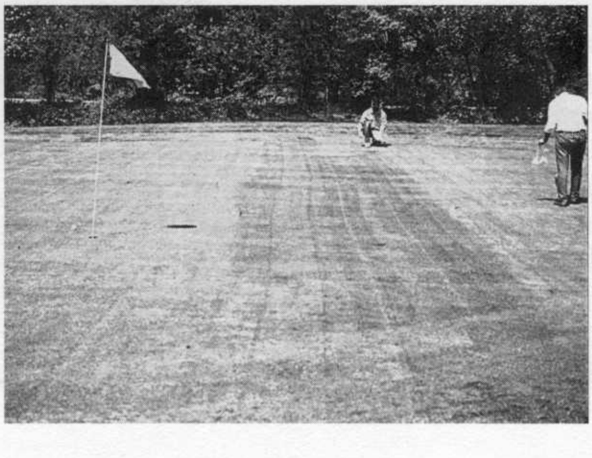


Figure 6. Population of soil bacteria throughout the course of a season following applications of compost the previous fall to a creeping bentgrass/annual bluegrass putting green. Note the elevated populations through July of the following season following applications with a turkey litter compost (Sustane®). Enteric bacteria refer to a specialized group of bacteria, many of which have important biological control properties.

Figure 7. Plots receiving dormant applications of compost.



A) Typhula blight on untreated areas of putting green. Under the compost cover, turf is free of any Typhula blight.



B) Spring green-up following dormant fall applications of compost.

experiment, we monitored snow mold development as well as soil microbial populations.

There were at least two intriguing observations from these preliminary experiments. First, higher levels of soil bacteria were observed in plots that had been treated with the composted turkey litter during the previous fall than in untreated plots or plots treated with composted cow manure (Figure 6). The increased levels of bacteria were evident as late as mid-July of the following season. Second, whereas significant levels of Typhula blight developed in untreated plots, those treated with either compost stayed essentially disease free throughout the winter and were of substantially higher quality the following spring (Figure 7).

This type of application strategy has promise for providing long-term disease control at least through spring and early summer when turf is susceptible to a number of disease problems. It may also provide a means of maintaining elevated levels of microbial activity and potentially reducing populations of pathogens in golf course putting greens.

Compost extracts

When applied as preventive treatments, aqueous compost extracts (also called compost teas) have been shown to control numerous foliar diseases as well as *Pythium ultimum* damping-off on a wide variety of crops. Extracts are generally prepared by mixing one volume of compost with 5-10 volumes of water (Figure 8). After soaking at ambient temperatures for 3 to 14 days, the solids are removed and the extract applied as a foliar spray or a soil drench.

Recent studies in our laboratory have verified the suppressive nature of compost extracts to diseases caused by *Pythium* species and have focused on the mechanisms by which compost teas 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 4 to 7 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 65-70^0 F also reduce the suppressive activity of the extract. Applications of different compost extracts, prepared by "brewing" for 4 days at 68^0 F and applied at 5-6 gal./1000 sq. ft, resulted in different levels of Pythium root rot suppression on creeping bentgrass turf (Table 1).

Table 1. Suppression of foliar symptoms of Pythium graminicola-incited root rot of creeping bentgrass with compost extracts

Compost Extract	% Area Symptomatic (± Std. Dev.)
None (untreated)	31 (13.4)
Chicken Manure Compost	25 (13.2)
Chicken/Cow Manure Compost	12 (5.7)
Brewery Sludge Compost	22 (5.7)
Turkey Litter Compost	19 (12.0)
Leaf Compost	35 (10.0)

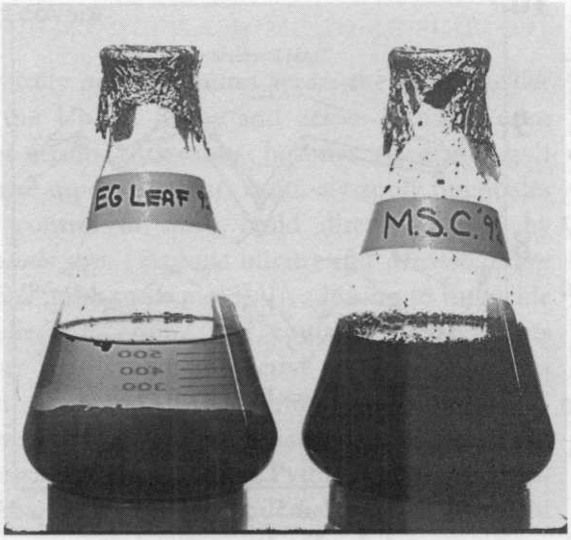


Figure 8. Compost extracts prepared from a yard waste compost (left) and a municipal biosolids compost (right).

The microbiological properties of extracts reveal important information about the ways in which composts and compost extracts suppress diseases. Only a limited number of composts have produced extracts with significant levels of turfgrass disease suppression. In those composts the microbial components of the extract, when isolated, suspended in water, and applied to turf, were capable of providing a high level of disease control.

Interestingly, individual microbial strains from non-suppressive extracts will also provide a high level of disease control, even though the original compost was also not suppressive (e.g., yard waste composts). Clearly, non-suppressive 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 control. 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 may then be used as compost inoculants or may be developed in their own right into biological disease control preparations.

Mechanisms of disease suppression with composted amendments

Despite the fact that a number of composts have been shown to be suppressive to 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 composted materials tested to date have been those prepared from brewery sludge, turkey litter, or from some batches of municipal biosolids. All batches of a brewery compost and a few batches of certain municipal biosolids composts, when allowed to age for a suitable period of time (2-3 years), have been highly suppressive (**Figure 9**).

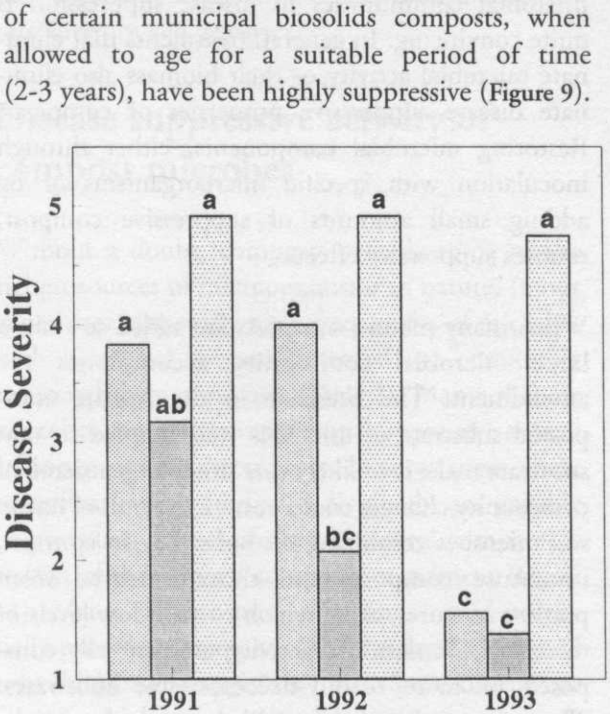


Figure 9. Increase in suppressiveness of a biosolids and a brewery waste compost to Pythium damping-off of creeping bentgrass with increasing compost age. Disease severity rated five days after sowing on a scale of 1-5 for which 1=asymptomatic turf and 5=100% nonemerged or necrotic seedlings. Ratings represent the mean of at least three separate bioassay experiments conducted in each of the three years. Columns with the same letter are not statistically different.

Furthermore, these materials contain relatively high populations of heterotrophic bacteria, actinomycetes, and fungi. These organisms can be eliminated by heating, but can be partially restored by incubating sterilized compost with small amounts of non-sterile 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 (1-3 mos) composts prepared from these same materials and still under going thermophilic decomposition are not suppressive to *Pythium graminicola.*

With the exception of antagonist–fortified compost, composts prepared from yard and lawn trimmings also do not suppress 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 in these materials 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 compost from brewery sludge and municipal biosolids 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 (**Figure 10**).

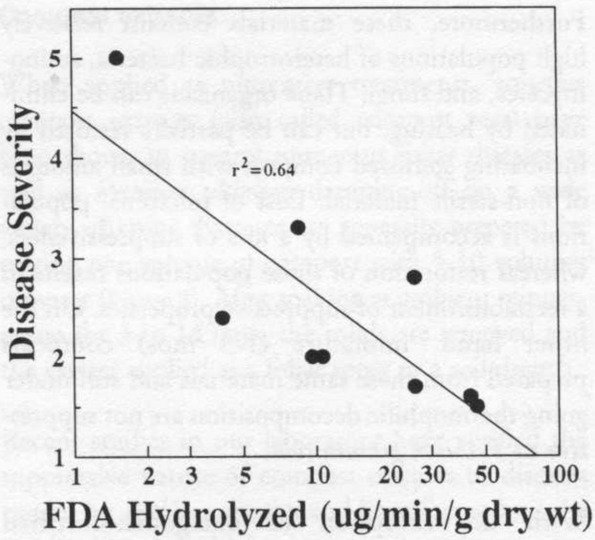


Figure 10. Relationship between microbial activity (as measured by FDA hydrolysis) and the severity of Pythium damping-off of creeping bentgrass seedlings grown in different composts. Disease severity rated five days after sowing on a scale of 1-5 for which 1=healthy turf and 5=100% nonemerged or necrotic seedlings. Each data point represents the mean of at least eight replicates for disease severity and three replicates for FDA hydrolysis. The composts used were four different batches of brewery sludge, two batches of a municipal biosolids, a batch of leaf/chicken manure, a batch of horse manure, and a batch of leaves.

From examining a number of suppressive and non-suppressive non-poultry composts, a direct and inverse relationship was established between microbial activity (expressed as the amount of fluorescein diacetate [FDA] hydrolyzed) in each of the compost samples and disease severity. These results also corroborate those of others in which direct relationships were observed between the amount of microbial activity and severity 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 the more suppressive composts.

We have learned that, 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 turfgrass pathogens and diseases.

Microbial communities and disease suppression

In studies with various types of composted amendments, evidence for the role of the activities of microbial communities in disease suppression is quite convincing. In general, treatments that eliminate microbial activity or their biomass also eliminate disease suppressive properties of composts. Restoring microbial components, either through inoculation with specific microorganisms or by adding small amounts of suppressive compost, restores suppressive effects.

When many mature composts are added to soils, a large microbial community accompanies the amendment. The presence in the mature composted substrate of microbes well adapted to that substrate make it unlikely that other large microbial community changes could occur as a result of native soil microbes colonizing the substrate. In contrast, immature composts and those prepared from poultry manures, all of which contain low levels of microbial biomass and activity, are generally composed of more readily-decomposable substrates. These composts are more likely to serve as substrates for microorganisms already present in the 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 microorganisms 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 matter availability and quality, coupled with microbial community dynamics in amended soils, is critical to an understanding of how diseases are suppressed in compost-amended soils. Critical gaps in our understanding of disease suppression by composted soil amendments lie in our limited knowledge of the biochemical changes in organic amendments which occur 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

Without a doubt, composts provide some of the richest sources of microorganisms in nature. In our experience, unusually high frequencies of microbes with biological control potential are commonly recovered from composts (Table 2). Many of these microbes can be recovered from suppressive as well as non-suppressive 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 (Figure 11). Many of these microorganisms could potentially provide the potential for the development of microbial-based fungicides for turfgrass diseases or for microbial compost inoculants. A few research groups around the world are currently investigating the possibility of using microbes with high biological disease control potential to inoculate composts as temperatures descend from the thermophilic phase into the cooling and maturation phase. At this stage, microbial activity is relatively low, making it easier to establish known biocontrol organisms. In this way, composts may be made more predictably suppressive. In fact, microbially-fortified yard waste composts have been suppressive to dollar spot disease on creeping bentgrass. Products based on this technology are expected in the next few years.

Table 2. Recovery of microbial antagonists from different composts as compared with turfgrass and non-turfgrass soils

Source of Microbes	% Microbes with Biocontrol Potential
Non-Turfgrass Soil	40.6
Turfgrass Soil (High Maintenance)a	41.3
Turfgrass Soil (Low Maintenance)b	45.6
Chicken Manure Compost	68.4
Food Waste Compost	68.8
Brewery Sludge Compost (1992)	85.7
Brewery Sludge Compost (1991)	86.4
Yard Waste Compost	100.0

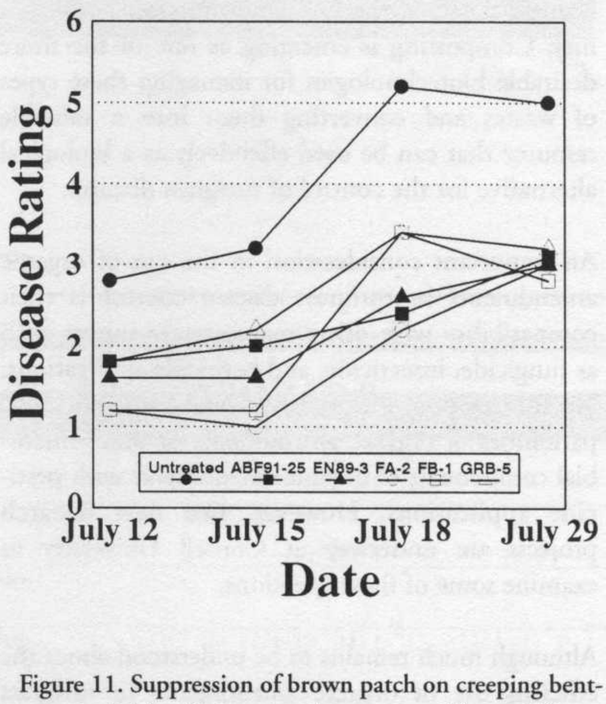


Figure 11. Suppression of brown patch on creeping bentgrass in field trails by microbes recovered from different composts. Plots rated on a scale of 0-10 where 0=asymptomatic turf and 10= 100% of the plot area diseased.

The future of organic amendments for turfgrass disease control

One of the greatest obstacles to the widespread acceptance of organic amendments for turfgrass disease control has been the inconsistent performance from site to site, batch to batch, and year to year. Much of the unpredictable nature of organic 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 turfgrass soils or when applied as topdressings. Increased research efforts in this areas will eventually make organic amendment use more predictable and manipulable.

As sources of peat continue to diminish, the use of alternative organic components of topdressings and construction mixes will continue to be identified. In particular, industrial and municipal wastes are being viewed as potentially important sources of organic amendments. The management and recycling of municipal and industrial wastes is one of 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 wastes and converting them into a valuable resource that can be used effectively as a biological alternative for the control of turfgrass diseases.

An important consideration in the use of organic amendments in turfgrass disease control is their 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. However, two new research projects are underway at Cornell University to examine some of these questions.

Although much remains to be understood about the efficient use of organic amendments in turfgrass 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 turfgrass health.

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Additional Reading

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4. Waddington, D. V. 1992. Soils, soil mixtures, and soil amendments. pp 331-383 In: Turfgrass. Agronomy Monograph No. 32, American Society of Agronomy, Madison, WI.
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Glossary

Aerobic	Conditions in the presence of or requiring oxygen.
Anaerobic	Conditions in the absence of or not requiring oxygen.
Brewery Sludge	Solids in the wastewater from a brewery (includes the rinsewater from brewing vats, floors, etc) that has undergone an anaerobic waste water treatment. The sludge is mixed with wood chips before composting. This sludge does not include spent grains from the brewing process.
Feedstock	The organic material used to prepare composts.
Fluorescein Diacetate	A chemical that breaks down from the action of microbial metabolism into a fluorescent pigment that can be easily measured. It is used to estimate the amount of microbial activity in soils since the amount of fluorescent pigment produced is directly related to the level of microbial metabolism.
Food Residuals	Food waste from cafeterias and food processing plants.
Mesophilic	Conditions associated with moderate temperatures. Usually refers to temperatures not greater than 85-90° F.
Municipal Biosolids	A relatively recent term to describe sewage sludge.
Thermophilic	Conditions associated with high temperatures. Usually refers to temperatures in excess of 95-100° F.
Turkey Litter	Manure and bedding from turkey production.
Windrow	Long, narrow piles of compost, usually placed directly on the soil surface. These are turned periodically to improve aeration and expose particles to thermophilic decomposition.
Yard Waste	Includes leaves, twigs, and grass clippings in various proportions.

In Future Issues

- Field Testing of Biological Pesticides
- Heat Stress and Creeping Bentgrass
- Fungicides: Handling Applying and Monitoring
- Nitrogen Usage

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