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Turf Grass TRENDS

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More than meets the eye:

The microbiology of turfgrass soils

by Dr. Eric B. Nelson

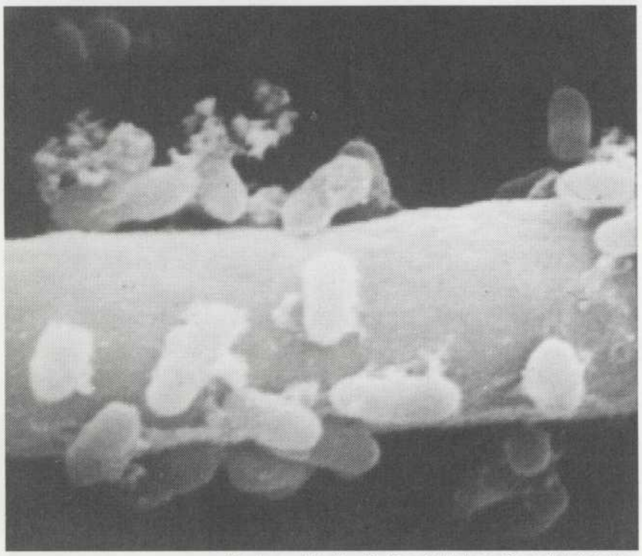

Photo provided by Dr. Eric B. Nelson, Cornell University

Bacteria adhere to the mycelium of a fungus. Note the size of the bacterial cells relative to the mycelium. See page 4.

FOR SOME TURFGRASS MANAGERS, soil is simply the "dirt" that holds plants in the earth and keeps them from falling over.

For the more advanced turfgrass manager, soil is held in higher esteem than dirt. Soil is considered by these turfgrass managers as the life-supporting matrix of the higher plant, since everyone knows that dirt is simply the stuff that accumulates under one's fingernails after a hard days work.

Turfgrass managers who know that plants are anchored in soil instead of in dirt might admit that, for the most part, their understanding of soil is poor at best. Everyone knows what soil looks like, but they are not quite sure where it actually comes from or how it can sometimes be black, brown, or red. Even though most people would admit that soil has a pleasant, somewhat fragrant odor, most are really not sure why soil smells as it does. They know that soil is a nutrient-holding material important in the health of the plant, although the exact manner in which this can be is sometimes obscure. Certainly most know that living things, such as worms and insects can reside in soil, but they're not sure where in the soil they live or what they live on.

In fact, it might be safe to assume that most turfgrass managers consider soil to be a mysterious world below the turfgrass canopy. Rarely do turfgrass managers consider soil as something that should be managed as prudently as the turf itself. It is becoming clear, however, that the management of the soil, in particular its biological components, is as important as the management of the plant for the long-term productivity and health of a turfgrass stand.

What is soil, anyway?

Before we begin our microbial journey through soil, it is important to ask the question: What is soil anyway? Soil is simply the outer

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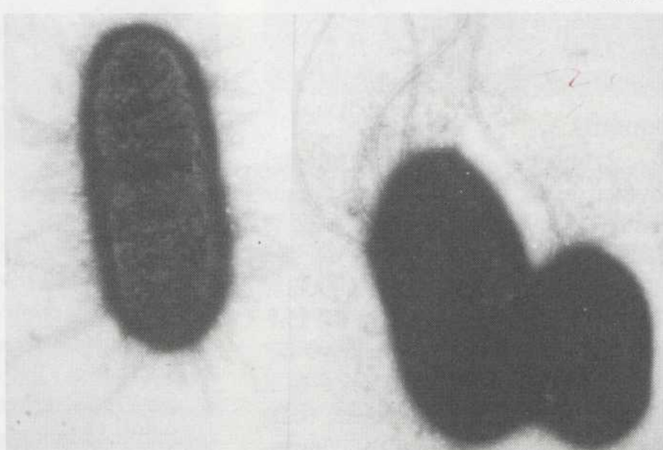

Photo provided by Dr. Eric B. Nelson, Cornell University

Bacteria have structures on their surface that facilitate reproduction and allow cells to swim in water films around soil particles. See page 4.

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loose material of the Earth's crust that accumulates from the weathering of rocks, the decay of organic materials, and the activities of man and other living organisms.

Agriculturally, this is the zone from which plants obtain mechanical support and most of their nutrients. Biochemically, the soil is distinctly different than the underlying bedrock, since many unique organic chemicals can be found there.

Microbiologically, soil is unique in that it contains a diverse array of bacteria, actinomycetes, fungi, algae, protozoa, and microarthropods. It is undoubtedly, one of the most dynamic sites of biological activity in nature. Nearly all of the processes, transformations, and associations important for the maintenance of healthy turfgrass plants take place at the microscopic level. Things such as nutrient cycling, organic matter degradation, nitrogen fixation, biological control of insects and pathogens, plant-microbe symbioses necessary for increased plant growth and pest resistance, and many more. All of these important attributes of the plant-soil association are mediated by a plethora of microorganisms. Without these microbial activities managing turfgrasses would be much more perplexing task than it already is.

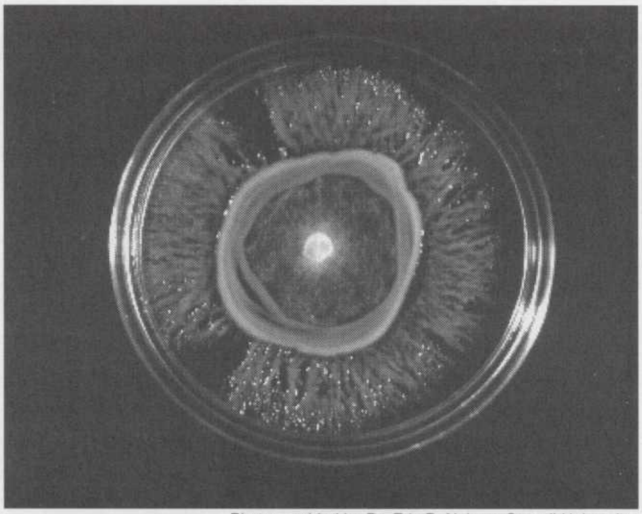


Photo provided by Dr. Eric B. Nelson, Cornell University

Bacteria compete efficiently with fungi. Here, bacteria on a petri plate ensheath the mycelium of a pathogenic species of Pythuim. See page 6.

Soil has five components

Soil consists of five primary components: a mineral component, organic matter, water, air, and living organisms. For any given native soil, the mineral and organic matter content are relatively constant whereas the air and water (i.e. pore space) can fluctuate widely. These fluctuations can indirectly affect the living organisms in the soil. Modifying native soils with amendments can change the relative relationships of its components, but only to a limited extent. On the other hand, in custom-made rootzone mixes for golf course construction, all of the components may be varied and manipulated as desired.

Generally, for most mineral soils, half of the soil volume is composed of pore space, with the other half

Univ. of Georgia study

Bad effects of soil compaction on turfgrass

Recent tests conducted at the University of Georgia have shown the detrimental effects of soil compaction on overall turfgrass growth and survival. Test plots were subjected to compaction that increased the soil bulk density by 6.1% at the 0-2 inch depth range and by 6.5% at the 2-4 inch depth. This increased the penetration resistance by an average of 23% at various depths down to 10 inches.

In the first year, this increased soil bulk density and penetration resistance reduced root density by 20% in the 0-4 inch range and by 77% in the 4-8 inch range. In these compacted soils, water extraction, a measure of the soil moisture holding capacity, decreased by 21% and 10% over the two depth ranges, whereas clipping growth was reduced by an average of 52%. Individual shoot size was reduced by an average of 23% whereas shoot density (number of shoots per area) increased by 9%.

The same research also examined five of the current soil aeration techniques for their abilities to correct the negative effects of compacted soils over three cultivations in a 15 month period. In the first year, only hollow and solid tine aeration eliminated the effects of soil compaction on soil bulk density at the 2-4 inch range and in the second year at the 0-2 inch range. However, all five aeration techniques eliminated root density losses in the first year at the 0-4 inch range by increasing root density by 23% over the non cultivated, compacted check. In the second year, all five techniques showed an average increase of 7% greater root density than the non-cultivated, non-compacted test plot at the 0-4 inch range. Additionally, all five restored water retention ability by 61% over the compacted, no cultivation check. Hollow tine aeration increased moisture retention by 16% over the no cultivation, no cultivation test plot.

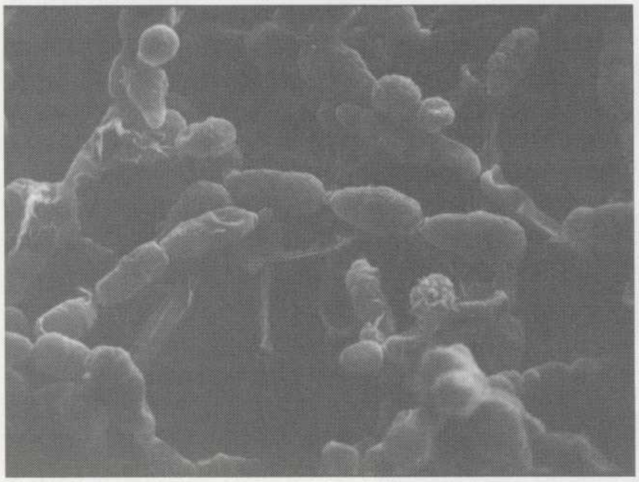
Field tip

The results show that hollow tine and to a lesser extent solid tine aeration is an excellent aeration technique that will show positive results in most circumstances even when only used twice a year. It can be very beneficial in reducing soil bulk density and in increasing root mass and moisture holding ability when used on compacted soils. Slicing and deep drilling did not show the same consistency of results.

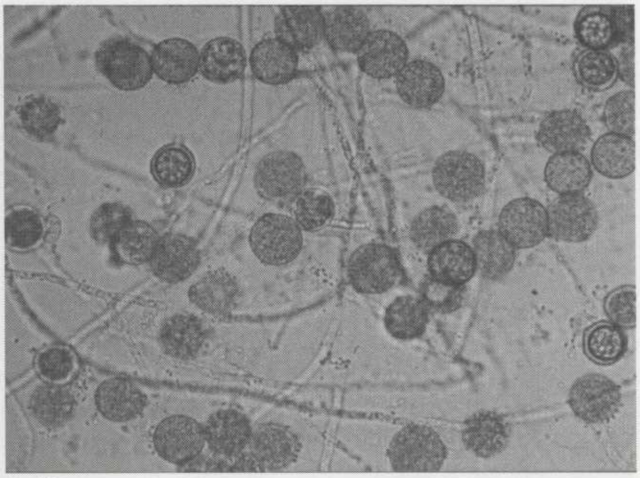
composed primarily of mineral matter. Organic matter may account for 2 - 10 % of the soil volume; the exception being organic soils where the organic matter content may range from 60 - 95%. Finally, small animals and microorganisms generally account for less than 1% of the total soil volume. Despite the small percentage of the soil matrix occupied by living organisms, this may be the most important soil component in terms of plant health.

Chemical properties of soil are important to plant health

Chemically, soils are quite variable. However, with the exception of muck soils, they are comprised largely of silicon dioxide (generally 70-90% of the total mass). Aluminum and iron are usually quite prevalent, along with lesser quantities of calcium, magnesium, potassium, manganese, sodium, nitrogen, phosphorus, and sulfur. Carbon

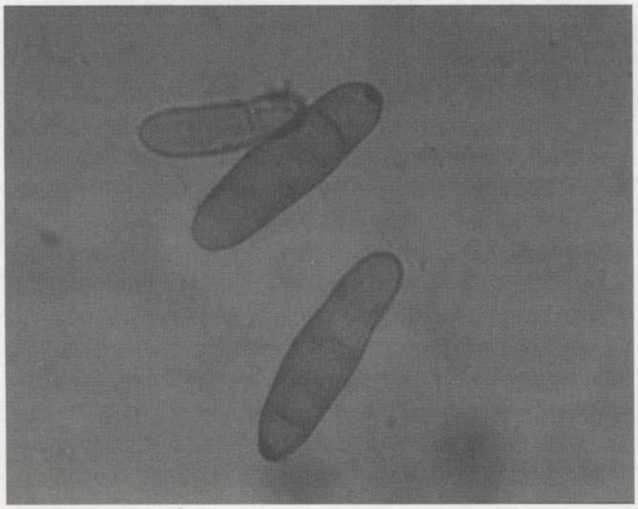


Alternaria

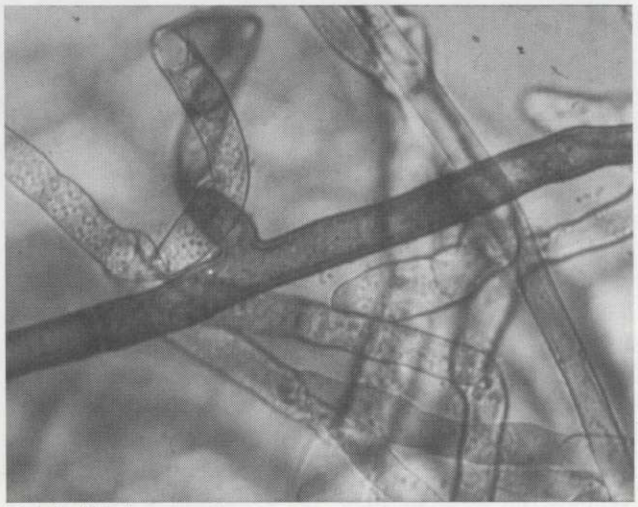


Pythium oospores

All photos provided by Dr. Eric B. Nelson, Cornell University



Dreschlera conidia



R. solani hyphae

Common soil fungi. Most spend their lives as quiescent spores. Only occasionally do fungi actively grow as a mycelium. See page 6.

The mineral components of soil, excluding stones, gravel, and foreign matter, are comprised of sand, silt, and clay. Sizes of these particles range from 0.05 - 2 mm for sand, 0.0002 - 0.05 mm for silt, and less than 0.0002 mm for clays. The relative proportions of these inorganic materials in soils is the basis for the different textural classes such as a clay loam, sandy loam, loam, etc. The different proportions of each of these mineral components, combined with organic matter, affect not only air and water movement and retention in soil but also affect nutrient-holding capacities and microbiological activities.

exists in soils in the form of decaying plant and animal material, living microbial cells, and humus which is a by-product of the metabolic activities of microorganisms. Although the exact chemical composition of humus is unknown, it can be characterized as a dark-brown to black organic complex of humic and fulvic acids together with other polymerized organic molecules.

Another chemical feature of soils, is their ability to retain ions. Nutrient ions are compounds that have either a positive or negative charge. For example, ammonium nitrogen, calcium, magnesium, and potassium are all positively-charged ions called cations. Cations are readily removed from the soil solution by organic matter and clays; the soils ability to remove these cations is referred to as the cation exchange capacity. As might be expected, soils high in clay or organic matter content will have a higher cation exchange capacity than sandy soils low in organic matter or clay.

Nutrient ions such as nitrates, phosphates, sulfates, and bicarbonates are negatively-charged ions called anions. These are not readily retained in most soils and are easily leached from the root zone during irrigations or rainfalls.

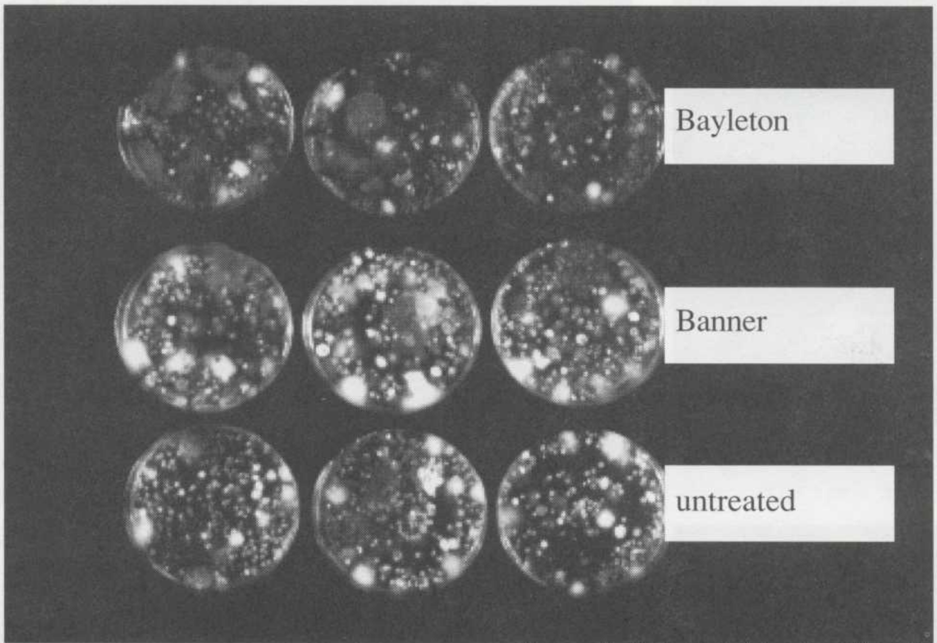


Photo provided by Dr. Eric B. Nelson, Cornell University

Broad spectrum fungicides may dramatically change the fungal species composition in turfgrass soils. Here are the fungal colonies from soils treated with Bayleton, Banner, or untreated. See page 6.

Perhaps the most important soil component from the point of view of a microorganism, is the organic fraction. The organic fraction is often termed humus. Humus serves, in the absence of any plants, as the dominant food reservoir for soil microorganisms. When plant or animal remains land on, are grown in, or are incorporated into soil, microorganisms begin the process of decomposition, using parts of these remains for their cell energy as well as for synthesizing new cell mass. During this decomposition, a number of by-products are formed from the initial organic material as well as from the microbial cells themselves. These by-products become resistant to further decay and persist for extended periods of time in soil as humus.

Biological components of soil are an important resource

Soils below turfgrass stands contain a vast array of living organisms, ranging from the larger macroscopic earthworms and insects, to the microscopic invertebrates, bacteria, fungi, actinomycetes, nematodes, algae, and protozoa. The physical and chemical characteristics of soil just described determine the nature of the environment in which these living organisms function. This environment further affects not only the types and numbers of organisms found but more specifically it affects their activities. These activities may be beneficial or harmful to turfgrass growth and development. The organisms most important to turfgrass health are the bacteria, fungi, actinomycetes, and algae.

Turfgrass managers are all too familiar with the harmful effects that some microorganisms have on turfgrass. These damaging microorganisms include fungal, bacterial, and nematode pathogens of turfgrass plants.

There are also cyanobacteria - a form of blue-green algae that causes black layer, and green algae that cause surface crusting and plant damage.

There are other groups of microorganisms that are indirectly harmful to turfgrass plants. These include pesticide-degrading non-pathogenic and pesticide-resistant pathogenic microorganisms. In nearly all cases, turfgrass managers have developed elaborate management techniques to avoid some of the detrimental effects caused by the activities of these organisms.

Not surprisingly, most soils contain large populations of beneficial microorganisms. These offer the most promise for enhancing turfgrass health and maintaining long-term productive turfgrass stands. (See Table 1 on page 5.) Yet, for the most part, we have not developed management strategies to promote the persistence and activities of these important microorganisms. In order to understand how to take advantage of these beneficial microorganisms, it is important that turfgrass managers develop a better understanding of the major groups of microorganisms in soil.

Bacteria predominate in the soil microbial community

Of the microorganisms in soil, bacteria are found in the greatest abundance and are perhaps the most diverse in their morphology and activities. (See photo on page 1.) Many different populations of bacteria with a wide array of activities can be found in most turfgrass soils; many carry out processes important to plant health. (See Table 2 on page 7.) However, the bacterial composition of each soil may vary depending on the soil type, prevailing environmental conditions, and management practices.

Bacteria are small, rod-shaped organisms that reproduce prolifically by simple cell division, producing massive amounts of cells in a short period of time. (See photo page 1.) Under favorable conditions, bacteria may divide every

20 minutes, so that conceivably, one bacterium could give rise to one million bacteria in 10 hours! Although the total numbers of cells can be great, the size of each individual cell is quite small, usually not more than one or two microns (0.00004 inches) in length.

During the explosive growth of bacteria, a diverse array of food sources must be available to support such a high rate of metabolic and reproductive activity. During the utilization of food sources, a number of metabolic by-products are also produced. As a result, great chemical changes may occur in the soil as a result of the proliferation of bacteria in the environment. This makes bacteria such significant microorganisms in the turfgrass environment.

Bacteria require water to grow and reproduce. Their survival is limited if water availability diminishes. Although, many bacteria are excellent saprophytes (i.e. they prefer to live on decaying organic matter), some are endophytic (i.e. they live inside healthy plants, usually in roots), where a limited number can cause diseases in plants. Those found in turfgrass ecosystems are either saprophytic or endophytic. In both cases, they are usually good competitors with plant pathogens which results in reduced damage from diseases.

Of importance to turfgrass health are the bacteria that play a role in nutrient transformations in soil, particularly those involved in nitrogen cycling. Numerous bacteria within the genera *Azotobacter*, *Azospirillum*, *Enterobacter*,

Table 1

Predominant bacteria and their known activities in turfgrass soils

Bacterial Genus	Principal Activities
Arthrobacter	Degradation of pesticides Decomposition of organic matter Pesticide degradation
Azospirillum	Nitrogen-fixation
Azotobacter	Nitrogen-fixation
Bacillus	Biological control of diseases and insects Decomposition of organic matter Degradation of pesticides Denitrification Phosphate solubilization Conversion of ferric to ferrous iron Release of native soil potassium Manganese oxidation
Desulfovibrio	Conversion of sulfates to sulfides
Enterobacter	Nitrogen-fixation Biological control of diseases
Flavobacterium	Decomposition of organic matter Phosphate solubilization Pesticide degradation Biological control of diseases
Klebsiella	Nitrogen-fixation Conversion of ferric to ferrous Manganese oxidation Pesticide degradation
Nitrosomonas	Oxidation of ammonia to nitrite (nitrification)
Nitrobacter	Oxidation of nitrite to nitrate (nitrification)
Pseudomonas	Decomposition of organic matter Biological control of diseases Plant growth promotion Some species can be pathogenic to turfgrasses Denitrification Phosphate solubilization Conversion of ferric to ferrous iron Release of native soil potassium Manganese oxidation Pesticide degradation
Thiobacillus	Conversion of inorganic sulfur and iron compounds to sulfates and ferric forms of iron Denitrification
Xanthomonas	Biological control of weeds Some species are pathogenic to desired turfgrasses Decomposition of organic matter

and *Klebsiella* are efficient free-living nitrogen-fixing bacteria. They take nitrogen from the atmosphere and convert it to a form that the plant can use. Although they contribute significantly to the nitrogen nutrition of such grass species as *Poa pratensis* (Kentucky bluegrass), the magnitude of their contribution to the nitrogen nutrition of turfgrass plants in the field is unknown. Undoubtedly these nitrogen-fixing organisms could contribute substantially to the nitrogen economy of a turfgrass planting if they were managed in an effective way.

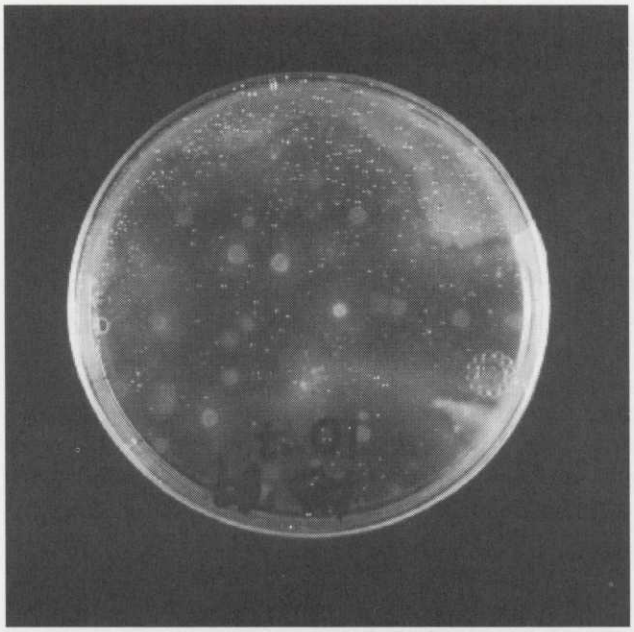


Photo provided by Dr. Eric B. Nelson, Cornell University

Soil actinomycete on a laboratory culture medium. These are antibiotic-producers, synthesizing by-products that inhibit fungi, bacteria, and other microorganisms. See page 7.

As important as the nitrogen-fixing bacteria are, there are more important microorganisms involved in organic matter degradation. These organisms play a key role in maintaining the delicate balance between thatch accumulation and thatch degradation. These organisms can be managed to some degree. In fact, there are a number of commercial preparations of thatch-degrading microorganisms as well as preparations of the enzymes that they produce. Some of these have been used successfully in a thatch maintenance program whereas other fail miserably.

One of the more pivotal groups of bacteria are those involved in the biological control of turfgrass pathogens. These bacteria can be found in all types of turfgrass soils, from low-maintenance to high-maintenance areas. Their effects often go largely unnoticed. However, they can have huge impacts on disease development. (See photo page 2.) In some cases, high populations of these bacteria are responsible for the development of what we call suppressive soils. These are soils where conditions are ideal for disease symptom development and the pathogens are present, but no disease develops because of the activities of these bacteria. Since all of these bacteria prefer to live on dead and decaying plant tissue, large amounts of organic matter, either in the form of top dressings or direct soil amendments, are usually very beneficial in promoting the activities of these bacteria.

Many of these biological control bacteria can be found in particular types of organic matter such as composted materials. In fact, the application of composted materials has been used as effective alternatives to fungicides in a number of instances. Similarly, a number of companies are now marketing preparations of bacteria as microbial fungicides. Although none of these materials are currently registered for use on turfgrasses, a number of materials are likely to be available in the near future.

Fungi - both friend and foe

Perhaps the next most abundant group of microorganisms in turfgrass soils are fungi. (See photos on page 3.) The fungi are best known for their disease-causing activities on turfgrasses since nearly all of the economically-important turfgrass diseases are caused by fungi. However, pathogenic fungi represent only a small proportion of the total communities of fungi in soil. The vast majority of fungi found in turfgrass soils are beneficial to plant health. Some of the major genera of fungi present in turfgrass soils include *Penicillium, Aspergillus, Trichoderma, Gliocladium, Fusarium, Mucor,* and *Mortierella.*

Fungi obtain their energy for growth through the decomposition of organic matter. It is not surprising, therefore, that organic matter decomposition is one of their predominant activities in turfgrass ecosystems. Generally fungi are more prevalent than bacteria in soils of pH lower than about 5.5 whereas bacteria tend to predominate in higher pH soils.

Since fungicides are the primary pest control chemical used on golf course turf, soils at these sites can vary dramatically in the composition of fungal communities, depending on the type, rate, and frequency of fungicides used. (See photo page 4.) Aside from the plant pathogenic and organic matter decomposition activities of soil fungi, some groups perform more specialized functions in direct association with the turfgrass plant.

Mycorrhizal fungi form unique symbiotic associations with plant roots called mycorrhizae. In mycorrhizal relationships, the fungus benefits from the carbon provided by the plant while the plant benefits from the increased phosphorus nutrition and water movement to the roots. Both bentgrasses and bluegrasses have been reported to be mycorrhizal, although little information is available on the beneficial or detrimental properties of mycorrhizae in these grasses. As with other fungi, mycorrhizal fungi are sensitive to a number of fungicides commonly used in turfgrass management.

Some of the better-known fungi used in turfgrass management are endophytes. Fungal endophytes are typically found in the seeds and leaf sheaths of nearly all of the turfgrass species. Most commonly, however, the endophytes of perennial ryegrass, tall fescue, hard fescue, chewings fescue, and creeping red fescue have been exploited. Useful endophytes have not been found in creeping bentgrass and Kentucky bluegrass.

The major fungus involved in these endophytic relationships is the genus *Acremonium*. This is a common soil fungus that infects the plant through unknown means. However, once inside the plant, the *Acremonium* fungus provides the host plant with increased insect and disease tolerance as well as improved stress tolerance. The nature of these effects are currently unknown but are being studied.

Many commercial varieties of turfgrass can be bred with known levels of endophyte infection. However, it should be noted that endophytic fungi remain viable in the seed for only about one year, unless the seed is refrigerated. Endophyte-infected seed should therefore be stored in a cool dry location to assure maximum benefits from the *Acremonium* infection.

Actinomycetes produce antibiotics suppressive to plant pathogens

One of the least known and least understood groups of soil microorganisms are the actinomycetes. These microbes are classified more closely with the bacteria but they grow more like a fungus. Although their populations in some soils can be quite high, their growth rates are much slower than the other microorganisms in soil. Much of the smell unique to high organic matter soils comes from the volatile compounds produced by actinomycetes.

Actinomycetes are typically more abundant in drier soils high in organic matter or in high temperature soils. As a group, they are not tolerant of low soil pH (i.e. less than 5.0). They prefer to grow at temperatures ranging from 80 to 100 degrees Fahrenheit. Some of the major genera of soil actinomycetes include *Streptomyces, Nocardia, Micromonospora,* and *Actinoplanes*.

These organisms are best known for their abilities to produce a number of industrially- and medically-important compounds. Many of the clinically-important antibiotics used in human and animal medicine come from soil actinomycetes. Like the fungi, actinomycetes rely on organic matter for their nutrition. In particular, actinomycetes appear to be more adapted to the decomposition of the more resistant plant polymers such as cellulose, hemicellulose and lignin as well as the fungal and insect polymer, chitin. In doing so, actinomycetes play a major role in the formation of humus in soils.

Actinomycetes also play a role in the suppression of soil borne diseases of turfgrass plants. Many of the antibiotic compounds produced by actinomycetes also affect the growth and development of pathogenic fungi. (See photo page 6.) Composts are particularly rich sources of actinomycetes that suppress turfgrass pathogens. Part of the beneficial effect of amending soils with composts is the disease control provided by these compost-inhabiting actinomycetes.

Table 2

Important beneficial microorganisms found in turfgrass soils

Microbial Group	**Major Benefit to Turfgrasses**
Nutrient-cycling microorganisms	Making nutrients available to plants Decomposition of organic matter
Thatch-degrading microorganisms	Thatch maintenance
Nitrogen-fixing microorganisms	Improvement in turfgrass nutrition
Endophytes	Pest resistance Stress tolerance
Mycorrhizal fungi	Improved phosphorus nutrition Plant growth promoting rhizobacteria Improved root development Disease tolerance
Biological control organisms	Protection from pests

Algae can cause significant problems in turfgrasses

Algae can be found in essentially all soils worldwide. However in most turfgrass soils, the algae are a minor microbial component of the total microbial ecosystem. Nonetheless, under certain conditions their presence can create difficult management problems. Unlike the previously-mentioned groups of microorganisms, algae do not require organic matter for energy and growth. Most algae are capable of photosynthesis, allowing them to produce their own carbon compounds. Since algae require light, their presence in turfgrass plantings is often observed on the soil surface in sparsely seeded areas and in excessively close-cut turf such as on putting greens.

The types of problems caused by algae in turfgrasses include 1) the formation of surface crusts, 2) the production of copious slime, and 3) the formation of 'black layer'. The soil algae responsible for these problems can be classified into the green algae and the cyanobacteria (formerly referred to as blue-green algae). The genera of green algae recovered from turfgrasses

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Turfgrass management in 2004

Products and services

by Christopher Sann

TAKE A BLANK piece of paper and a pencil and list the areas of turfgrass management that will change in the next ten years. The list you produce will have any number of entries, but those entries will probably fit into one of three basic categories:

1) Applications, products and services,
2) Business, regulatory and environmental issues,
3) Basic turfgrass research.

Here I will focus on the first category: applications, products and services and I will examine the future of new products, new equipment, and changing turf management techniques.

New Products

I predict that the next ten years will see a diminishing number of new or unique chemical controls making their debut on the turf market. The tightening economics of the turf industry and more importantly agriculture, from which about 95% of all turfgrass control products originate, will limit manufacturers' potential for making a profit. The economics of agriculture make the amount of money and time that they must invest to bring a new product to market increasingly prohibitive.

For a period of time, products that are already in the pipe line will continue to become available, but the streamlining of corporate structures that has been going on over the past three years, along with the associated reductions of spending on research and development will begin to show in five to seven years as a reduction in the number of new pest control chemicals coming to market. The new chemical products that do appear will probably be smaller niche products; products that dramatically improve efficacy and cost, or new labeling for existing agricultural products that have not been available in the turf market.

"Me, too" products or reformulations of existing products on new carriers or in different packaging will increase as smaller formulators try to grab market share enjoyed by the larger producers. "Me, too" products, or the licensed reformulation of brand name products by smaller repackagers, will proliferate because they offer the original manufacturers the chance to sell additional product without the high cost of research and development. They will be able to make a profit marketing their reformulated products in smaller market areas that have been prohibitive to the manufacturer.

The same forces that will restrict the introduction of new chemical products will cause a dramatic increase in the number of biologically-based control products as the traditional chemical control manufacturers look for areas to make higher profits. Biological controls, both bio-active and bio-based, will cost the manufacturers only a fraction of the amount required to develop a new product. With the new EPA streamlined registration policy for biologicals, it should only take one- quarter to one-third the time to get through the regulatory process. No doubt, these reduced costs will not be fully seen in the retail prices of biologicals but their pricing should be more in line with the pricing of competitive commodity chemical controls like 2,4-D and Diazinon.

New Equipment

New equipment introductions will continue, particularly in the area where the new machines solve problems for smaller unserved niche markets and in areas were the new equipment offers a substantial advantage over its existing competitive equipment.

But, because of the high cost of production equipment and the loss of market share to international manufacturers, the number of new "copy cat" equipment introductions will probably be smaller than in recent history. The number of computer controls and solar-powered combinations with existing equipment will start to rise and should be very popular by 2004.

The major area for change in equipment will be in the type and availability of small engines as engine manufacturers begin to meet new anti-pollution and anti-noise guidelines. The number and variety of high-polluting, smaller, two-cycle engines will be reduced. Some engine manufacturers have already decided to replace their two-cycle engines with less polluting small four-cycle engines, and the cost of meeting these new standards will likely result in several of the smaller manufacturers going out of business or merging with larger companies.

Computers will become far more common in the office and new communication devices, like personal digital assistants and other portable computers will be showing up in the field. Of all the equipment, computers and communication devices will have the greatest effect on turf management practices. As these devices become more commonly used, new software will be designed that will greatly increase the turfgrass managers effectiveness.

So-called expert software will help the turf managers to make management decisions, meet regulatory record-keep-

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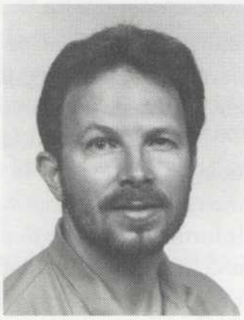
Future trends in turfgrass research

Science and Technology

by Dr. Eric B. Nelson



PREDICTING THE future is something I hesitate to do because I find, that once the future has arrived, I'm usually wrong. At the risk of being wrong again, I think there are some clear trends to where turfgrass science and technology are heading in the future. A number of these trends are shaped by the overwhelming changes in which our society and planet find themselves in the present.

In the next 10 years and beyond, our lives will be considerably different than they are now. For example, the poor distribution of global wealth and an additional one billion people will present challenges for everyone. Issues of waste management and utilization of resources will predominate the social and political agendas worldwide. The increase in population, coupled with the decline in usable green space, will place increasing emphasis on managing and maintaining turfgrasses and ornamental plants as conservation measures. The pressure to increase food production will come into conflict with the increased pressure to effectively deal with the growing pollution of the planet. This in turn will continue to fuel the growing movement to limit pesticide use.

Societal distrust

So what does all of this have to do with trends in turfgrass science? First, there has been a growing societal distrust for science. This has arisen because of the perceived neglect of scientists in addressing societal problems in favor of high-profile projects with questionable long-term benefits. This has been amplified in recent years because of policies of several preeminent universities on the use (or misuse) of federal funds. As a result of this controversy, science infrastructure and scientists will have to become more accountable to society.

Those of us involved in science will have to increase our efforts to "educate" an increasingly skeptical society as to the long-term benefits of basic scientific research. This education will help refocus a larger part of scientific resources on answering the basic questions involved in societal problems. Basic research will be required to address increasing problems of pollution, waste management, conservation of environmental and natural resources, pesticide use and exposure, agricultural and health issues. This education will come only when society endorses the goals of basic research and engages financially in a greater part of the scientific effort. This will require everyone, the society in general and turfgrass managers specifically, to become more scientifically literate.

What are the specific areas in science that will effect turfgrass management in the next century? If we look at science at large, some of the more recent and revolutionary developments have come in the biological sciences. The advent of recombinant DNA technology is changing all aspects of the plant sciences. This revolution will continue into the 21st century, with novel forms of plant resistances to pests, increased plant adaptation and productivity, novel industrial uses of plants and microbes, such as in the production of chemicals, medicines, and for bioremediation.

Biotechnology has been leading and will continue to lead our technological revolution. Modern biotechnology will greatly affect turfgrass management, particularly in pest control and other forms of varietal improvement. Turfgrass plants and turfgrass-associated microbes are proving to be quite amenable to genetic manipulation using modern tools of recombinant DNA technology. This aspect of biology will find increasing turfgrass applications in the future, such as the genetic engineering of specific desirable traits from other organisms into turfgrass varieties. Furthermore, research into the manipulation and management of microorganisms for the purposes of pest control will greatly benefit from the advances in recombinant DNA biology.

Turfgrass as a recycler

It is becoming clear that turfgrasses, in addition to providing an esthetically pleasing living environment as well as a recreational surface, will find important uses in cleaning up our environment. The great filtering properties of turfgrasses coupled with their abilities to support high levels of microbial activity, make them an ideal tool for bioremediation.

Furthermore, because of their non-food-crop status, turfgrasses will become a repository of unwanted, recycled, or reformulated waste materials and agricultural and industrial by-products. Research into environmental aspects of turfgrass management will become increasingly important in the elevation of turfgrass to its proper place as an important resource.

Turfgrass science in the 21st century will be considerably more technical than in the past. Turfgrass research will place greater emphasis on environmental issues employing some of the latest biotechnology for the management of pests and stresses as well as in

-continued on page 14

The future of the business of turfgrass business

The back office

by Christopher Sann

There will be considerable changes in the future, in both the levels and kinds of turfgrass research conducted and the ways in which the field work of turfgrass managers is accomplished.

But by far the greatest changes in the turfgrass industry will occur in the organizational and business practices of any organization whose operation has the potential of causing substantial environmental damage.

The changes that will occur in research and practice will be measured in percentages, but the changes that will effect the back offices of turfgrass management organizations will be measured in quantum leaps.

Concern for the environment will dominate

Concern for the environment, which manifests itself in increasing doubts of the current political system's ability to recognize the situation, will lead pressed bureaucracies to develop broad new paperwork and data storage regulations. The turfgrass management industry, horticulture and landscape management and other business types that have the potential to cause environmental harm will all be forced to march to the same drummer.

Protests by businesses over the correctness, severity and the appropriateness of these new regulations will prove futile. Finger-pointing by one affected group at another affected group will be commonplace. If we in the green industries with our meager resources try to slug it out with the big boys of agribusiness and petro-chemical manufacturers and the heavy hitters of energy, paper and plastics in the arena of the insiders, we will surely lose.

If the turfgrass management industry can keep its wits about it while everyone else is consumed by the chaos, then we stand an excellent chance of not only surviving the next 10 to 20 years intact but of actually raising the current negative image of turf to one of a respected partner. But in order for that to occur, the turfgrass management industry must prepare for the heavy demands that will surely come.

Automation is the key

The turfgrass management industry must completely computerize its office functions — from application record keeping to application scheduling, from records of site weather conditions to site diagnosis, from probabilities to precise pesticide inventory records. It must also automate application justification thresholds, have controlled paper trails on disposal of toxic wastes, and keep records on current and ongoing training qualifications of all handling and application personnel.

The turfgrass industry will have to change the way it does business if it is to survive the onslaught of environmental paranoia that will surely follow the loosening of the information noose that will be the natural outgrowth of the end of the Cold War. We must allow the computer, both at the office and in the field, to become the new backbone of how we operate.

Computers are everywhere

It was recently reported that 30% of all blue collar workers use computers daily and that 60% of all white collar workers use computers daily. It is estimated that 25 million homes in the US have computers. This increase of the use of computers in the home and workplace has occurred within the last decade.

During this most recent recession, businesses all across the US have grown leaner: hundreds of thousands of people have been let go, offered early retirement or laid off. The majority of these jobs have disappeared. These jobs will not be filled when the economy turns around and things get better. The work that the now unemployed workers did still needs to be done, it is not going to be done by people, it is being done by computers. Hundreds of thousands of repetitive, tedious jobs have vaporized never to return.

One industry has risen to the challenge

Perhaps an examination of the recent history of the petroleum refining industry and how far it has computerized to meet the ever increasing regulatory cost and liability pressures of the last 10 years, would prove to be very illustrative.

At many modern petroleum refineries, the computer has gone from being the glorified adding machine days of a mainframe computer operated by clean office personnel, used to invoice billing, run payroll and track inventory, to being the garage mechanic's partner on his work bench.

Instead of a shelf full of manuals designed to cover the maintenance and repair of up to 300 different pieces of rolling stock that the mechanic must know how to work on, he now has a computer terminal with a CD-ROM library of all the manuals and direct modem connections to all the manufacturers of the equipment. If he has a problem that the CD-ROM libraries cannot answer, then he has the parts that he needs to repair the equipment delivered to his bench by a local off-site parts supplier who is connected to his bench on-line by computer and delivers just the parts needed for that job within one hour.

The maintenance man or pipefitter at the refinery who works on the plant fixtures downloads all the information that he will need into his laptop computer before he leaves the garage to replace a valve or put in a replacement gizmo. That computer tells him where that old part is, what tools he will need to remove it, how to take it out, and whether he will need a helper. It will let him know whether the fire and safety personnel should be at the site, and when he should expect to return from the job.

The modern tanker truck that is used to deliver product from the refineries will not even start if the computer in the cab of the truck does not have the correct information from the 30 to 40 sensors placed on the rig to check the braking system, the tires, and the axles. In addition, the driver will have to have the right product code to be able to start the engine.

A new diesel engine designed for these big rigs has just been introduced that actuates the valves on the engines by computer. It completely eliminates the valve train system that has been standard on internal combustion engines for the last 90 years.

A bumpy road to full computerization

The petroleum refinery industry has responded to the pressures of federal, state and local regulators, the dramatic increases in liability costs and the cost pressures of the market place. It has looked at every operation within their complex business structure and asked the question: how could a computer help us here?

The turfgrass industry must take the same approach. It must examine every dusty corner, every half used bottle of pesticide or bag of fertilizer, and every lost employee hour. Hours waiting for a piece of equipment to be repaired, dollars lost in scheduling problems or lost inventory and say: can a computer help me solve these problems?

Computerizing will not come easily. There's a revolution, not an evolution in small, hand-held computers and the coming wireless communications network that could link field computers to the computers in the office. Much of the customized software that the industry will need to solve its various problems does not exist yet.

The computer hardware business is different from any business we have been used to. It is not like the present equipment supplier, the present mower manufacturer, or bag goods supplier. Thecomputer hardware suppliers will not come to you and offer you turn key solutions to your problems. You must go to them. You must let them know what your problems are and together develop the software and hardware configurations that will answer your questions. Computers are dumb tools and turf manager will have to invest considerable time and energy to make those dumb tools turf smart.

Change, our constant companion

The world of computers is constantly changing, with innovations often coming so fast that it is easy to become overwhelmed. But the computer is the only way we have to deal with the tremendous pressures to come. The information requirements and the data storage requirements of the near future will make the last 10 years look like a walk in the park.

Feeling overwhelmed is not a new feeling for turfgrass managers. We operate in an ever-evolving business climate. When we make our living in what is considered to be the most complicated of the plant sciences, often requiring intimate knowledge of as many as ten scientific disciplines, change is our constant companion. If we can see the problems that are coming in the near future, anticipate the solutions, and have confidence in our abilities to adapt to change, we will survive.

Management in 2004 *continued from page 8*

ing requirements and keep databases of collected site-specific information. This will lead to predictive modeling software that anticipates problems before they develop. These same databases could be used to develop "what if" scenarios, such as exist with today's spreadsheet programs.

Services

The number and types of services offered to the turfgrass manager will increase dramatically. As the amount of new knowledge and the increase in the learning curve continues, managers already strapped for time will increasingly hire consultants to help them manage their facilities.

Services like soil testers and fertility specialists, application specialists, computer programmers and advisors, I.P.M. scouts, risk assessment analysts, specialized outside mechanical consultants, water and drainage experts, and a host of others offering specialized services, will become more frequent visitors to larger facilities. Already, soil testing and fertility specialists and application specialists are increasingly being called upon for advice or work by facilities managers.

Field Management Techniques

Actual field management techniques will be substantially affected by all of the above changes as well as by new, more accurate, scientific information, as more money is spent on basic turfgrass research. These forces will all combine to change the number, frequency and spectrum of activities on turf sites and probably reduce the number of persons directly employed by these facilities.

DuPont wins fifth of nine Benlate lawsuits

The DuPont Co. has said that a federal judge granted a motion for summary judgment of the fifth of nine pending lawsuits connected to its Benlate fungicide.

A former clerical worker at a DuPont plant in Belle, W. Va., was told by the judge that she had produced no evidence that Benlate or other chemicals at the Dupont plant had caused her permanent illness.

Meanwhile, the Wilmington, Del., News Journal reported that media speculation linking Benlate and birth defects, especially the birth of babies with severe eye defects, is unsubstantiated. A Dupont spokeswoman said, according to the News Journal, that there was "'not a fact, not a shred, not an iota of proof anywhere to substantiate these irresponsible claims about our products.'"

Report from Iowa State University

Slow release fertilizers increase root mass

Application of four fertilizers, two synthetic slow release and two organic slow release, increased root dry matter from 52% to 131% over as compared with an unfertilized control plot. The fertilizer with the highest water-soluble nitrogen fraction, methylene urea, showed the lowest increase in root mass. The remaining slow release synthetic fertilizer, Ureaform, and the two organic fertilizers, Milorganite and corn gluten meal, all resulted in increases of over 100%. Accompanying this increase in root mass were some minor negative effects on overall quality (7% -11% decrease) for the two fertilizers that showed the greatest increase in root, Ureaform and Milorganite.

TGT's view: *This study demonstrates the long suspected benefits on root development of slow-release fertilizers. The more than 100% increases in root mass that occurred with the organic and slow release synthetic fertilizers strongly indicate that highly water soluble fertilizers based on urea and ammoniacal sources should not be used where turfgrass root development is an important consideration.*

This should also be a strong consideration where root damaging diseases such as Necrotic Ring Spot, Pythium Root Rot, Take-all Patch, Summer Patch, and Spring Dead Spot are an existing or possible problem. — CS

Michigan State study

Aeration, rototilling before planting improves rooting

A Michigan State University study found that sod rooting improved considerably when the sites where cultivated by aeration or rototilling prior to the sod installation. Rooting of Kentucky bluegrass sod improved by 49% 30 days after installation and by 46% 90 days after. This improved rooting was still evident 300 days after installation, with increased rooting ranging from 32% to 51% over non-cultivated controls. Solid tine aeration produced the best average increase of root mass (36%) over the 300 day period, followed by rototilling (29%) and hollow tine aeration (21%).

TGT's view: *Any site being prepared for sod installation should have some cultivation. If solid tine aeration is not available then either tilling or hollow tine aeration will help. Any activity that causes compaction should be avoided as the long term sodding results may prove very unsatisfactory.* —CS

Report from New Zealand

Soil permeability and deep cultivation techniques

The study compared the effects of three deep cultivation practices, Vibramole, Hydrojet and Vertidrain, on the permeability of sandy loam soil. Penetration techniques produced positive results that lasted for up to seven months. Vibration or soil-shattering did not, although the soil moisture levels were high enough to probably negate any benefits. The treated area showed increased permeability but these effects were limited to areas immediately surrounding the holes and were a function of the number of holes the procedure produced. Unlike core aeration, these techniques did not increase root mass.

TGT's view: *The use of deep cultivation techniques can be successful when used to alleviate standing water, poor drainage, or saturated soil problems, but their use as a means of improving root mass directly, like other aeration practices, is questionable. Indirectly the root mass should improve in combination with additional practices designed to combat the very negative effects of saturated soil conditions, such as improved soil chemistry and the use of wetting agents and root protecting fungicides.* —CS

New Zealand study

Greens establishment shows dramatic loss of water infiltration rates

A New Zealand study of six different means of establishing turf coverage on sand based greens showed dramatic losses of water infiltration rates for all of the establishment techniques after the turf was subjected to simulated wear.

Six different cover establishment techniques were used.

Table 1 shows the reduction in water infiltration rates of the six different establishment techniques after one simulated wear session and after a second wear session.

TGT's view: *This study shows that wear or traffic stress will always reduce water infiltration rates on turf areas but turfgrass managers should choose establishment techniques with these results in mind.*

Penn State research has shown that turf establishment by sod is the best method in non-wear areas but this study suggests that, where traffic is a concern, seeding at normal and high rates is the preferable method of establishment for long term turf survival. —CS

Table 1

Percent Reduction In Water Infiltration Rates

Technique	After First Wear	After Second Wear
Seeded at 7lbs./1000 sq. ft.	41% reduced	22% reduced
Seeded at 21lbs./1000 sq. ft.	48% "	23% "
Juvenile sod (6-8 weeks old),	37% "	64% "
Mature sod on sandy soil,	89% "	91% "
Mature sod on clay loam soil,	95% "	78% "
Washed sod (sandy sod with soil removed).	77% "	68% "

Illinois study

Dormant fertilization shows higher rates of nitrogen produce best results

A study of various dormant fertilizer sources applied at two rates over a four-month span found that the higher rates of nitrogen produced the best spring green-up results in the spring. The study conducted in Illinois examined three fertilizers at 1# and 2# nitrogen rates applied in October through January. Although the spring green-up varied in its time of occurrence and was not comparable from year to year, the 2# nitrogen applications consistently produced better spring green-up results than the same fertilizer applied at the 1# nitrogen rates. Applications of Urea produced the best results when applied in December or January, while organic-based fertilizers were consistent in their response by month and SCU produced the best results when applied in November and December.

TGT's view: *The date of application should be determined by the fertilizers that are to be applied. Organics can be applied any time the turf has reduced its vertical growth. Intermediate release fertilizers should be applied in November and fast release fertilizers should be applied as late as possible.* —CS

News Briefs

University of Rhode Island study

Tall fescues are more efficient at leaf growth

A study at the University of Rhode Island tested six varieties each of three turfgrass species for their ability to take up nitrogen and their ability to turn that nitrogen into leaf growth. Six varieties of tall fescue, bluegrass and perennial ryegrass were rated for their ability to produce clippings, nitrogen leaf concentrations, and efficiency of nitrogen use. Over the growing season, the tall fescue varieties produced an average of 50% more leaf tissue while having the lowest leaf nitrogen content and the greatest nitrogen-use efficiency. Table 1. below lists the results of this study.

TGT's view: *Tall fescue varieties would be excellent choices for turf areas that have limited fertility or that have limited budgets for control or preventative applications. Tall fescue's efficient use of available nitrogen combined with that species insect and disease resistance make it an excellent choice for low maintenance areas.* —CS

Table 1

Species	Leaf Growth	Nitrogen Leaf Content	Nitrogen Use Efficiency
Ryegrass	0% increase	16% increase	4% increase
Bluegrass	28% "	12% "	0% "
T. fescue	50% "	0% "	21% "

Meets the Eye *continued from page 7*

include *Cosmarium, Coccomyxa, Cylindrocystis, Dactylothece, Mesotaenium, Klebsormidium,* and *Ourococcus*. All but the latter two are capable of producing surface crusts and slime. The two most abundant genera of cyanobacteria in turfgrasses include Nostoc and Oscillatoria. The latter genus has been implicated as the primary cause of slime formation on golf greens. The cyanobacteria are also known for their abilities to fix atmospheric nitrogen, which, in some instances, may actually contribute to the nitrogen nutrition of the turfgrass plant.

Algae are strictly dependent on adequate soil moisture for activity. Algal problems occur whenever the soil remains wet for prolonged periods of time and where the soil surface is exposed or the turfgrass stand is thin and weak. Although fertility has no clear relationship to algal activity,the use of acidifying fertilizers such as ammonium sulfate can enhance algal colonization.

In addition to the more conspicuous colonies of algae on the surface of turfgrass soils, many algae colonize the surfaces of plants. Although in greenhouse ornamental production, many of these plant-colonizing algae can be detrimental to plant growth, their effects on turfgrass plants are largely unknown.

Challenges for the Future

Soil contains an extremely rich wealth of biological resources in the form of microorganisms. These microbes influence all of the important processes related to plant nutrition and the general maintenance of plant health. Furthermore, soil microbial communities provide a genetic resource of potentially useful products and processes that can be exploited for the management of turfgrasses. The challenge to turfgrass managers is to become experts, not only in the management of what they can see above-ground, but to master the management of the beneficial soil microorganisms to achieve the maximum, sustainable means of plant nutrition and plant protection.

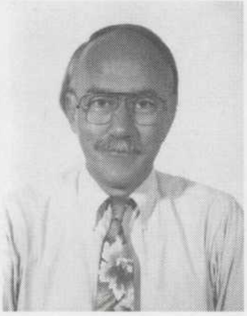
Science Trends *continued from page 9*

enhancing fertility and horticultural properties. This emphasis will reflect sources of future funding for turfgrass research as well as a renewed sense of accountability among scientists and academic institutions in addressing and solving problems facing our society.

Because of the increased technical competence and knowledge base required of turfgrass professionals in coming years, we at *Turfgrass Trends* will do our best to keep you abreast of the latest developments in turfgrass science and technology as well as in management and regulatory issues affecting your profession. Information management will be central to your abilities to keep up with a rapidly changing societal, political, and scientific environment.

Expo Fever: TGT at the GIE

By Juergen Haber



I had the good fortune of attending the Green Industry Expo in Baltimore in November.

The prime reason that I attended this GIE was that I was an enthusiastic newcomer to the turfgrass industry. Oh, sure, I've worn an exhibitors badge before — this wasn't my first trade show. But this was different.

All the major players — exhibitors as well as attendees — were there, and a lot of not so major players. The exhibits were well laid out. During the few minutes when I wasn't busy handing out sample copies of *Turf Grass Trends* and answering questions from the many subscribers who came by the booth — some surprised that we were back — I went around to see the other exhibit. The other exhibitors were attentive to my questions and were forthcoming when answering some of the hard questions that I posed to them. I learned a lot. Even I, new to the turfgrass business, could tell there were a lot of new products, new approaches with old products and an attitude by the exhibitors that said customers were important to them.

Even if the GIE is far away in the next years, it will be well worth any discomfort that getting there. The GIE gives you, the buyer of all these goods and services, the best opportunity that you can to see the full spectrum of the industry in one location. I can guarantee that you will come away from the GIE with very sore feet but well-informed about our industry.

Field Editor Chris Sann joined me and we passed out those 1000 or more copies of TGT to people who stopped by our booth. We got into friendly and lively discussions about the state of the industry and what front line turfgrass managers and others want from an industry news source.

The message was loud and clear. Whether it was from the turfgrass magazine publisher from Argentina, the new lawn care business owner from just outside Paris, the horticulture expert from New Zealand or the enthusiastic local lawn care operator who took two dozen copies to hand out to his friends at the University of Maryland Applied School of Agriculture' s Turf Institute, the message was: We are professionals in a $23 billion industry. Give us timely, accurate information in a form we can use and let us make our own decisions."

This was the idea that drove Chris to start *Turf Grass Trends* almost three years ago and the same idea I have continued in reviving it.

I came away from the GIE having met a great many interesting people and having gained dozens of new ideas which I hope to see realized in the coming months and years. If I didn't see you in November, let's try again this year!

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Coming attractions

March Issue

Controlling weeds within an IPM format
by Dr. Joseph C. Neal, Associate Professor of Weed Science, Cornell University

Understanding and controlling annual bluegrass
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An examination of 2,4-D and its safety
by Christopher Sann

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