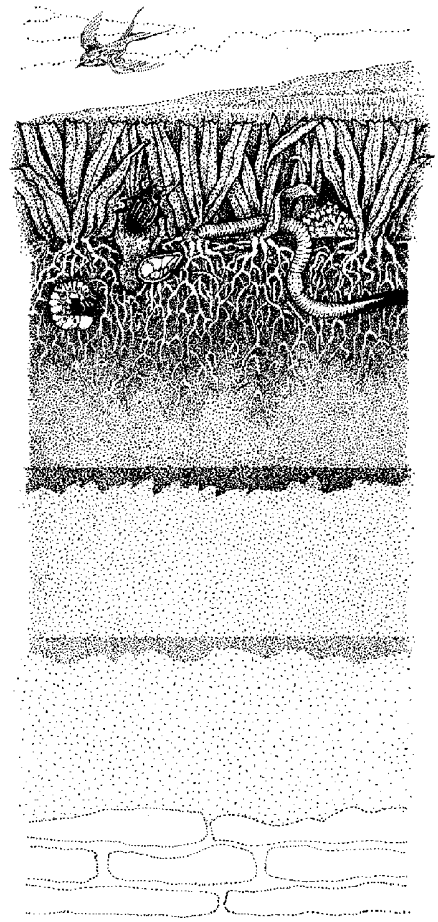
CORNELL UNIVERSITY TURFGRASS TIMES

CUTT

Spring 1998 • Volume Nine • Number One • *A Publication of Cornell Cooperative Extension*



Understanding Seed Treatments for Turfgrass Establishment

Seedling establishment is the most critical stage in new turfgrass installations or renovations. Establishment efficiency can be affected by many different factors including speed of germination, inherent competitiveness with other turfgrass varieties as well as grass and broadleaf weed species, and susceptibility to seed rotting and damping-off pathogens. These pathogens are perhaps the most troublesome yet one of the most infrequently recognized cause of establishment failures. To understand ways of improving stand establishment, it is important to understand the nature and control of seed rotting and seedling pathogens of turfgrasses. ■

Seed and Seedling Pathogens of Turfgrasses

As mentioned previously, many times the major limiting factors to stand establishment are seed rotting and damping-off fungi. The more common seed and seedling rotting fungal pathogens include species of *Pythium*, *Fusarium*, and *Rhizoctonia*, along with a myriad of other minor species comprising over 15 fungal genera. Few studies have focused on the ecology, epidemiology, and control of *Fusarium*- and *Rhizoctonia*-incited damping-off diseases of turfgrasses. However, turfgrass seedling diseases caused by *Pythium* species have been widely studied and this group of turfgrass pathogens are perhaps the most important in limiting stand establishment .

Not only are *Pythium* species major seed rotting and seedling rotting pathogens, but, once established in a turfgrass planting, become major root rotting pathogens as well. In a survey if pathogenic *Pythium* species recovered from mature bentgrass turf, the more aggressive creeping bentgrass damping-off pathogens included *P. graminicola*, *P. aphanidermatum*, *P. aristosporum*, *P. vanterpoolii*, *P. myriotylum*, *P. tardicrescens*, and *P. volutum*. All of the highly aggressive isolates were more virulent to creeping bentgrass seedlings at warm temperatures (28°-32°C) than at cooler temperatures (16°C).

In another study of *Pythium* species on creeping bentgrass and perennial ryegrass, *Pythium graminicola* was isolated most frequently from mature stands of turfgrasses and nearly all isolates tested were highly virulent as seed rotting pathogens of creeping bentgrass and perennial ryegrass. Additional pathogenic species recovered were isolates of *P. aphanidermatum*, *P.*

continued on page 4

This Times

Short Cutts

Grants, progress reports and subsequent publications and presentations are available in the Cornell Turfgrass Annual Report, published in August for the Field Day.

Frank Rossi points out characteristics of bluegrass cultivars at the 1997 Field Days at Cornell.

Cornell Turfgrass Program has a Successful Granting Season

The primary source of income to operate our the research programs comes from actively pursuing “extramural funding.” No turfgrass team member has an operating budget from the state or college. Simply, our team members must write grant proposals to address specific scientific or educational needs to public organizations such as the United States Dept. of Agriculture, the Environmental Protection Agency, or the NY State IPM Program. In addition, we compete with our national colleagues for industry dollars from the United States Golf Association, Golf Course Superintendents Association, and Turfgrass Producers International. Of course, we also rely heavily on support from the New York State Turfgrass Association, the Regional Golf Superintendent Associations, and the Tri-State Turf Research Foundation to answer more applied questions. As you might imagine, actively pursuing these funds consumes at least 30% to 50% of our time as researchers and educators.

Drs. Villani and Nelson continued their successes by receiving additional funding from the USDA for their basic research activities on the ecology of turfgrass insects and diseases. Drs. Rossi and Petrovic will be receiving funding for the development of Best Management Practices for Golf Courses in the NY City Watershed from the EPA. In addition, Dr. Villani received another three year grant from he USGA to continue his collaborative work on mole crickets. Another exciting area included a partnership among Eric Nelson, David Chinery, our turfgrass specialist in the Capital region, the Northeast Golf Superintendent Association, and the GCSAA. This project looking at microbial disease management on the golf course was selected from a very competitive pool of projects on a national level.

In state, all team members benefit from the annual grant from NYSTA that enables us to move forward with a variety of initiatives from predicting grub infestations to disease management in the seedbed, to the fate of pesticides, and even the weekly turfgrass conference call (Hotline) for specialists and agents. Finally, several projects received funding form the NYS IPM program to address the pest management needs throughout the state. This program coordinated by Team Member, Rod Ferrentino and facilitated by Drs. Nelson and Villani has supported research and educational programs in turfgrass management for over a decade.

We continue to seek new funding opportunities to help us, help the industry become more resource efficient, providing a high quality, safe, and environmentally beneficial turf with reduced inputs. These grants, the progress reports, and the subsequent publications and presentations are all available for your information in Cornell Turfgrass Annual Report, published in August for the Field Day. If you’d like a copy of last year’s report contact the program office at (607) 255-3090.

Take the Bus to the Golf Turf Field Day in 1998!

In effort to highlight our specific research activities in golf turf, the Cornell Turfgrass Program is proud to announce the first Golf Turf Research Field Day scheduled for Tuesday August 18, 1998. This day will allow golf superintendents the opportunity to view the “cutting edge” research being conducted at Cornell on alternative pest management, such as nematodes, microbial fungicides, non-chemical weed control; putting green establishment and grow-

continued on page 14

CUTT, "Cornell University Turfgrass Times" is published four times per year by Cornell Cooperative Extension and the Turfgrass Science Program at Cornell University, Ithaca, New York 14853. Address correspondence to: *Cornell University Turfgrass Times*, 20 Plant Science Building, Cornell University, Ithaca, NY 14853; telephone: (607) 255-1629

Editor: Frank Rossi
Masthead Illustration: Benn T.F. Nadelman
Illustrations: Timothy Tryon, Patti Zimmerman, Kenn Marash
Design & Production: Ghostwriters, inc., Ithaca, NY

Scanning the Journals

A review of current journal articles

The Naturalistic Golf Course

Max Terman, a faculty member of the Biology Department at Tabor College in Hillsboro, KS, has opened an important scientific discussion regarding the influence of a golf course on wildlife habitat. In his article, "Natural Links: Naturalistic Golf Course as Wildlife Habitat" he uses a comparison between two adjacent properties in Kansas. One managed area is the Prairie Dunes Country Club and the other is the Sand Hills State Park. The Sand Hills Park is considered a low impact area with minimal human disturbance, while the golf course regularly considered in the top 25% of the world is considerably more managed and certified as a cooperative sanctuary through Audubon International.

This study surveyed the abundance and diversity of bird species on each property. He classifies the bird population according to a previously developed system that labels them, urban avoiders, urban exploiters, and suburban adaptable species. While the two managed lands had shared many species, the golf course had more urban exploiter and suburban adaptable species. Simply, the golf course was able to sustain species that had unrestricted habitat needs and higher tolerance for disturbance, while the State Park had habitat sensitive birds that require areas away from human disturbance. Interestingly, the State Park had more species (greater diversity), it had 15 different species that were not found on the golf course, however, the park had less individuals, i.e. a greater number of birds in total were found on the course.

The article continues to discuss the ecology of a golf course as it pertains to fragmenting habitat, how large unused areas are vital for encouraging threatened species, the role of architects, and how golf course development done properly is a progressive approach to habitat preservation. The article concludes by elaborating on management topics that most turf managers are familiar with, but relates them to how they effect the wildlife habitat. Golf course management should be viewed as ecosystem management. "When niche, corridor, buffer zone, ecotone, foraging area, and nesting site, join bogey, par, birdie, and eagle on a naturalistic golf course, all take on more meaning and significance."

From: Terman, M.R. 1997. Natural Links: Naturalistic Golf Courses as Wildlife Habitat. Landscape & Urban Planning, 38:183-197.

Selecting Water Efficient Bluegrass Cultivars

As concern for water use in turfgrass management grows in many parts of the country, the need for cultivars that use less is a primary component of the solution. Furthermore, many unirrigated, high use turf areas could benefit from cultivars that are wear tolerant, have adequate recuperative ability, and are aesthetically pleasing.

Dr. Scott Ebdon, former graduate assistant at Cornell, now Assistant Professor at the University of Massachusetts, and Cornell Turfgrass Team member Marty Petrovic have attempted to develop a system to evaluate the water use of Kentucky bluegrass cultivars. This system could be used by breeders through the collection of simple measurements such as leaves per shoot, leaf width, leaf angle, vertical leaf extension, etc.

The results of this exhaustive investigation suggest that cultivars that have a higher shoot density and more horizontal leaf orientation, as well as cultivars with slow vertical leaf extension and narrow leaf width, use less water. This type of information could be used by turfgrass breeders who are striving to improve water use efficiency among bluegrass cultivars.

From: Ebdon, J.S. and A.M. Petrovic. 1998. Morphological and Growth Characteristics of Low- and High Water Use Kentucky Bluegrass Cultivars. Crop Sci. 38:143-152.

"When niche, corridor, buffer zone, ecotone, foraging area, and nesting site, join bogey, par, birdie, and eagle on a naturalistic golf course, all take on more meaning and significance."

The results suggest that cultivars with higher shoot density and more horizontal leaf orientation, as well as cultivars with slow vertical leaf extension and narrow leaf width, use less water.

Turfgrass Establishment

continued from front cover

Pythium *damping-off of turfgrasses is known to be affected by a number of factors which directly impact establishment efficiency:*

- ***Germination time***
- ***Soil Moisture and Oxygen Levels***
- ***Soil Temperatures***
- ***Planting Depth***
- ***Sowing Density***
- ***Cultivar Selection***

aristosporum, *P. torulosum*, and *P. vanterpoolii*. At least one isolate within each species was highly virulent to creeping bentgrass seeds and seedlings. *Pythium torulosum* was the most frequently recovered species from turfgrass roots and crowns, but nearly all isolates were nonpathogenic. Five pathogenic isolates of *P. torulosum* were recovered and, with the exception of one isolate, all were only weakly virulent to creeping bentgrass seedlings at cool (13° C) or warm (28° C) temperatures.

Conditions Favoring Pythium Damping-Off of Turfgrasses that also Affect Stand Establishment

Pythium damping-off of turfgrasses is known to be affected by a number of factors which directly impact establishment efficiency. These include a number of important environmental and cultural factors and are described below:

1) Germination time. The longer seeds spend in moist soil, the greater the potential for seed and seedling rots. Kentucky bluegrass may take 2-3 weeks after planting before emergence whereas fescues and bentgrasses may take a week to 10 days. Perennial ryegrasses generally require less than 1 week for emergence.

2) Soil Moisture and Oxygen Levels. All *Pythium* species require abundant moisture for germination and dispersal. Prolonged wet soils will favor seed and seedling rots. Unfortunately, these prolonged wet periods are necessary for adequate seed germination and seedling establishment. Generally the greater the soil moisture, the lower the oxygen levels in soil. Increased soil compaction also decreases soil oxygen levels by decreasing the amount of air-filled porosity.

3) Soil Temperatures. *Pythium* species are capable of inciting severe seed and seedling rots at both cool and warm temperatures. In our laboratory, we have found that the majority of *P. graminicola* isolates and all *P. aristosporum* isolates recovered from mature stands of turf are highly virulent as seed and seedling rot pathogens at both 13° and 28° C. In these studies, damping-off severity of specific isolates of *P. graminicola* and *P. vanterpoolii* on creeping bentgrass was favored by either cool or warm temperatures, depending on the isolate. Although isolates of *P. aphanidermatum* were virulent at both temperatures, in general, they were more virulent at 28° C than at 13° C. At 28° C, some isolates of *P. graminicola, P. aphanidermatum* and *P. aristosporum* were pathogenic to perennial ryegrass in growth chamber experiments, whereas none of the isolates of *P. torulosum* and *P. vanterpoolii* were pathogenic. On perennial ryegrass, isolates of *P. graminicola* ranged from nonpathogenic to highly virulent. Because of the wide temperature optima of individual strains as well as the presence of both cool temperature and warm temperature strains in many turfgrass soils, it is difficult to find temperature conditions that are not favorable for seed and seedling diseases caused by *Pythium* species.

4) Planting Depth. Planting depth affects susceptibility of seedlings to damping-off by increasing the amount of time susceptible tissue spend in soil exposed to pathogens. The more quickly the seedling emerges, generally the more quickly the plant can escape infection from seed rotting pathogens.

5) Sowing Density. Seeds of turfgrasses are sown into a variety of habitats. Typically, seeds are sown into a well-prepared plant-free seed bed or they are overseeded into an established turfgrass stand. It is typical practice to continually overseed thinning areas of turf or to transition from a warm-season grass to a cool season grass. In both cases seeding rates are generally excessive. The notion among most turfgrass managers is the more seed you sow the better the stand. However, it has been shown in studies with other plant species that increased seedling densities may enhance *Pythium* damping-off severity. The increased seedling densities are comparable to increasing the soil inoculum of *Pythium*. Increasing the seedling density increases the germination frequency of *Pythium* propagules and also enhances the plant-to-plant spread of the pathogen.

6) Cultivar Selection. A number of studies of Pythium resistance among turfgrass species and cultivars have been conducted. Results from such evaluations are considerably incomplete, inconsistent, and focused on *Pythium* blight of mature stands of turf, not on damping-off of seedling turf. In early surveys of a limited number of turfgrass species, nearly all of the cool-season grasses, including creeping bentgrasses, were all susceptible to foliar blights caused by *P. aphanidermatum* or *P. ultimum* whereas warm-season species were not. However, results from a more detailed study of creeping bentgrasses in Georgia indicate that cultivars such as Providence, Penneagle Emerald, Cobra, Putter, and others were more resistant to foliar blighting caused by *P. aphanidermatum* than were cultivars such as Penncross, Pennlinks, and National. In contrast, results from a similar study in Texas suggest somewhat the opposite: that cultivars such as Providence were the most susceptible to foliar blighting caused by *P. aphanidermatum* whereas Pennlinks, Penncross, and National were among the most resistant. These conflicting results suggest that some level of *Pythium* blight resistance can be found in creeping bentgrass cultivars but that this resistance may be expressed differently in different climatic areas. To our knowledge, there are no complete and contemporary studies on susceptibility of bentgrass varieties to *Pythium* damping-off.

Why are Seeds and Seedlings So Susceptible to Damping-Off Pathogens?

Of all stages of plant development, the germinating seed and seedling stage are perhaps the most vulnerable to a variety of stress-related factors that could potentially be fatal. Not only are plants at this stage more vulnerable to water deficits, temperature extremes, and pesticide toxicity than mature plants, they are also much more susceptible to infection by soilborne pathogens.

One of the principle reasons for the increased susceptibility of germinating seeds and seedlings to infection, particularly by *Pythium* species, is the exudation of cellular compounds into the soil surrounding the seed or spermosphere during the germination process. The spermosphere is a zone of increased microbial activity around a seed. The spermosphere is established through the exudation of molecules into the surrounding soil during the germination of seeds (see Figure 1). Some of the molecules found in seed exudates stimulate the infection of plants by pathogens. Spores of *Pythium* species germinate when they are within the spermosphere. No infections are initiated from spores that are outside the spermosphere.

During initial stages of seed germination, the uptake of water into the seed results in the physical damage to cell membranes. Even though the plant eventually repairs this damage, many cell constituents leak out of the seed into the surrounding soil during the first few hours of germination before repair processes are complete. Under high moisture conditions or suboptimal conditions for seed germination, seeds release more exudates.

Nearly all seed- and seedling-rotting pathogens utilize these exudates as a food source and to sense the presence of a susceptible host plant. Many pathogens, such as *Pythium* species, are ecologically adapted to respond very rapidly to the presence of these exudates since they do not persist for long periods of time in the soil.

The presence of seed and seedling exudates are critically important in regulating responses of pathogens to plants and in supporting microbial interactions and processes in the spermosphere. If there are insufficient concentrations of exudates in the spermosphere, *Pythium* species do not respond to the presence of the plant and do not infect the seed or seedling.

continued on page 6

Many pathogens, such as* Pythium *species, are ecologically adapted to respond very rapidly to the presence of these exudates since they do not persist for long periods of time in the soil.

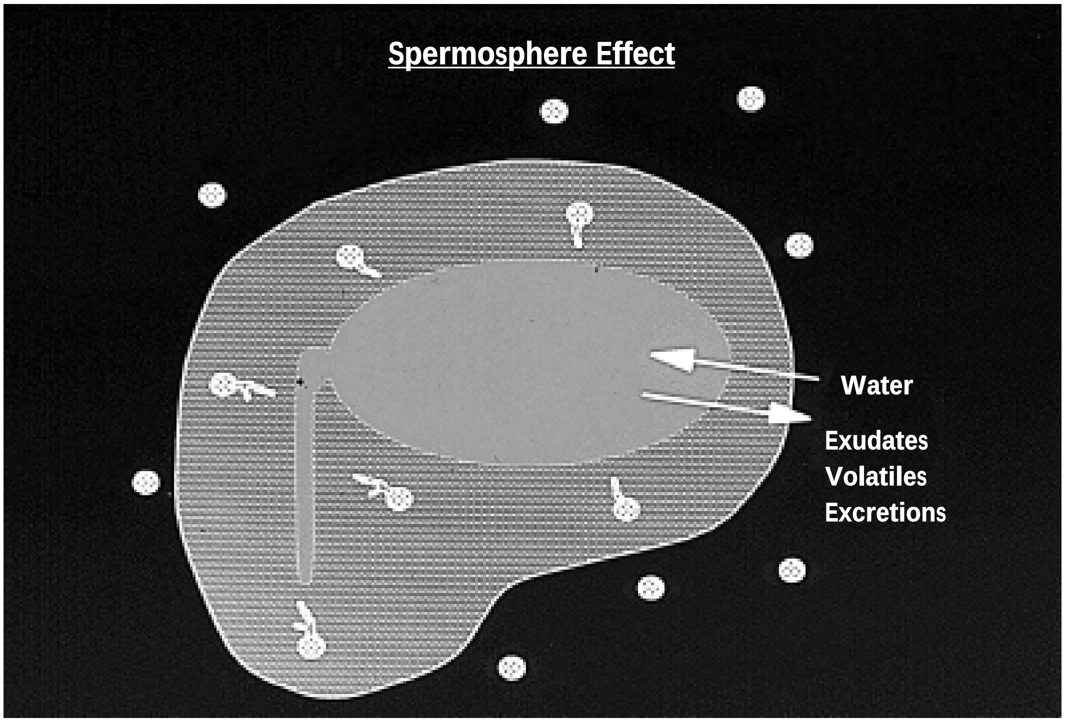


Figure 1

The spermosphere is established through the exudation of molecules into the surrounding soil during the germination of seeds. Some of the molecules found in seed exudates stimulate the infection of plants by pathogens.

Turfgrass Establishment

continued from page 5

Unlike pregermination treatments, primed seed can be rinsed and dried after the priming process and can be planted like untreated seed.

If done properly, pathogen stimulatory exudates are removed in both pregermination and seed priming techniques making seeds much less susceptible to Pythium *seed and seedling diseases when planted.*

Seed Treatments to Improve Stand Establishment

Pregerminated Seed. Presoaking seed treatments that result in the emergence of the radicle are referred to as pregermination treatments. These treatments generally involve the soaking of seed in until radicle emergence and then planting the germinated seed as a slurry. This is done to enhance the germination rate of seed once planted in soil. Even though this method greatly decreases the establishment time, seeds planted in this manner is not only difficult to handle since they must be planted immediately and require specialized equipment, but germinated seeds are much more susceptible to physical damage than are ungerminated seeds.

Studies with pregerminated seeds of other plant species have shown that the soaking process releases many pathogen stimulatory exudates within the first 24 hours of soaking. When these seeds are then planted in soil infested with pathogenic *Pythium* species, seeds and seedlings are much less susceptible to disease.

Seed Priming. Seed priming has also been referred to as osmoconditioning. This process differs from presoaking treatments in that the radicle never emerges from the seed coat. In the priming process, seeds are soaked in a solution of various salts or polyethylene glycol to limit water availability to the seed. Concentrations of these solutes are adjusted to allow the seed to imbibe just enough water to initiate the biochemical processes required for seed germination but not sufficient quantities of water to initiate radicle emergence. Unlike pregermination treatments, primed seed can be rinsed and dried after the priming process and can therefore be planted like untreated seed.

Both types of presowing treatments are most effective on slow-to-germinate species such as Kentucky bluegrass or bermudagrass and may increase the emergence time by up to 10 days over nontreated seed. These effects are particularly pronounced in cool soils where *Pythium* seed rots and damping-off can be more serious problems.

Different species, varieties, and even seed lots vary in the time it takes for each of these processes to run to completion. Without knowing the exact priming times required, it is possible to end up with insufficiently-primed seed or seed that has been soaked too long and is deteriorating.

In both pregermination and seed priming techniques, solutions must be aerated to supply sufficient concentrations of oxygen to the seed during water imbibition. This allows the seed to imbibe water normally. If done properly, pathogen stimulatory exudates are removed in both pregermination and seed priming techniques making seeds much less susceptible to *Pythium* seed and seedling diseases when planted in soil.

Fungicide Seed Treatments. In nearly all of the studies with fungicide seed treatments on turfgrasses, positive improvements in seedling stands have been obtained. Nearly all of the published studies have been conducted with annual or perennial ryegrasses. To my knowledge, only one study has been conducted on creeping bentgrass and this has not been published in widely accessible sources (Leslie MacDonald and Ken Ng, TurfLine Newsletter of the WCTA). In some cases, improvements in seedling stands of over 70% have been observed. In other cases, protection may last up to 10 weeks after sowing.

Biological Seed Treatments for Control of Seed and Seedling Pathogens

Biological seed treatments and seedbed amendments have proven to be quite effective in suppressing damping-off diseases of turfgrasses incited by *Pythium* species. In a study of bacteria suppressive to damping-off of creeping bentgrass and perennial ryegrass incited by *P. aphanidermatum*, nearly 45% of all bacteria recovered from mature turfgrass stands were suppressive to *Pythium* damping-off. A higher frequency of antagonistic strains was found among the general heterotrophic bacteria than within the selected groups of enteric bacteria and *Pseudomonas spp.*, groups known to be antagonistic to many turfgrass pathogens.

Although isolations of general heterotrophic bacteria yielded higher frequencies of effective antagonists, strains of enteric bacteria, particularly strains of *Enterobacter cloacae* were more highly suppressive to *P. aphanidermatum* on perennial ryegrass than general heterotrophic bacteria or *Pseudomonas spp.* The level of control was as good as that provided by the fungicide, metalaxyl.

Other studies have shown that, in addition to *E. cloacae*, a wide variety of bacterial strains are suppressive to damping-of of creeping bentgrass incited by *P. graminicola* when applied as seed treatments. These strains are effective at both cool (20 °C) and warm (28 °C) temperatures and, at least for some strains, they were highly suppressive for at least 11 days.

There are now a number of products on the market consisting of microbial preparations. These are marketed in a variety of ways but are generally targeted at improving soil properties. Particularly when sowing seed in a high-sand-content environment where microbial activity may be somewhat low, some of these types of products may provide some benefit in reducing problems with *Pythium* damping-off and improving stand establishment. Unfortunately, there is no microbial-based product that is currently registered with the US EPA for control of *Pythium* damping-off diseases in turfgrasses.

In addition to bacterial seed treatments, some composted organic amendments are also suppressive to *Pythium* damping-off and the subsequent symptoms from root rot damage. Amending sand with composts prepared from a variety of feedstocks suppressed seedling and root diseases of creeping bentgrass caused by *Pythium graminicola*. Among the more suppressive materials in laboratory experiments are industrial sludge and municipal biosolids composts. Leaf, yard waste, food, and spent mushroom composts, as well as certain biosolids, cow manure, chicken/cow manure, and leaf/chicken manure composts are generally not suppressive to *Pythium* damping-off. *Pythium*-suppressive composts typically have higher microbial populations than non-suppressive composts. Furthermore, a strong negative relationship between compost microbial activity and *Pythium* damping-off severity was observed, indicating that much of the suppressive activity was due to microbial activities present in the compost amendment. A number of microbes recovered from these suppressive composts are equally suppressive to *P. graminicola*-incited damping-off when applied as seed treatments.

Conclusions

Pythium seed rot and damping-off takes a countless toll on newly developing turfgrass seedlings. In the past, seedling stand losses due to *Pythium* damping have never been of particular concern because of the relatively low cost of turfgrass seed. To my knowledge, the magnitude of losses during seeding and over-seeding programs has never been documented. However, there is now much more interest in stand losses because of the ever-increasing cost of seed and the increasing amount of over-seeding during transitioning of golf course turf. Seed treatments may provide a significant improvement in stand establishment and may provide a significant saving in seed costs.

Options are available for the treatment of turfgrass seed. Presowing germination and priming techniques appear to be of limited value to most turfgrass species, particularly those such as ryegrasses that germinate rapidly. The greatest benefit of these techniques has been seen with slowly germinating varieties (such as Kentucky bluegrass) sown in cold soils and in situations where a rapid weed-free turf cover is essential. Although there have been methods described for priming seed, it is advisable to leave the presowing treatments to the seed producers since light, temperature, oxygen levels, and solution concentrations are critical and must be monitored carefully. Any mistakes can result in the loss of the seed. Currently, fungicide seed treatments are the most effective approach for controlling *Pythium* damping-off in newly-sown areas. Several products are currently available as seed treatment formulations. Although microbiological products are not currently labeled for seed and seedbed treatments, many of these types of products can be used successfully to improve stand establishment by reducing damage from seed rotting pathogens.

Eric B. Nelson
Cornell University Turfgrass Team

Strains of* Enterobacter cloacae *were highly suppressive to* P. aphanidermatum. *The level of control was as good as that provided by the fungicide, metalaxyl.

Unfortunately, there is no microbial-based product that is currently registered with the US EPA for control of* Pythium *damping-off diseases in turfgrasses.

Silicon: The Universal Contaminent

Research Report

In acidic soils high in aluminum and iron, silicon counteracts toxicities, responsible for reduced root growth, by complexing in solution and preventing plant uptake.

Hydroponically grown cucumbers in nutrient solutions amended with soluble siilicon had less severity of* Pythium *sp. and greater yield.

Bentgrasses on golf courses throughout the United States are challenged with environmental (heat, traffic, etc.) and biological (insects, diseases, etc.) stresses. As a result of intensive management practices, not to mention high quality expectations, bentgrasses are exposed to serious levels of stress. Survival under stress often reduces stand vigor and provides opportunity for attacking fungal pathogens.

Root and crown rot, as well as post emergence damping-off, induced by *Pythium aphanidermatum*, are diseases that affect both seedling and mature stands of creeping bentgrass. Given the proper conditions of high relative humidity and temperature and the sufficient inoculum density, *P. aphanidermatum* can be devastating. Demanding quality expectations in the shortest amount of time combined with the potential virulence of the pathogen, leaves the golf course superintendent reliant on preventative applications of synthetic fungicides as the primary disease management tool. Public concern for ground and surface water quality has prompted research into other avenues of control less dependent on synthetic fungicides.

Visualizing the disease triangle, we see that a disease is the result of three factors occurring simultaneously: a susceptible host, a pathogen capable of infection, and favorable environmental conditions. A fundamental approach to disease management requires a vigorous stand of turf that will be better able to tolerate stress and resist disease. Therefore, it is important to develop an understanding of plant health that results in a high quality turf. Knowledge of site conditions, soil properties (obtained by laboratory analysis) and well adapted species or cultivar selections, seeded at the proper rate, are vital first steps. Integration of cultural practices such as mowing height and irrigation methods along with refinement of nutrient applications has been shown to improve plant health. Furthermore, the source, concentration, and timing of essential mineral nutrients has been proven to influence overall plant health and disease susceptibility.

Silicon Dynamics

While research into the mineral nutrition of higher plants recognizes 14 essential macro and micro elements for plant growth, the essentiality of silicon (Si) is controversial. The necessity of this element has been difficult to prove as it is hard to work in an Si free environment. The pioneer of plant nutrition, Dr. Emanuel Epstein refers to Si as a “ubiquitous contaminant”; in fact, leaf tissue dry weights of plants not amended with Si can contain upwards of 400 mg Kg^{-1} .

Approximately 90% of the earth’s crust is comprised of silicon, occurring in nature, not as Si, but as silicon dioxide (SiO_2) or silicates. Si is rendered accessible from two sources, weathering minerals and the more readily available opal phytoliths from decomposing plant material. In the soil solution, Si exists as monosilicic acid ($Si(OH)_4$) with concentrations about equal to those of the macronutrients potassium (K) and calcium (Ca). Si concentration in solution is indirectly proportional to pH, iron (Fe), and aluminum (Al) concentrations. Si availability in soil solution decreases at increased pH or with increased amounts of Fe and Al. Nutritionally, Si can modify or counteract adverse soil conditions. Manganese (Mn) rich soils often result in reduced plant shoot growth. Si has been shown to affect the microdistribution of Mn in the leaves leading to an increase in plant tolerance of the element. In acidic soils high in Al and Fe, Si counteracts toxicities, responsible for reduced root growth, by complexing in solution and preventing plant uptake.

Plants are classified as either Si accumulators or non-accumulators. Rice, sugar cane, and equisetum are accumulators, in that uptake of Si can exceed the rate of transpiration. Si uptake in the grasses occurs at a similar rate as transpiration, whereas dicots can exclude Si at the root. Plant uptake of Si is considered passive, and translocation via the xylem is in the form of monosilicic acid. There is no known downward movement of Si in the plant phloem.

Table 1. Silicon nutrient concentration (mg Kg^{-1}) analysis of creeping bentgrass roots, crown, and leaves.

Treatment	Root	Crown	Leaves	Total
1. Fungicide, nutrient solution + K	1672	750	1521	3943
2. Nutrient solution - K + Si (100 mgL^{-1})	1146	854	521	2521
3. Nutrient solution - K + Si (50 mgL^{-1})	1185	702	1060	2947
4. Nutient solution + K	1577	773	1601	3951
5. Nutrient solution - K	1535	607	1399	3541

Structural and Physiological Role of Silicon

Silicon is deposited in the plants as silica gel in areas where it complexes with other molecules and/or areas of Si saturation. In the roots it is deposited in the tracheids, vessels, and endodermis. The nodes and internodes contain Si around vascular bundles, epidermal cells, and stomates. The leaf sheath and leaf blade have Si in epidermal cells, guard cells, and serrated hook cells located along the margin of the blade. Silicon is also found in the spikelet and lemma of the inflorescence. Once deposited the Si is immobile for the life of the plant, with mature plants having more Si than young plants.

The role of Si in plants is varied. Epidermal cells impregnated with Si on the abaxial surface of the leaf blade increases the erect posture of the leaves for light interception. This enhanced light interception could result in increased photosynthetic activity leading to increased growth and plant health. Si is known to counteract high applications of nitrogen (N) which decreases leaf erectness as result of tissue succulence. Structurally Si is considered analogous to lignin by increasing cell wall rigidity and preventing lodging.

Physiologically, Si is involved in plant water relations, reducing water loss by acting as a physical barrier. Deposits of Si in epidermal and hook cells act as barriers to surface feeding herbivores. With regard to disease severity, research has shown nutrient solutions amended with soluble Si and applied to cucumbers, roses, and grapevines had reduced incidence of powdery mildew. In addition, hydroponically grown cucumbers in nutrient solutions amended with soluble Si had less severity of *Pythium* sp. and greater yield.

Experiment

A study was initiated to investigate the effects of soluble silicon on plant growth and disease severity caused by *Pythium aphanidermatum* in creeping bentgrass establishment. Research was conducted for seven months in controlled environmental chambers at Cornell. Five treatments were imposed on the creeping bentgrass "Penncross," grown in a slightly acidic greens sand (pH 6.8) and supplied with one of four basic nutrient solutions supplemented with 0 mg L^{-1} Si, 50mg L^{-1} Si, 100 mg L^{-1} Si, or 0 mg L^{-1} K. The source of silicon was potassium silicate ($K_2O{\cdot}SiO_2$). Plants were grown for three weeks at 20˚C under 14 hours of light and on the 21st day either inoculated with *P. aphanidermatum* and rated for five days or harvested, weighed, and analyzed for nutrient content. Metalaxyl was applied to Treatment 1 plants prior to inoculation to serve as a standard. Over the seven month time period this experiment was repeated five times and data was collected on dry weight yield, nutrient content, and disease severity.

A study was initiated to investigate the effects of soluble silicon on plant growth and disease severity caused by Pythium aphanidermatum in creeping bentgrass establishment.

Table 2. Nutrient content of creeping bentgrass leaves as influenced by silicon and potassium applications.

Treatment	N	P	K	Ca	Mg	Si	Mn	Fe	Al	Zn
	Nutrient conc. in leaves									
	g Kg^{-1}					mg Kg^{-1}				
1. Fungicide, nutrient solution + K	15.1	4.8	26.5	9.1	2.5	1300	430	2200	650	50
2. Nutrient solution - K + Si (100mgL^{-1})	23.2	4.5	22.4	8.9	2.2	480	360	1700	460	40
3. Nutrient solution - K + Si (50 mgL^{-1})	19.2	5.0	18.5	10.4	2.6	1200	370	2300	490	40
4. Nutrient solution + K	19.7	4.0	21.1	7.6	2.1	1500	410	3100	810	40
5. Nutrient solution - K	24.8	5.0	8.3	13.5	3.7	1300	450	3900	770	50
Sufficiency range	27-35	3-5.5	10-25	5-12.5	2-6	n/a	25-150	35-100	n/a	20-55

Results and Discussion

Growth, as measured by dry weight yield, three weeks after seeding was significantly influenced by the treatments. Total dry weight of the bentgrass plants receiving soluble Si was significantly greater than the bentgrass not supplied with additional Si or lacking K (see Chart 1). Interestingly, Si content in the leaf tissue was consistently low for plants receiving Si (see Table 1). In addition, the Si amended plants had less Fe, Al, Mn, and Cu in leaf tissue (see Table 2).

continued on page 10

Total dry weight of the bentgrass plants receiving soluble silicon was significantly greater than the bentgrass not supplied with additional silicon or lacking potassium.

Silicon

continued from page 9

This study indicates that perhaps silicon indirectly enhanced the growth of plants by suppressing aluminum and iron uptake and increasing the plant's tolerance to manganese.

A clear separation between treatments for disease incidence was evident on days 4 and 5 (see Chart 2). Disease severity was greatest on the plants supplied with the high rate of Si as compared to plants treated with the low rate of Si and plants lacking K. The interactive response of growth and disease was exhibited at the low rate of soluble Si that consistently resulted in higher yield and less disease.

Conclusion

In acidic soil conditions, Al, Mn, and Fe toxicities can be detrimental to plant growth. This study indicates that perhaps Si indirectly enhanced the growth of the plants by suppressing Al and Fe uptake and increasing the plant's tolerance to Mn. Plants supplied with the highest rate of soluble Si had less actual Si in the leaf tissue and greater disease damage. Studies have shown that plant succulence, increased population density from high seeding rates, and a uniform age of the stand enhance disease development; all three factors were evident.

Seeding is best suited to spring or fall with the goal of a dense stand of turf, able to establish an area and resist stresses. These findings suggest the possible benefit of Si amendments during establishment by increasing plant health and vigor without increasing disease severity caused by *P. aphanidermatum*. Further research of this "ubiquitous contaminant" in acid soils involving alternate cool season pathogens may increase our understanding of Si, and a possible optimum level, to be of benefit as an amendment during establishment.

Evie Gussack, Marty Petrovic, Frank Rossi
Cornell University Turfgrass Team

***These findings suggest the possible benefit of silicon amendments during establishment by increasing plant health and vigor without increasing disease severity caused by* P. aphanidermatum.**

Figure 1. Total Dry Wt.

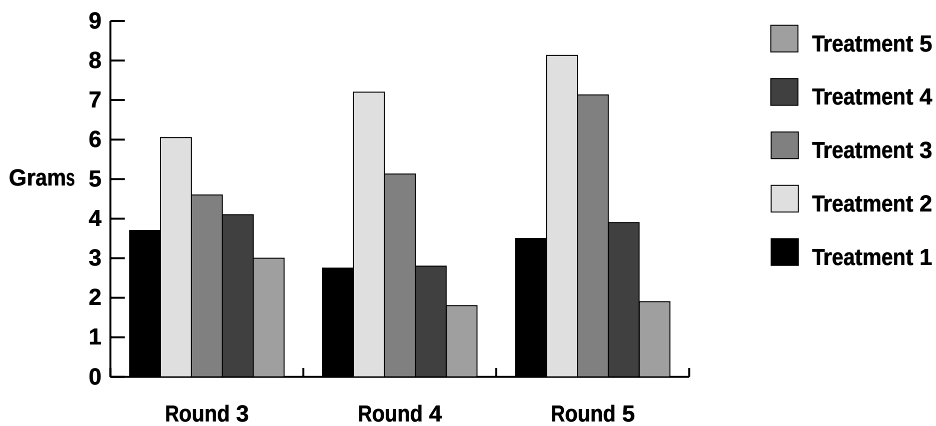
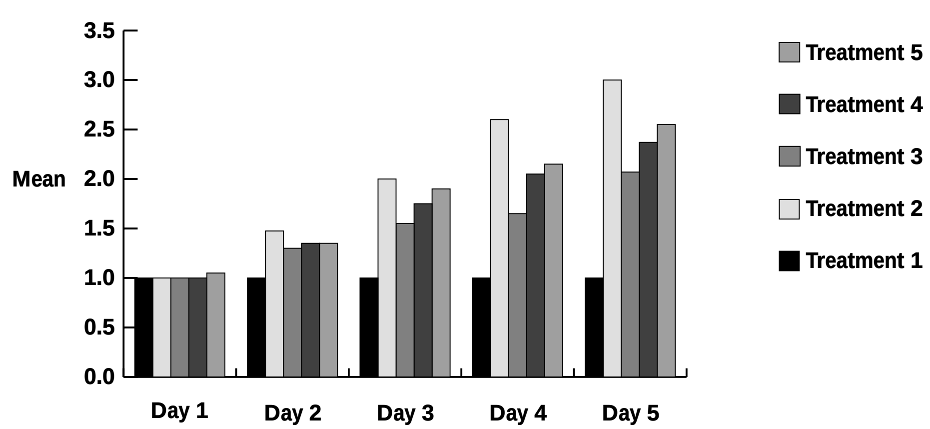


Figure 2. Mean Disease Rating By Day



Tree Leaves and Kentucky Bluegrass Growth and Quality

It is a common turf maintenance practice in temperate climate zones to collect and re move fallen deciduous tree leaves from turfgrass sites in the late fall into the spring. Without tree leaf removal, turfgrasses can sustain severe damage due to light exclusion and high temperature buildup under the tree leaves during warm weather. The collection and tree leaf removal processes are very labor intensive and costly, and sites for disposal are becoming very limited.

Yard waste management in the 1990s has become a major issue for many municipalities. The US EPA estimated in 1991 that in the US more than 31 million tons of waste is grass clippings, 20 per cent tree leaves and five per cent brush. In 1993 there were 15 states that had banned all yard wastes from landfills and 10 more are considering bans.

Mulching mowers, that distribute the grass clipping back on the turf site, have been widely recommended and utilized to reduce the amount of yard waste generated. The advantages of returning grass clippings include: a reduction in the time and energy associated with removal of the clipping either to landfills or composting facility, and the recycling of nutrients from the clippings back to the growing turf.

Depositing deciduous tree leaves into the turfgrass ecosystem might modify the soil environment with the addition of nutrients and acidifying organic material and contribute to greater thatch accumulation due to the influx of more lignin into the system from deciduous trees than cool-season turfgrass species. The net effect of tree leaf deposition may be an alteration of the plant growth, where less growth would occur if soil pH dropped below an adequate level or an increase in growth if nutrients were released during the decomposition phase.

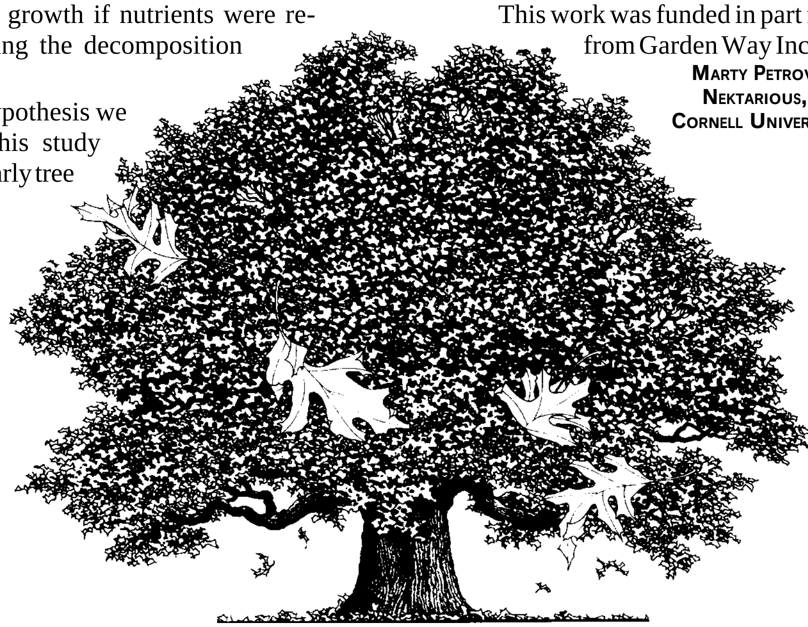
The hypothesis we tested in this study was that yearly tree leaf deposition had no effect on Kentucky bluegrass shoot growth, visual quality, soil pH, and thatch accumulation, thus, would be a suitable landscape/solid waste disposal method.

The study was conducted at the Cornell Turfgrass Research and Education Center in Ithaca. The site was a 10 year old stand of Adelphi Kentucky bluegrass grown on a fine sandy loam soil. Three treatments were evaluated: red oak leaves, Norway maple leaves and a plot not treated. Fallen leaves of red oak and Norway maple were air-dried, deposited on the turf surface at a thickness of 5 inches once or twice per year (rate of 0.54 Kg of dry leaves/m^2), and mowed with a mulching mower. Turfgrass clipping yields were collected weekly and at least monthly visual quality rating was determined. Thatch thickness and soil pH levels were determined at the end of the second and third years of the study.

We found that mulching mower-deposited tree leaves, of either species, had no effect on visual quality, shoot growth, thatch accumulation, and soil pH during the three years of this study. Therefore, using mulching mowers to finely grind and deposit fallen tree leaves on turf provides an alternative tree leaf disposal method while having no effect on the health and vigor of lawn turf. However, results from a laboratory study in Wisconsin indicated that phosphorus in turf clippings and from tree leaves are likely to leach out when dried or frozen and could be part of the increase in phosphorus levels in landscape watersheds observed in late fall through spring. We are planning to study the impact of turf clippings and tree leaves on phosphorus runoff from mixed landscapes (trees and turf).

This work was funded in part from a grant from Garden Way Inc., Troy, NY.

Marty Petrovic, Panayiotis Nektarious, Debbie Sender
Cornell University Turfgrass Team



Program Update

We found that mulching mower-deposited tree leaves, of either species, had no effect on visual quality, shoot growth, thatch accumulation, and soil pH during the three years of this study.

Results from a laboratory study in Wisconsin indicated that phosphorus in turf clippings and from tree leaves are likely to leach out when dried or frozen and could be part of the increase in phosphorus levels in landscape watersheds observed in late fall through spring.

Communication Skills for Effective Interaction

Human Resource Update

When I discuss listening in my workshops, I ask the participants what they are doing when someone else is talking. The first answer is usually "thinking about something else."

"You aren't listening!"
"You make me mad when you ____ !"
"You don't give me any feedback."

How many times have you heard these statements from family, co-workers and employees? Usually when we hear and use these or similar statements there are strong feelings and high levels of stress. Can we learn anything to more effectively handle such difficult questions? The answer is "YES". Each of these statements is addressed below.

Effective Listening

When I discuss listening in my workshops, I ask the participants what they are doing when someone else is talking. The first answer is usually "thinking about something else." This we can avoid by focusing on what is being said. More challenging is the next response of "thinking about how we are going to respond." We all do this but it is not effective listening. We need to have the patience and focus to only listen until whomever we are talking to has finished, and only then think about how to respond.

A very powerful tool in listening is to practice active or empathetic listening. In active listening the listener listens for both content and emotional aspects and provides feedback on both. This means listening for the content and also the underlying feelings that may or may not be stated explicitly. This listening tool has additional attributes that it can be used to focus on joint problem solving and it fosters open communication and personal development.

"I Statements"

The problem with "You make me mad…!" is twofold. First, the recipient of the statement will often be offended and become defensive. This is certainly not conducive to good communications. Second, the feeling of anger results from an action of the person, *not* the person himself or herself. An "I" statement, however, is a much superior method for giving criticism,

explaining a problem, making a suggestion, or expressing an opinion.

An "I" statement has two parts:

- First part: Describe your feelings without blaming others.
- Second part: Describe how you would like things to change.

For example, when you are disappointed and frustrated that an employee cannot remember simple instructions, you would state, "When what I think are simple instructions are not followed, I feel disappointed and frustrated. I

continued on page 15

Table 1. Comparisons of "YOU" and "I" statements.

"YOU" Messages (blames others)	"I" Messages (first part)
You really make me mad.	I'm feeling upset about this.
You sure are disorganized.	I feel ineffective when things are not organized
You're always interrupting.	I feel frustrated when I am interrupted.

CUTT Index Update

Beginning with its first issue in the spring of 1990, this is the 26th issue of Cornell University Turfgrass Times (CUTT). The audience for this publication continues to grow and we welcome all our new readers as they join us. Over the years, CUTT has presented a diversity of topics reflecting the interests of Cornell's turfgrass team and the needs of the turf industry.

The last time we published an index to CUTT articles was back in the Fall 1996 issue. It's time for an update to help newer readers discover what they may have missed and where to find articles that interest them. Note that "Short Cutts" and "Scanning the Journals" sections are not indexed individually.

Back issues of CUTT are available for $4.00 each and may be ordered by contacting Frank Rossi, 49C Plant Science, Cornell University, Ithaca NY 14853.

Back issues of CUTT are available for $4.00 each and may be ordered by contacting Frank Rossi, 49C Plant Science, Cornell University, Ithaca NY 14853.

Short Cutts

continued from page 2

To make your attendance more convenient, we are working with leaders of the regional golf superintendent associations and industry vendors to provide round trip bus transportation from all the major metropolitan areas in NY.

The Golf Turf Course will include a comprehensive exam at the end, making it able to provide tested CEU's for GCSAA-certified superintendents.

in investigating new cultivar traffic tolerance and stimpmeter readings; the fate of pesticides and nutrients at establishment; selecting grasses for rough areas that will require less maintenance; managing tee boxes in the shade; annual bluegrass control strategies, and plant growth regulators to enhance stress tolerance.

To make your attendance more convenient, we are currently working with the leaders of the regional golf superintendent associations and industry vendors to provide round trip bus transportation from all the major metropolitan areas in NY. This means you get on the bus in the morning, spend the day with us viewing research, have some lunch (the famous Cornell chicken barbecue), "kick some tires" at the trade show, and be home for dinner from Buffalo to Lake Placid to Long Island. For more information about this exciting event contact the Turfgrass Program at (607) 255-3090.

Frank Rossi instructs participants at the Long Island Short Course on the proper calibration of a drop spreader.

Short Course Season Success! Innovations Ahead!

Once again the cornerstone of the Cornell Turfgrass Program's continuing education efforts yields high marks and raves of great success. Now comprised of two events, the 13th annual Turfgrass Management Short Course held in January in Ithaca brought fifty energetic professionals to expand their knowledge of turf management, while thirty dedicated learners joined the program at the second Short Course held on Long Island. Ever improving, several sections of the course were updated to address changes in cultivar selection, primary cultural management, environmental issues, and pest management. Still, some of the highest rated aspects of the course continue to be the hands-on lab sessions, where students identify specimens of grasses, weeds, insects and calibrate spreaders and sprayers.

The next few years will see several changes planned for this successful educational delivery. First, the two-week course in Ithaca will be altered to provide two one-week sessions as the 1st Annual Advanced Turfgrass Short Courses. The first week, currently scheduled for January 4 through 8, 1999 will focus on Golf Turf Management, addressing issues of construction and renovation, turfgrass selection, environmental management as part of the Audubon International Program, cutting edge irrigation technology, and the latest in alternative pest management, as well as our now famous human resource educators Milligan and Maloney. The Golf Turf Course will include a comprehensive exam at the end, making it able to provide tested CEU's for our GCSAA-certified superintendents. The second week of the new advanced course will be focused on Sports Turf Management scheduled for January 11 through 15, 1999. Areas that will be covered will include construction and renovation with emphasis on soil modification, turfgrasses for high traffic areas, managing the

continued on page 15

Pest Watch

continued from back cover

entomopathogenic nematode. SC is easy to produce in both in vivo and in vitro cultures, and it is the most widely available commercial nematode. SC is representative of classic "ambush" or "sit and wait" host-finding strategy, and can infect several insect orders, especially lepidoptera and some coleoptera. Therefore, it is an important standard for comparison in nematode testing.

Heterorhabditis bacteriophora **(HB).** HB has also been well studied, though not as extensively as SC. These nematodes are relatively easy to produce in vivo, and are commercially available. HB exhibits a "searching" or "hunting" host-finding strategy, and can infect several insect orders. They are especially effective against some scarab grubs, including the Japanese beetle.

Steinernema feltiae **(SF).** Much less is known about this nematode species, but it is commercially available on a limited basis. The few field tests of SF against scarab grubs have yielded mixed results.

Steinernema glaseri **(SG).** This nematode is not currently available on a commercial basis, but is known to be a strong "searcher" and an aggressive grub pathogen.

MIKE VILLANI
CORNELL UNIVERSITY TURFGRASS TEAM

Short Cutts

continued from page 14

multi-use fields, and developing communication skills for dealing with coaches and administrators.

The Long Island Short Course will complete the three year commitment made in partnership with the NSLGA. The 1999 course is scheduled for February 15 through 26. Following this effort, discussions will continue regarding how the Cornell Turfgrass Program in partnership with the County Associations and industry leaders best address the continuing education needs of the region.

As you can see, exciting times lie ahead as your Cornell Turfgrass Program prepares to enter the next century with a "full head of steam". If you have any questions about the short course, contact our Director, Joann Gruttadaurio at (607) 255-1792.

Human Resource Update

continued from page 12

want you to listen more carefully, write things down if necessary and ask questions if anything is not clear."

Note that the first part of this statement used an "I" message where you state how you feel using the word "I" so that the other person does not feel offended by what you say. It doesn't blame "YOU" — the other person. Table 1 compares "YOU" and "I" messages.

Feedback

In studies where employees have been asked about their performance, the most common response is, "I must be doing well because I haven't heard that I'm doing anything wrong." This response implicitly suggests that feedback is very limited and that the expectation is that feedback will be negative. Both are mostly true and neither is conducive to good communication and high productivity.

First, feedback should be common and should be based on performance. Remember, in his book, Everyone's a COACH, Don Shula states, "Good performance should be treated differently than poor performance." When we give feedback, it should respond to:

- positive consequence
- a need for redirection; performance stopped and redirected using training
- a negative consequence; requires a reprimand, a punishment, a demotion, removal from activity.

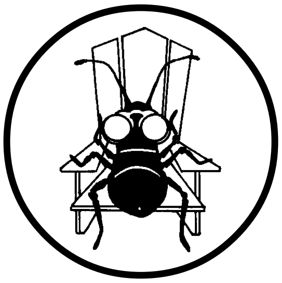
The following are ideas for improving our feedback-giving activities:

- Ken Blanchard says, "Catch your employees doing something right."
- Give four compliments for every constructive criticism.
- From Jane Magruder Watkins of Transformational Management, "Practice Appreciative Inquiry: the process of asking questions about what is going well, rather than what is going poorly."
- Use the PIN technique to find positive aspects of performance even when you must say "no":
  - focus on **P**ositive aspects
  - focus on what is **I**nteresting and innovative
  - focus on what is **N**egative.

ROBERT A. MILLIGAN
CORNELL UNIVERSITY TURFGRASS TEAM

In studies where employees have been asked about their performance, the most common response is, "I must be doing well because I haven't heard that I'm doing anything wrong."

Moisture Effects on Entomopathogenic Nematodes



Pest Watch

It may be possible to take advantage of the nematodes' quiescent survival ability by applying them early in the season, and "activating" them with irrigation later in the season when an insect pest is present.

Entomopathogenic nematodes are well adapted to infect larval insect pests liv ing in soil, and have the potential to be important biological control agents in turfgrass. In the mid 1980's, several species of entomopathogenic nematodes became commercially available for insect pest management. Initially, small-scale production and limited marketing resulted in these products being used mainly for home gardens, lawns and landscapes. More recently, a few large companies have attempted mainstream marketing aimed at the commercial turf, vegetable, and fruit industries, but acceptance has been hindered by variability in the success of the nematodes' ability to control target insects.

More consistent results have been achieved by educating users on better application techniques and appropriate selection of nematode species and strains for particular uses. However, the impact of the agronomic environment on nematode ecology must be better understood before nematodes can be a reliable pest management alternative. Our work examines the effects of soil moisture on entomopathogenic nematode infectivity, under both laboratory and field conditions.

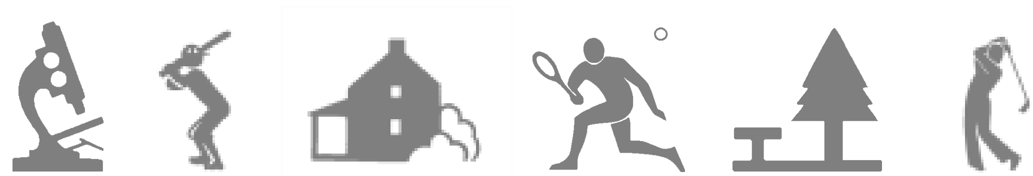
Our studies indicated that HB nematodes tolerated dry soils and very moist soil better than SG nematodes. HB rebounded to higher levels of infectivity after rehydration and remained infective longer than SG. These results have many practical implications. Growers/managers can better determine if nematode applications will be effective in specific field situations if they know more about tolerable soil moisture conditions for nematodes. They can also manage irrigation to stay within these limits. It may also be possible to take advantage of the nematodes' quiescent survival ability by applying nematodes early in the season, and "activating" them with irrigation later in the season when an insect pest is present. Home lawns infested with scarab grubs could be an ideal system for exploring this concept.

In the future, we would like to investigate nematode mechanisms of infectivity including the role of quiescence and mobility. This would include comparisons of nematode species and the effect of many soil physical factors. Information gained would be used to better select nematodes for specific field applications and possibly for selecting and breeding nematodes with desirable traits. Close comparison of laboratory soils and in-situ field soils will also be necessary. Eventually we hope to be able to evaluate field soil/sites for suitability to nematode applications.

The nematode species used in any studies mentioned, and reasons for their selection are described below.

Steinernema carpocapsae **(SC).** More is known about this species than any other

continued on page 15



Cornell Cooperative Extension

CORNELL UNIVERSITY TURFGRASS TIMES
20 Plant Science Building
Cornell University
Ithaca, NY 14853