Welcome to the Microbial World

The role of this dynamic community in turfgrass management has raised a variety of opinions, questions, and products.

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The soil microbial community consists of a wide array of organisms with numerous and many yet-to-be-understood complex interactions (14). Although studies of soil microbiology have been conducted for decades, scientists have recently made considerable progress in furthering our understanding of microorganisms and their function in soils supporting turfgrass growth.

Public outcry and opposition to the use of synthetic fertilizers and pesticides have prompted much of the recent research.

While very useful findings have been obtained through many painstaking and novel research strategies, these studies have yielded the realization that considerably more research will be necessary to develop solid recommendations for managing soil microbial populations. This article will review soil microbiology and discuss how to select and investigate the use of various products and management techniques. The intent is to provide information for golf course superintendents and other turfgrass managers so they can objectively evaluate the plethora of products that claim to produce better turf by influencing soil microorganisms.

Soil Microbiology

A productive, biologically active soil can contain as many as 45 quadrillion microorganisms in the rootzone of 1,000 square feet of turfgrass (19). This population consists primarily of bacteria, actinomycetes, fungi, and algae. Within each of these groups of organisms are many diverse genera and species whose populations fluctuate widely both spatially and temporally. Among the factors contributing to this variation are energy sources, nutrients, water availability, temperature, pH, atmosphere, and the genetics of the organism (6).

The result is a very complex and highly competitive system influenced by a combination of biotic and abiotic forces. The specific function and characteristics of the constituents of the microbial community are not straightforward and are not thoroughly understood.

Fungi are involved in organic matter decomposition, mycorrhizal associations, and turfgrass diseases. Mycorrhizal associations are known to improve nutrient and water uptake, and also stabilize soil aggregates. In fact, mycorrhizal associations have been shown to provide interspecific transfer of phosphorus and other nutrients (3).

Endophytic fungi form associations with plants and discourage insect predation. Actinomycetes decompose organic matter, particularly complex organic molecules such as cellulose and chitin. Actinomycetes are also capable of producing antibiotics that may confer disease suppressive qualities (15, 22).

The bacterial populations in soils contribute a range of benefits to plant growth. Included in these are nutrient cycling, soil aggregation, solubilization of immobile elements, competition with pathogenic organisms, organic matter decomposition, and the production of phytohormones.

Bacterial populations and their associative functions are diverse and highly significant to plant productivity. Bacteria tend to utilize simple organic compounds such as plant exudates, while fungi and actinomycetes are more proficient users of complex organic compounds (6).

Much of the activity described above occurs in the region of the soil environment influenced by roots, known as the rhizosphere. Within this region from the root surface outward approximately 10mm is found enhanced nutrient cycling, exudates that affect pH, redox potential, and nutrient availability; symbiotic associations with soil microbes; colonization by microorganisms; interactions with roots and pathogens; and metal mobility and complexation. More simply put, this region is the dynamic interface between plants and soil where microbial function is in action.

Grasses have a significant amount of rhizosphere due to their fibrous and extensive root systems. Although our understanding of the organisms, processes, and dynamics is increasing, there has been relatively little discovered that would enable turf managers to exploit the rhizosphere for improved turfgrass health. Researchers have, however, used mineral nutrition to affect rhizosphere pH and control root-infecting pathogens (4, 23). Beyond this, there is a host of unsubstantiated product claims that purport to favorably affect rhizosphere processes. In turfgrass systems, there is a significant lack of research to validate these claims, not the least of which include the lack of repeated studies and findings at diverse sites or across a variety of soil systems.

Most soils supporting turfgrass growth contain a very active and diverse microbial population. Some people have alleged that the use of synthetic fertilizers and pesticides reduces or eliminates the microbial community by altering the pH of the soil or causing direct and indirect toxicity to organisms. Except for the presence of inert ingredients in some emulsifiable concentrate formulations that have caused toxicity, preliminary results from one ongoing study indicate that pesticides do not adversely affect most non-target microorganisms (16). Due to the high productivity and rapid turnover of turfgrass roots, as well as the high lignin content in the stems and leaves, organic matter and microbial habitat are rarely deficient in turf grass systems (12).

The one system that may limit microbial activity due to a lack of favorable habitat is a newly constructed high-sand-content root zone, likely due to reduced nutrient and water-holding capacity. Keep in mind, however, that the advent of the sand rootzone system and sand top dressing arose to address severe agronomic difficulties, namely soil compaction and poor drainage of native soil greens. Sand-based rootzones have created physical characteristics that allow golf course superintendents to provide superior playing conditions and also maintain an oxygenated root zone. Microbial populations generally will stabilize 3-5 years after establishment, so amendments to the sand that can facilitate a more rapid colonization of the rhizosphere should lend stability to the system (6). These amendments would include various organic types, including composts and/or inorganic amendments. The challenge of establishing turfgrass on new, sand-based rootzones could be due in part to the lack of sufficient microbial activity to buffer the system from environmental extremes and harmful pathogens

Soil Management and Microbial Enhancement

Testing for Soil Microbes

Undisputed is the important role microorganisms play in plant and soil health. The difficulty is in quantifying and qualifying that role. Recent advances in molecular testing capabilities have enabled fairly accurate quantification of the microbial component in soils. While this will not yield a clear understanding of the diverse function and interaction of the various organisms, it is a beginning point for assessing microbial health in soils. Keep in mind that microbial populations fluctuate widely across sites and over the course of a season, however, so testing for microbial activity may produce somewhat confusing results until a large-enough database can be assimilated. This currently may not be feasible or cost effective, and it will certainly take time. However, microbial testing may provide comparisons of soil that supports healthy turf versus soil struggling to support turf. Be sure to account for other factors that may be limiting growth, such as sunlight, air circulation, drainage, fertility, traffic flow, etc. (13). Soil testing for microbes may help assess whether microbial activity is influencing turfgrass quality.

Biostimulants

Biostimulant is a loose term that includes microbial inoculum, energy sources for microbes, soil conditioners, plant hormones, and other non-nutritional growth-promoting substances. In recent years, products containing both biostimulants and fertilizers have further muddled this definition. This makes differentiating between fertilizer response and biostimulant response difficult, if not impossible. No doubt this is precisely what the manufacturers of such products have intended, since the non-nutritional component alone may not elicit a plant response.

One group of biostimulants is plant hormones. These products may contain one or more of the following: cytokinins, gibberellins, auxins, abscisic acid, and ethylene. When growing under normal conditions, plants have adequate levels of hormones for normal growth and development. Most physiological processes in plants involve an interaction of several hormones, and individual hormones have several functions. Further, many hormones have different functions in different plant species (8). Normal hormone production can be influenced by environmental and cultural stress. Different species of plants, growing in different environments, with different

Soil Microbes

Bacteria: Single-celled organisms without a nucleus. Perform an important role in organic matter decomposition, nutrient cycling, soil aggregation, competition with pathogens, production of phytohormones. Also forrn symbiotic associations with plants.

Actinomycetes: Filamentous bacteria. Decompose complex organic matter molecules like chitin and cellulose, produce antibiotics, and regulate bacterial populations.

Fungi: Very good degraders of organic matter. Mycorrhizal and endophytic fungi form beneficial associations with plants. Most turfgrass pathogens are fungi.

Algae: Autotrophic organisms. Some fix nitrogen. Excess nutrients can result in an unwanted bloom.

Protozoa: Important in nutrient cycling and organic matter decomposition. Feed on bacteria and control bacterial populations.

stresses, at different times of the year are quite likely to react in different ways. One of these different reactions will undoubtedly be with hormone regulation, and this is consistent with the variability in plant response to hormone applications in research results and field trials across the country. There currently is no evidence to suggest that applications of plant hormones will yield favorable or consistent results with respect to improved plant health. Furthermore, adding hormones to plants beyond normal levels may produce an inhibitory or undesirable effect. Without research information to identify and quantify treatment regimes, it may be wise to avoid tampering with plant hormonal activity (7). Anecdotal evidence and testimonials have been the substitute for independent research results repeated at multiple locations.

Another type of growth stimulant available on the market contains humate or humic acid. These are naturally occurring organic compounds that are the end products of biological decomposition. Accordingly, they are extremely resistant to further decomposition. Products containing humates claim to increase cation exchange capacity, increase microbial activity, and chelate micronutrients. Kussow reviewed manufacturer recommendations for amending a sand-peat root zone mix with humate and found it to be a very expensive means of increasing the CEC by 13% (9). His review further concluded that iron, copper, manganese, and zinc are rarely deficient in turfgrass soils, thus enhancing micronutrient availability may only provide negligible benefits. Another study clearly demonstrated that since humates are the end result of decomposition and thus resistant to further breakdown, they do not stimulate increased microbial activity (25). Yet another study reviewed the effects of six non-traditional growth-promoting products on the establishment of creeping bentgrass in high-sand-content rootzones. Only one of the products produced significant differences from the control, and the product contained humate. Upon chemical nutrient analysis of the product, however, it was discovered to contain 6% N, 5% P, 2% K, 4% S, and 4% Fe. Using this product at

Evaluating Independent Research

- Who (principal investigator) did the research?
- Where was the work done (lab or field, sand or soil)?
- Look for replication, good comparative treatments, and statistically significant differences.
- Have the results been duplicated at another site by another independent researcher?
- Have the results been published in a refereed journal?
- Slick brochures can be confusing! Don't be fooled by sales techniques.

the recommended application rate was equivalent to applying an additional 0.75 pound N, 1.3 pounds of P, and 0.34 pound of K per 1,000 square feet per month (7). It may well be that this response could have been duplicated with conventional fertilizer, and it would seem to request an independent nutrient analysis of any growth stimulating products you intend to try.

Finally, there have been studies that indicate humates and humic acids can reduce the efficacy of pesticides by reducing their absorption by plants and pathogens (9). It is also reported that the fulvic acid component of humates can actually increase the solubility of pesticides and possibly increase mobility (2S). Most of the studies that claim any benefit from adding humates were in either nutrient culture or sand culture systems, not in field situations. The variation in humic substances from different sources and lack of research that supports their use on turfgrasses currently do not justify their use in turf management.

Carbohydrate fertilizers, another biostimulant, have not been proven to improve turfgrass stress tolerance or have any lasting impact on soil microbial populations. Again, research on turfgrass and carbohydrate application is lacking, but observations across the country indicate no observable benefits. Any stimulation of microbial activity is likely to be very short-lived.

Microbial Inoculants

Various microbial inoculants have been formulated for use on turfgrass, with claims of accelerated organic matter decomposition, improved nutrient use efficiency and availability, soil conditioning, disease control, mycorrhizal associations, and others. The success of these inoculants has been limited for a number of reasons. At this point, you should be aware that the microbial community is a very diverse and complex set of organisms The degree of natural competition, antagonism and predation limits the successful establishment of introduced species. Persistence of applied organisms is further hindered by the continual temporal and spatial fluctuation of microorganism populations (6). Formulation and delivery of the organisms present even more problems for microbial inoculation (15). If the organisms can be kept alive until application, many are sensitive to UV light and must be applied frequently (in some cases nightly) to establish sufficient populations. Although there have been efforts to apply microorganisms through irrigation systems, the results remain largely inconsistent (2). Finally, some companies will not even list what organisms they have formulated, because they are proprietary. Without knowing what is being applied, it is impossible to gauge the potential benefits. These organisms could be detrimental to your turf by actually competing with the beneficial organisms already present in your soil (7).

Composts

With little doubt, the most promising method of managing and enhancing the activity of soil microbes is with composted organic matter in wastes and other materials. Ironically, this is also one of the oldest agricultural practices. Composts have been shown to add an active microbial component to soils and to stimulate those microbes already present in the soil (14). Well decomposed organic matter provides excellent habitat and energy sources for soil microbes, and will provide more permanent benefit than inoculation with microorganisms. Composts will effectively enhance soil aggregation, provide nutrients, reduce compaction, and improve soil porosity. Sandy soils amended with compost will exhibit greater nutrient- and water-holding capacity (10). While limited evidence exists, there is some data to suggest amending sand-based rootzones with compost can offer improved establishment and disease control over commonly used peat amendments (5, 14).

The use of composts in turfgrass management presents a viable means of recycling municipal and industrial wastes while improving turfrass quality. Composts can vary considerably, however, depending on their source. Commonly used composts include brewery sludge, yard wastes, poultry litter, animal manure, municipal wastes, and food wastes. It is recommended to have composts tested for organic matter content, ash content (especially if used as a topdressing), moisture content, pH, nutrients metals, and soluble salts (10). On-site composting operations should follow guidelines to ensure that the material has been properly and sufficiently composted (14, 20, 28). The disease-suppressive characteristics of composts will be discussed in the next section.

On-Site Testing Protocol

- Test products at several locations representing different conditions on the golf course.
- Use controls (no product) to establish comparisons.
- At least two years of field data are necessary to obtain an accurate assessment.
- Rate the plots monthly to track differences (color, disease, stress tolerance, rooting, etc.).
- Conduct an independent nutrient analysis of new products. You may be seeing a fertilizer response!
- Be honest! Is it the product or favorable weather, better cultivation, an improved growing environment, or other changes in management strategies?

Biological Pest Control

In recent years, considerable focus has been placed on the biological suppression or control of various turfgrass pests, including diseases, insects, and weeds. Reducing the pesticide load on the environment is the primary impetus behind such study. While research has proven effective pest control with various biological entities in the laboratory, few have proven consistently effective in field studies.

Biological control operates on five basic interactions with the turfgrass-soil community: competition, antagonism, predation, parasitism, and pathogenicity (1). The two ways of exploiting these interactions include microbial inoculants and organic amendments. While dozens of organisms with potential as inoculants for disease control have been studied (17, 18, 24) few have demonstrated any efficacy in the field, and only one product (Biotrek 22G, (Trichoderma harzianum) has been registered for disease control on turf (11, 15). Biological control of insects has been somewhat successful in recent years with such organisms as entomogenous nematodes, soil bacteria and fungi although registered products are still limited (21, 26).

Serious shortcomings exist in the understanding of the pest control mechanisms themselves, relationships with other organisms in the community, and formulation and delivery technology. Furthermore, foliar disease control with inoculants is limited due to UV sensitivity of the organisms and wide fluctuations of environmental parameters in the turfgrass canopy.

The difficulty in delivering organisms to the roots has preempted much success in controlling root diseases. Because successful pest control typically depends on the establishment of high population levels, frequent (and arguably unsustainable) applications become necessary. Injecting organisms through irrigation systems has yet to be proven as an effective method of uniform and consistent microorganism application

Keep in mind that 1) population interactions within the soil are dynamic and interrelated, 2) introduced organisms are slow to colonize habitat and generally fail to persist, and 3) it is unclear whether the introduction of microbes in the environment will produce a lasting change and if the introduction will be beneficial in the long run (1, 15).

Organic soil amendments and additives, particularly compost, have perhaps a greater potential for effective biological control of diseases than do inoculants. Well-composted material (2-3 years) often exhibits disease-suppressive characteristics (14).

Studies at Cornell University have demonstrated significant and lasting disease suppression of Pythium root rot, dollar spot, and snow mold when composts were used as amendments or topdressing (14).

Continued research in this area to reveal the microbiological mysteries should help develop more reliable and predictable composts for disease suppression and soil conditioning. As alluded to earlier, proper composting techniques and laboratory testing coupled with on-site testing will reveal what to expect from composts.

New Products

Never before has the turfgrass industry had as many commercially available products for use. Financial responsibility and sound management dictate that product purchasing decisions are of extreme importance. So how does one choose between the good, the bad, and the ugly?

The first place to start is with the product label. There are products that have been registered with the EPA and can legally justify the claims of the product. These are products that contain active ingredients (29). There are unregistered products marketed for various uses, some of which are supported by independent research. Then there are products marketed for various uses without supportive research. These products use testimonials and fancy marketing to make a sale, and often can be classified as snake oils.

Let's be sure we understand the independent, scientific research that supports product use. Be sure you know who conducted the research, where, under what conditions, and the relevancy to turfgrass systems. Also, look for replication in the study, good comparative treatments, and least significant differences. Check closely to see that the results have been duplicated at another site by another independent researcher, and that results have been published in a refereed journal. Make no mistake, slick brochures and displays can be confusing! One product advertisement I recently reviewed claimed the product would cause no grow-in layer, extend the useful life of greens, reduce grow-in time, eliminate the possibility of nitrite (yes, they said nitr*i*te, not nitr*a*te!) and phosphate leaching, and reduce labor, among other things. This company may need legal counsel as much as scientific counsel. Finally, call the researchers and ask technical representatives what the active ingredients are and what are their modes of action (29). University extension personnel and USGA agronomists can also provide valuable information.

If a product you are interested in passes this initial screening, it is strongly recommended to conduct on site testing at your golf course. Many of these products are not cheap, and good manage-

Literature Cited

1. Berndt, W. L. 1996. Population interactions: the key to unlocking natural pest control. *The Turf Letter.* 1(3):1-8.

2. Bresnahan, J. 1998. Bioject: results of 1997 research trials. Presented at New England Regional Turfgrass Conference and Show Providence, RI. March 4,1998.

3. Chiariello, N., J. C. Hickman, and H. A. Mooney. 1982. Endomycorrhizal role for interspecific transfer of phosphorus in a community of annual plants. *Science* 3:941-943

4. Dernoeden, P. H. 1987. Management of take-all patch of creeping bentgrass with nitrogen, sulfur, and phenylmercury acetate. *Plant Disease.* 71 (3):226-229.

5. Hall, R 1996. Composts vs. peats: composts win. *Landscape Management.*35(8):14.

6 Holl, F.B. 1997. The mysterious world of the turfgrass root zone. *Turfgrass Trends.* 6(11):1-8.

7. Isaac, S. l998. Bio-stimulants and all that! *International Turfgrass Bulletin.* 199:9-10.

8. Karnok, K. J. 1989. The use of plant hormones as non-nutritional turfgrass growth enhancers. *Golf Course Management.* 57(7):28-38.

9. Kussow, W. R 1994. Humate and humic acid. *The Grass Roots.* 22(2):18.

10. Landschoot, P. 1998. Using composts to improve turf performance. *Turfgrass Management in the Pacific Northwest.* 1(1):32-34.

11. Lo, C. T., E. S. Nelson, and G. E. Harman. 1996. Biological control of turfgrass diseases with a rhizosphere competent strain of Trichoderma harzianum. *Plant Disease*. 80(7): 736741.

12. Loomis, R S., and D. J. Connor. 1992. *Crop ecology.* Cambridge University Press, New York, NY.

13. Moore, J. F. 1997. Let's give credit where credit is due. *USGA Green Section Record.* 35(2):20.

14. Nelson, E. s. 1996. Enhancing turfgrass disease control with organic amendments. *Turfgrass Trends.* 5(6):1-15.

15. Nelson, E. B. 1997. Biological control of turfgrass diseases. *Golf Course Management.* 65(7):60-69.

16. Nelson, E. B. 1998. Turfgrass pesticides and biological disease control: are they compatible? *CUTT* 8(4):7-9.

17. Nelson, E. B., and C. M. Craft. 1991. Introduction and establishment of strains of Enterobacter cloacae in golf course turf for the biological control of dollar spot. *Plant Disease.* 75:510-514.

18. Powell, J. F, M. G. Nair, and J. M. Vargas, Jr. 1994. Utilization of a bacterial metabolite for the management of dollar spot disease of creeping bentgrass (Agrostis palustris). *Phytopathology.* 84(10):1077.

l9. Roberts, E. C. 1998. Turf research: nature, needs and net results. *Turfgrass Trends.* 7(1):i-9.

20. Senseman, R. Y. 1995. Composting: turn your eyesore into black gold. *USGA Green Section Record.* 33(3):8.

21. Shetlar, D. J. 1996. Field testing of biological pesticides. T*urfgrass Trends.* 5(8):1-9.

22. Stockwell, C. T., E. B. Nelson, and G. M. Craft. 1994. Biological control of Pythium graminicola and other soil borne pathogens of turfgrass with actinomycetes from composts. *Phytopathology.* 84-1113.

23. Thompson, D. C., B. B. Clarke, J. R. Heckman, and I. A. Murphy. 1994. Suppression of summer patch in turf with acidifying nitrogen fertility programs. *Phytopathology.* 84(10):1085.

24. Thompson, D. C., B. B. Clarke, and D. Y. Kobayashi. 1996. Evaluation of bacterial antagonists for reduction of summer patch symptoms in Kentucky bluegrass. *Plant Disease.* 80(8):856 862.

25. Varshovi, A. 1996. Humates and their turfgrass applications. *Golf Course Management.* 64(8):53-56.

26. Vilani, M. G.1996. Biorational control agents for Japanese beetle management. *CUTT* 7(1):1-7.

27. Wegner, T. 1997. Bentgrass response to non-traditional soil additives. *The Grass Roots.* 25(4):58-61.

28. Zontek, S.1974. Composting alchemy in action. *USGA Green Section Record.* 12(3):9-11.

29. Zontek, S. 1997. Buyer . . . beware. *USGA Green Section Record.* 35(1):17.

ment involves an economic analysis. Test the material at several locations on the golf course representative of different conditions, replicate (meaning include repeated treatments at each site), and use untreated controls and other treatments in side-by-side comparisons. All too often, new products are tried all over the golf course without a control; thus, it is impossible to determine what effect, if any, the new product has. Perceived benefits could be a result of favorable weather or other management techniques (7, 13). Take consistent, monthly ratings of the plots for color, disease, and rooting depth and mass, and note stress tolerance differences. Good tests require at least two years of field data. Because a product will cause no harm is not reason to use it, and such a decision is representative of poor management.

Conclusion

Turfgrass management is a continually evolving science, and as our understanding of the microbial community in turfgrass systems improves, new products will routinely hit the market. Some of these products will be useful, and many others will not. Independent reseach will be essential to the development of effective products. Perhaps companies marketing biological products would be wiser to fund some research than to purchase full page ads in popular trade magazines (if they have faith in their products) !

If completely organic management is ever realized, it will certainly be through a gradual phase-out of synthetic products. Along with the advent of biological products, golf course superintendents must also keep themselves apprised of advances in synthetic chemistry. Many new products have been developed from synthesized organic compounds that are effective at very low levels of active ingredients, have low water solubility, short half lives, and a strong binding potential with soil and organic matter. The new synthetic chemistries are better for the environment than many of the older chemistries.

The importance of a strong microbial community cannot be questioned. The effectiveness of various products available to stimulate microbial activity can be questioned. Become familiar with soil microbiology and processes, check for duplicated independent research to support product claims, and test the material yourself to be sure it is effective and makes good economic sense. But whatever you do, don't forget the basic tenets of successful turfgrass agronomy: adequate sunlight, drainage, air circulation, proper fertility, good water management, traffic control, and cultivation.

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Microbes: The Real Millennium Bugs

Microbes! Those little microscopic links in the chain of life. We all know that they're out there in the soil, water, air and in our bodies. What we don't know exactly is how they really work, what affects their populations the most, and how we can harness them to maximize turfgrass management.

Just like many of you, I have anecdotal experience that would suggest that this product or that product did indeed produce some sort of positive results. The challenge comes in finding reams of peer-reviewed scientific studies that give us a better idea of what's going on and how predictable a product or its results might be. We may soon find ourselves on a path that separates the snake oil from salvation.

Synthetic chemicals and fertilizers are under constant attack these days. They have been quick, effective tools to solve turf problems for about 50 years. Now the politically correct and environmentally conscious activists are waging a holy war to eliminate as many pesticides and fertilizers whether or not they are truly harmful. We can fight back, but it is a constant battle and the end users are at the mercy of too many things they can't control like the media, and politics and the manufacturers' bottom lines.

So, what if we could find more natural, benign ways of producing strong, healthy turf in a very active, healthy, growing medium? Maybe we can reduce our dependence on synthetic products, which are likely to start disappearing anyhow. Maybe we can find less expensive ways to enhance the natural systems at work and eventually produce stronger, healthier playing surfaces. The following articles provide information, insight, caution and hope for microbial solutions, and we are poised to start funding more research on these millennium bugs.

Former Sales Rep is Sold on the Products, Not the Sales Pitch

Since I tried to sell this technology to most of you for two years, I felt obligated to respond to this Hands On topic, "Microbes – The Real Millennium Bugs." I'm not going to waste my time or yours continuing to sell you on this concept. By now you either believe that using microbial products is good science or you think it is a deception.

Now as a superintendent once again, I use the Green Releaf products that I sold, but not exactly in the way I sold them. I tried to sell programs that incorporated small amounts of all the products that Green Releaf sold on a 7- to 14-day schedule. Green Releaf trained us to sell the products that way, because if you bought into the program you would not have room to use other people's products. The program I use incorporates several different brands of products.

I basically spray my greens every week with a mixture of nutrients. I determine which nutrients to use and the amount of nutrient needed by tissue sampling. In that mixture I incorporate two gallons of Green Releaf 5-10-5 plasma per acre. I use the plasma because of the carbohydrates, amino acids, and humates that are in the product. The nutrients in the plasma are just a bonus.

The theory is that if you increase the amount of food source for the microbes in the soil, you will increase their population. The more microbes that are in the soil the more efficient the plants will become.

I'm pretty sure that all the so-called biological products are based on this theory. In my mixture, I add one gallon of fulvic acid per acre to help hold the nutrients in the soil. My own personal theory is that by using plasma and fulvic acid, I can get by with using the lower-priced liquid nutrients and get the same results as if I used the high-priced ones.

When I was selling microbes for Green Releaf, most microbiologist were skeptical of the validity of the products. Every researcher I spoke with said that, in a laboratory setting ,the microbes did all the wonderful things that Green Releaf claimed. However, only a few scientist felt the microbes could live long enough to get down into the root zone.

Even the most discriminating skeptics felt that if you could get the microbes into the root zone they would be notably beneficial. Because of this, I use the living microbes in two ways. I use them when I aerify, and I inject them with a hydroject.

When I aerify, I spray 5 gallons of Bio A and Bio B+ per acre after the cores are removed and before I topdress. I immediately flush the "bugs" into the soil with 10 to 15 minutes of irrigation. I then add 300 lb. per acre of Green Releaf 15-4-7 organic granular (to feed the microbes), then drag it into the holes with the topdressing.

What I see by doing this process is rapid recovery from the aerification, and a flush of root growth even in the summer months.

During the winter I inject microbes into the greens monthly. Last May going into the rainy season, the roots on my greens were 6 to 8 inches deep and dense (I'm not just blowing smoke, several people can attest to this). During the heaviest part of the rainy season the roots shrunk to 2 to 3 inches, but new root growth was always occurring.

So here is the question: Can I attribute the success that I have had to microbial products? I don't know! It could be the microbes and carbohydrates. Or it could be that the weather was good last year, or my water management was better this year, or my nutrient management is better than when I used granular fertilizers.

I honestly don't think there is any way to tell for sure if the microbes and carbohydrates have made a difference without conducting a lot of expensive research. However, I am not willing at this time to take the microbial products out of the program. Not until someone proves to me that using microbial products is not good science.

Do I think there should be money laid aside to research microbial products? Absolutely! In my opinion, with all the radical environmental groups trying to get us shut down, anything we can do that is environmentally responsible is worth researching..

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***Editor's Note:** At its fall board meeting the FGCSA agreed to submit a proposal from Dr. Monica Elliott on microbes to the GCSAA for research funding. The purpose of the project will be to determine if* Bacillus *microbes applied to bermudagrass putting greens do survive and establish on either the turf or in the soil. The project will also determine the effect of frequent, multiple applications on the* Bacillus *populations. The research will be conducted on a portion of the FGCSA's Otto Schmeisser Research Green at the University of Florida's Research and Education Center in Ft. Lauderdale*

Microbes Play Varied Roles in All Facets of Human Existence

If champagne, a loaf of freshly baked bread and a fragrant cheese will figure prominently in your Year 2000 celebration, then you can thank your local microbe. Human beings are dependent on microbes for many foods such as yogurt, sauerkraut, sour cream, beer and other fermented drinks.

There is also a type of bacterium that lives in the human intestine that makes vitamin K, a factor needed to clot blood.

In addition we take advantage of bacteria for their ability to protect us from microbial invaders. Human beings have their own special bacteria that have adapted to life in a salty, ocean of sweat on our skin. These bacteria keep out pathogenic fungi and bacteria. We also have a host of bacteria living in our throats, noses, intestines and other areas of the body. These friendly bacteria are tremendously effective at keeping the disease-causing bacteria away from their homes, our bodies!

A diversity of bacteria that associate with plant roots serve the same purpose of holding pathogenic microbes at bay.

Biological control agents, such as bacteria and fungi, work through a variety of mechanisms. These mechanisms include the production of antibiotics and other inhibitors; simple competition for food, water and space; stimulation of the plant's own system of defenses; and an environment around the plant roots that encourages growth of beneficial microbes.

Beneficial bacteria and fungi can form a barrier against pathogen invasion of plant roots. Because turfgrass's roots are surrounded by a host of friendly bacteria, it is much more difficult for *Gaeumannomyces* (take all disease organism) to reach its intended target.

In laboratory testing, conclusive tests have shown that *Gaeumannomyces* is sensitive to substances produced by several different species of bacteria. When a diverse group of microbes exists in the soil in the plant root zone, many reciprocal benefits are derived from that relationship. When bacteria and fungi colonize the rhizosphere, they are fed a steady diet of plant sugars. The plants in turn benefit from colonization of non-pathogenic microbes.

What happens if friendly plant bacteria are not available to protect plants? Soil that has been treated with harsh chemicals may deplete soil of the beneficial bacteria and fungi. When fungi and bacteria are no longer available as a shield pathogenic microbes may then be able to invade plants.

Within the past 50 years, the public has been taught that the only good microbe is a dead microbe. Nothing could be further from the truth. Without beneficial microbes, our plants would die and our own existence would be in jeopardy. And yet we continue to douse microbes with bactericides and fungicides in an effort to exterminate the pathogens, but in doing so many beneficial are also depleted in numbers.

Some helpful bacterial species include *Pseudomonas, Bacillus, Cellumonas, Corynebacterium, Rhodococcus,* and other member of the *pseudomonads actinomycetes.* Some species of *Pseudomonas* help break down urea-based fertilizers enzymatically and convert urea to ammonia. Ammonia is then converted by nitrifying soil bacteria to nitrates, a form of nitrogen readily available for plant utilization

Certain species of *Bacillus* produce insect toxins as well as antibiotics that inhibit fungal growth. *Bacillus* is an extremely hardy microbe. These bacteria form endospores under adverse conditions, enabling the microbe to withstand drought, high heat and adverse pH conditions. *Cellumonas* is extremely helpful in producing substances that break down dead plant material in the soil, thus helping remove thatch buildup. *Rhodococcus, Bacillus* and *Pseudomonas* are proven pesticide and herbicide degraders; therefore much of the excess biodegradable pesticides are devoured by microbes.

One important factor to remember is that just one bacterial type cannot do a job alone.

This is the reason why it is important to maintain a highly diverse population of microbes. What one bacterium can break down in the soil may not be an available food source for another microbe. As mentioned above, several different bacteria are needed in the first step of converting urea to ammonia. Without a team of urea-degrading organisms, the nitrifiers would be powerless to use urea-based fertilizers as a nutrient and thus produce nitrates for plants.

Without many different bacteria and fungi in the soil, a healthy environmnent cannot be maintained. In the decomposition of dead plants and animals, certain inorganic elements such as phosphates are released and made available for plant nutrition. Many different bacteria utilize common organic wastes and produce carbon dioxide and water.

Without microbial diversity, nutrient

cycling would be incomplete and the soil could be said to be "imbalanced." When nutrient/mineral imbalances occur, it leads the way for certain microbial populations to proliferate and dominate. If pathbgenic species dominate an area, then sensitive plants are in danger of becoming infected and an epidemic ensues.

While only a relatively few microbes, both bacterial and fungal, cause disease in plants and animals, a single infestation of *Rhizoctonia* (brown patch) or *Gaeumannomyces* can devastate a green. When a fungus invades an area it is difficult and costly to eradicate. From a fungal point of view, all any fungus wants is a warm moist place to live with an ample supply of food close at hand. A golf course usually provides the precise conditions that not only allow certain fungi a free ride, but in a sense, invite them in to stay.

However, certain defenders of the turf can and will defend grasses and other plants from the insidious invaders. Over the past 20-30 years, the prevalent method of ridding a green of the fungal marauders was to add fungicides. In recent years, golf courses and farms have come under attack for their supposed contamination of the environment with major amounts of chemicals and fertilizers applied in an effort to grow lush green lawns and a food supply to feed the world respectively.

In response to new governmental restrictions on chemical use, some operators are trying the natural approach of building and maintaining organic golf courses. A recent innovative approach is to add small doses of nutrients and microbes simultaneously to the courses. The result is efficient use of the fertilizers with the added bonus of inoculation with a diverse bacterial population.

This method of microdosing is being implemented successfully by such golf course superintendents as Jon Snider (Texas Star GC, Dallas/Ft. Worth) and Nels Lindgren (Loch Lloyd, Kansas City).

Use of the microdosing technique allows a reduction in the amount of chemicals applied and also allows the elimination of certain growth regulators. The use of such microbially-based inoculants as SuperBio microorganisms, a diverse group of 30 different microorganisms, promotes the growth of healthy grass and other vegetation. Microbial products are not meant to replace traditional uses of fungicides, but may allow fewer chemicals to be applied. When SuperBio microorganisms are applied several days after application of fungal control agents, the bacterial diversity in the treated area is restored. In preliminary tests, certain of the SuperBio bacteria are showing promise in retarding growth of selected fungi such as *Gaeumannomyces* (take all) and *Cylindrocladium* (damping off).

Traditionally, the scientific community has been slow to support the need for research in microbial diversity since much of academic bacterial research is performed on pure cultures made up of only one bacterial type.

The problem in this approach lies in the fact that bacteria and indeed all other organisms on earth rarely if ever exist in pure cultures. All creatures on earth need help from other organisms, whether they are microbes, animals, plants, scientists or golf course superintendents.

However, within the past 10 years, the scientific community has begun to view microbial diversity in a different light. More research is now being done on mixed cultures of microbes in their natural habitats. The time has come to work together, microbes and man, for a healthier, safer place to live, work and play in the new millennium.

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Bibliography

Agrios, G.N. Plant Pathology. Academic Press, San Diego, CA, 1997.

Sylvia, D.M., J.J. Fuhrmann, P.G. Hartel and D.A. Zuberer. Principles and Applications of Soil Microbiology. Prentice Hall, Inc., Upper Saddle River, NJ, 1998.

Ostmeyer, T. "Turning back the clock." Golf Course Management. July 1999, pp. 22-30.

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