BIOLOGICAL TOOLS FOR GOLF TURF MANAGEMENT

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A guide to the use of biological methods

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Soil Foodweb New York at: http://soilfoodwebnewyork.com

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Introduction

Biological management of golf turf has the potential to mitigate ground water contamination that can occur from use of pesticides, as well as reduce the costs associated with fertilizer and fungicide applications. One of the major stumbling blocks to the increased use of biological methods continues to be a lack of understanding of how the microbial communities work in the soil.

To better explain how biological techniques can help turf managers, Soil Foodweb New York (SFNY) set up a research and development project at Timber Point Golf Course in Great River, NY. Timber Point is located on the Great South Bay and has been very pro-active in minimizing its use of pesticides and soluble fertilizers. With funding from the NY State Department of Economic Development, biological turf management techniques were applied over a 2-year period.

This turf care guide explains alternative practices that were used in this project in day-to-day turf management. It outlines some of the savings that can be achieved with reduced chemical inputs. Whether you are a concerned citizen, golfer, or golf superintendent, biological turf management has multiple benefits for increasing the health of golf turf while improving the environment were golf course are located.

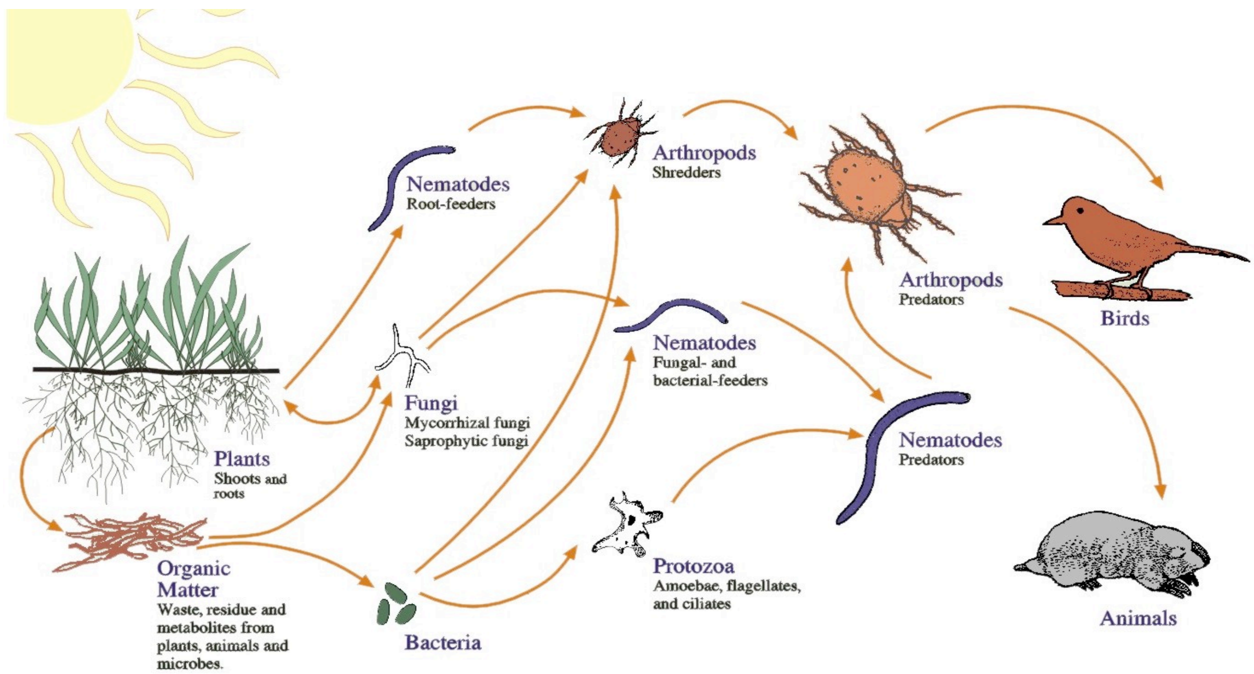
Timber Point Golf Course is located on the Great South Bay in Great River, New York.

Soil Biology Basics

It is well known that grass can be used to reduce nutrient runoff. Compost companies routinely use grass swales and grass-lined catchment basins to hold nutrients, and turf has been used in numerous projects to mitigate groundwater pollution by trapping nutrients in its biomass. In contrast, on some golf courses there is as little as one-quarter inch of rooting depth, which does not prevent nutrients from entering adjacent lakes and waterways.

How can grass be such a good biofilter in one situation, and yet in another not to help at all? The answer lies in the biology and structure of the soil.

Much of this information was first brought to public attention when the USDA published The Soil Biology Primer in 2000 (Soil and Water Conservation Society (SWCS), 2000 *Soil Biology Primer.* Rev. Ed., Ankeny, Iowa) http://soils.usda.gov/sqi/concepts/soil_biology/biology.html.. In this publication, scientists defined the term **"Soil Food Web" as "the community of organisms that spend all or part of their life in the soil".**



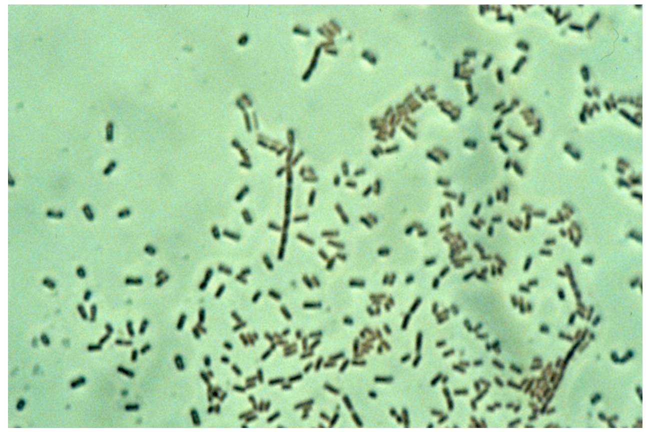
The Soil Food Web

For many, this publication was the first time they learned the role microorganisms play in fixing carbon dioxide, creating good soil structure, reducing plant disease, and cycling nutrients. Since its first publication, numerous businesses have formed that use horticultural applications that are based on the principles described in the book. Perhaps one of the most dramatic statements of the Soil Biology Primer was that: All plants – grass, trees, shrubs, agricultural crops – depend on the food web for their nutrition.

> **"All plants – grass, trees, shrubs, agricultural crops – depend on the food web for their nutrition."**
>
> - The Soil Biology Primer

While at first this might seem like common sense, what this publication was saying was that biological processes in the soil are equally important as the physical and chemical characteristics of soil. For many years, scientists had been able to identify total populations of organisms in soil, but now, with new slide staining techniques they can actually count individual organisms that are *active* the in the soil. When the proper population and diversity of organisms are present, soil and plant health soar; when they are not present, disease, nutrient deficiency and compaction problems can occur. This can lead to excessive water logging of soils (as less water is taken in), and can increase drought stress in warm months (when less water is held in reserve). These factors greatly affect the health of golf turf, the costs to maintain it, and the potential for groundwater contamination.

This information represents a huge change in how turf management practices are viewed. Being able to identify and improve beneficial organism populations in soils, turf managers now have the means to be proactive in combating plant disease and increasing the efficiency of nutrient delivery. With this new technology, turf specialists now have a new "tool" which can be added to the box of tools (chemicals, cultural practices, fertilizers) that golf superintendents can use to grow healthy turf. The beauty of this process is that, in many cases, biological tools can actually help turf managers reduce input costs without sacrificing playability. A detailed explanation of the functions of soil microorganisms is shown in Appendix I.

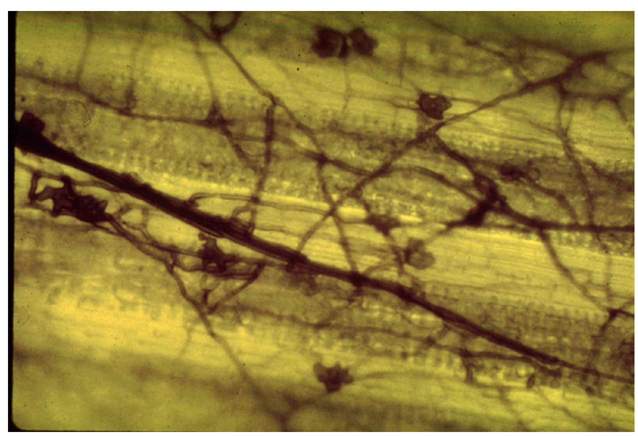


A ton of microscopic bacteria may be active in each acre of soil. Credit: *Michael T. Holmes, Oregon State University, Corvallis*

WHAT DO SOIL ORGANISMS DO?

"Growing and reproducing are the primary activities of all living organisms. As individual plants and soil organisms work to survive, they depend on interactions with each other. By-products from growing roots and plant residue feed soil organisms. In turn, soil organisms support plant health as they decompose organic matter, cycle nutrients, enhance soil structure, and control the populations of soil organisms including crop pests. "

- The Soil Biology Primer



Fungus beginning to decompose leaf veins in grass clippings. Credit: *No. 48 from Soil Microbiology and Biochemistry Slide Set. 1976. J.P. Martin, et al., eds. SSSA, Madison WI.*

Biological Tools for Turf

With new testing methods, the community of organisms in any soil can be identified, the soil can be compared to similar soils with high yields, where there are no disease problems and where few pesticides are required. Thus a healthy food web "standard" can be defined for various soils, climates and plant groups.

What SFNY has learned at Timber Point and at other courses is that focusing on Bacteria, Fungi, Nematodes and Protozoa in the soil can greatly improve turf health and profitability for golf and turf industries.

For instance, on the Presidio Golf Course (near San Francisco, California), soil food web methods were applied on a regular basis to golf course turf grass. Turf treated with compost tea had longer root length, less disease and higher density than untreated turf, and did not differ from untreated turf in color or overall quality (*BioCycle*, 2001). In New Jersey, the Woodbury Country Club reported a 33% reduction in fertilizer applications over three years when using compost tea. They also saw a 70% reduction in fungicide costs, and greatly reduced dollar spot (*Sclerotinia homoeocarpa*) on their greens (Ingham, 2002). With proper development of this technology, similar savings can be achieved at other golf courses. **The Biological Tools used to reduce fertilizer and fungicide applications include:**

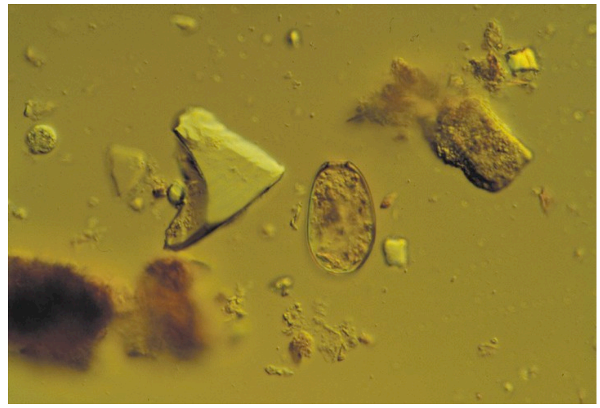
Biological Soil Tests

Biological Inoculants

Application Techniques

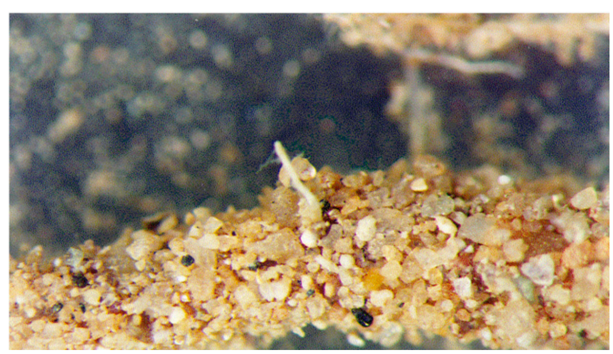
Cultural Practices

Methods to Verify Results



Protozoa play an important role in nutrient cycling by feeding intensively on bacteria. Credit: *Elaine R. Ingham*

Beneficial Nematode eating a root feeding nematode. Credit: *Paul Wagner*



Sand grains are bound to a root by hyphae from endophytes (fungi similar to mycorrhizae), and by polysaccharides secreted by the plant and the fungi. Credit: *Jerry Barrow, USDA-ARS Jornada Experimental Range, Las Cruces, NM*

1. Biological Soil Tests

Biological soil tests provide information on the amount and diversity of organisms that are present. The testing provided by Soil Foodweb NY focuses on: Total & Active Bacteria, Total & Active Fungi, Protozoa (Flagellates, Amoebae, Ciliates), Beneficial Nematodes, Root Feeding Nematodes, and colonization of roots by Mycorrhizal Fungi.

By comparing soil biology data from greens, tees, and fairways, and comparing it to healthy turf systems, it is possible to see where the soils are deficient in terms of the overall population and diversity of the groups of organisms present. It should be noted here that biological soil testing does not take the place of soil chemistry analyses. To maintain quality turf a good balance of nutrients is required, as well as a good balance of beneficial soil organisms.

Each plant group has levels of soil microbes that are considered ideal. For most cool season grasses balanced levels of soil bacteria and fungi are desired. Since bacteria and fungi retain plant nutrients, in order to make them available to the plant, high levels of predatory microbes like protozoa and nematodes must also be present. Protozoa and nematodes feed on bacteria and fungi and cycle nutrients.

A 2004 soil biology report is shown on the following page. Comparing the results from the soil samples from the 9th Green and Fairway to the desired ranges (shown at the bottom of the report), SFNY began to see what is lacking in terms of an "ideal" soil condition.

A composite soil sample is obtained by pulling soil from at least 8 areas of the green

Sample Soil Biology Report

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Soil Foodweb Analysis

Fall 2004

Organism Biomass Data

Sample #	Unique ID	Dry weight	Active Bacterial Biomass (µg/g)	Total Bacterial Biomass (µg/g)	Active Fungal Biomass (µg/g)	Total Fungal Biomass (µg/g)	Hyphal Dia (µm)	Protozoa Numbers/g Flagellates	Amoebae	Ciliates	Total Nematode Numbers #/g	Percent Mycorrhizal Colonization of Root	Plant Available N Supply fromPredators (lbs/acre)	Root-feeding Nematode Presence
3969	#9 Green	0.79	33.6	288	66.4	**169**	2.5	**3,503**	**3,503**	**0**	**1.7**	**6%**	**25-50**	**Multiple**
3968	#9 Fairway	0.81	34.7	224	38.6	423	2.75	5,714	5,378	72	2.2	13%	75-100	**species**
Desired Range		0.45 - 0.85	1 - 5	175 - 300	1 - 5	175 - 300	2.5 +	5000 +	5000 +	50 - 100	10 - 20	40% - 80%	75lbs/ac+	None

Bold
Means Low

On the 9th Green, fungal biomass needed to be increased in order to provide needed nutrient retention and improve soil structure. Protozoa, nematodes and mycorrhizal fungi all had to increase in the soil. Treatments were designed to address these specific imbalances and deficiencies. These are shown in the spray schedule example on page 7.

On the 9th Fairway, the soil is a bit too fungal, and bacterial biomass needed to be boosted. Protozoa levels were in good range, but nematodes and mycorrhizae were too low. Some common commercial products can address different biological deficiencies, but in most cases a customized approach is best.

Soil sample cores can be used to monitor compaction and rooting depth.

2. Biological Inoculants

Biological inoculants refer to the various products that can be purchased or manufactured to re-introduce beneficial organisms on plant and soil surfaces. As with testing, the organisms to focus on are Bacteria, Fungi, Protozoa and Nematodes.

Inoculants can be either liquids or solids. They usually contain beneficial organisms, microbial foods and plant nutrients. While it would be impossible to go into detail on all the inoculant products on the market today, these products can generally be categorized as: composts (thermophillic and vermicompost), granular or powdered products (humates, kelp, biogranules), and liquid amendments (compost teas, extracts, microbial foods, plant nutrients).

Below is an example of SFNY's 2005 spray schedule for Timber Point. The biological inoculants used are highlighted in green. The reduced risk fungicide Zerotol was included, as it is a contact fungicide that quickly oxidizes the microbes it contacts. It is unique in that it has no residual affect. A major benefit of the mode of action of Zerotol is that diseases do not build up a resistance to the product, which reduces frequent changes in management programs. This has been useful in "cleaning up" over-wintering disease organisms. A concern that some courses have had with Zerotol is that it is non-selective and kills both beneficials and diseased organisms, therefore leaving the turf open to new infection. With Soil Food web inoculants we have the ability to re-introduce beneficial organisms back onto leaf and soil surfaces, immediately after application (because there is no residual affect from the Zerotol). In the following example the reader can see that humic acid, fish hydrolysate, compost, compost granules and compost tea were applied to enhance microbial populations (highlighted in green). Compost products add a diverse, beneficial microbial population and the additives feed these organisms.

SPRAY SCHEDULE EXAMPLE

Begin season with ZeroTol application to all areas ASAP (March).
If possible, also apply ZeroTol to practice green prior to first compost tea spray.

Tees and Greens

Immediately after ZeroTol, apply 400 lbs per acre **compost granules.**
Beginning April 8th, Apply **compost tea** at each week at a rate of 13.5 gallons per acre

Fairways

Immediately after ZeroTol, apply 2 yards per acre **compost**.
Apply **Compost Tea** to 3 Fairways per week at a rate of 13.5 gallons per acre

Tank Mix Formulas

Teas in April, July and August will have 1QUART/acre **fish hydrolysate** and 20 OUNCES each of LC12 **humic acid** and Natures Essence **kelp** per acre (added to the tank mix).

Teas in May, June and September will have 1PINT/acre **fish hydrolysate** and 30 OUNCES each of LC12 **humic acid** and Natures Essence **kelp** per acre (added to the tank mix).

No other products should be mixed with the teas. Tank mix and fertilizer recommendations are based on existing product list.

Compost

Quality compost has been well proven to add beneficial organisms to soils and also provides an excellent habitat and energy source for microbes already present. Compost helps soil retain nutrients, improves water holding capacity and porosity, as well as reduces soil compaction.

In an article in *TurfGrass Trends*, Dr. Eric Nelson of Cornell stated that "Of all the natural organic materials commonly applied to turfgrass, composted amendments have been among the most consistently effective in reducing the severity of turfgrass diseases. Results of studies conducted over the past 10-15 years have clearly shown the potential for compost amendments to reduce the severity and incidence of a wide variety of turfgrass diseases, particularly when applied either as a topdressing, a winter cover, a root zone amendment, or as an aqueous extract" (Nelson, 1996).

So, why hasn't compost become a bigger part of golf turf management?

The answer is that the quality of the compost (biological, chemical and physical) must be consistant in order to be effective. Indeed, one of the greatest obstacles to widespread use of compost has been it's inconsistent performance due to a lack of understanding of compost microbiology (Nelson and Boehm 2002 - Intl. Compost Symposium May, 2002).

SFNY's specifications compost for application to golf turf requires methods that provided very aerobic compost, stabilize nutrients, and suppress fungal pathogens (Nilsson, J, et al. 1997, 1999 and 2001). To meet the needs of a biological program compost must meet biological quality specifications (shown in Appendix II). On the fairways this product was applied at a rate of 2 yards per acre.

Making compost from 2 of Long Islands most renewable resources
- duck manure and leaves -

Compost Granules

In the Timber Point project compost was applied on fairways in 2005. In 2006 compost granules were used. This product is a blend of concentrated beneficial microbes, enzymes and microbial foods that is applied through conventional spinner spreaders.

Compost Granules can be spread with conventional spinner spreaders.

Granules were chosen in the second year because they are much easier to apply require less labor, and because local sources of quality compost could not be obtained.

While this may seem insignificant at first, it is an industry wide problem for the golf industry. In some cases superintendents have claimed that they have actually lost greens due to poor quality compost. Given the wide range of feedstocks available for composting and the amount of compost operations that are present in NY, this is something that could be corrected. In order to address this problem, in Appendix I we have provided information on compost specifications as well as sources for methods of production. While many compost operations make good compost for soil incorporation, the needs of golf courses are much more stringent and therefore require more time, effort and cost to make.

Until more trials can show the added value that compost can provide it is unlikely that most compost manufacturers will make the type of quality required.

Liquid Inoculants

In general, there are 3 different classifications of liquid inoculants.

1. Cultured and packaged liquids are becoming more popular since they are very consistent, and require no labor resources to produce. These are cultured in a laboratory, and packaged so they can be directly placed into a clean sprayer and applied.

2. Compost extracts are typically superior to the cultured inoculants since they will have usually thousands of species of beneficial microbes as opposed to the 20-300 found in the cultured products. The extracts have some requirements, however. To maintain quality, superior sources of compost need to be found locally or shipped to the course on a regular basis. In addition, an employee needs to be trained to operate the extraction machinery. Extracts are made weekly with water being sprayed under pressure through the compost to extract the beneficial microbes. The solution is then loaded into the sprayer and applied.

3. Compost tea continues to be one of the most effective liquid inoculants and is one that has come into widespread use in agriculture over the last several years. This is made similar to extract, but less compost is used and microbial foods are added to allow the microbes to multiply over 12 to 24 hours. Again, compost needs to be sourced and labor is needed to produce the tea if it can't be purchased from a local producer. After the tea is produced it is loaded into the sprayer and applied.

One of the best resources on compost tea can be found from the National Sustainable Agricultural Information Service website at http://www.attra.org/attra-pub/PDF/compost-tea-notes.pdf

A typical setup for manufacturing and loading of liquid inoculants.

Fish Hydrolysate
This is a food resource for the growth of beneficial bacteria and fungi, as well as an organic fertilizer that is a good source of nitrogen, phosphorus, potassium and many micronutrients. On many turf management programs fish hydrolysate can provide a fair amount of the nitrogen applied.

Humic Acid, Humates
Humic acids and humates are primarily fungal foods, but can add to fertility and can boost the cation exchange capacity of the soils to which they are applied. These are available in granular forms that are insoluble for a longer lasting food resource or a soluble liquid or powder that can provide quick food resources to grow beneficial fungi.

Kelp
Kelp is another strong fungal food resource, that is also a great source of trace minerals and potassium. Although kelp is available as a granular, most of the time soluble forms are used.

Mycorrhizal fungi
This group of beneficial fungi form a symbiotic relationship with the roots of the plants. This group of fungi grow in the soil and bring nutrients and water directly to the plants. Mycorrhizae provide high amounts of the nutrients needed by plants, so fertilizers can be reduced. In fact over use of fertilizers will actually reduce the amount of the fungi that will colonize plants. Applications are made following core aeration so that the fungal spores are introduced directly into the root zone. Surface applications won't readily colonize the plants unless they are applied with grass seed.

3. Application Techniques

Solids - With any application of biology the most important consideration is to make sure that the environmental conditions for the organisms being added allow the best chance for survival. Toxins in the soil environment can kill microorganisms and therefore must be minimized to get good results. Some common problems that occur in golf applications are: high salts in soils from fertilizers, residues from pesticides, and toxins in water sources. Since microorganisms are much more sensitive to their environment than plants, this is an area that is easy to overlook.

Therefore, a few rules of thumb are worth following. First, make sure to get the product you are applying down into the soil. Compost, granules, and microbial foods all work best when they are incorporated. Below ground, beneficial organisms have protection from ultraviolet rays and access to stored soil moisture and nutrients. Second, unless there is already good soil moisture it is best to water them in. This is because adequate soil moisture increases survival. Third, work these applications into your current practices. Solids are preferable when doing new construction, during aeration or during top dressing.

Well made compost can be spread with conventional top dressers.

Liquids - Liquid inoculants work well with normal spray schedules. In some cases, foliar nutrients can be applied at the same time. However, just like solid forms you have to be careful not to kill the critters you are trying to get to help you. Water quality is extremely important. If chlorinated water is used it must be de-chlorinated. The water can't be high in salts and if it contains pesticides, chances are, it will kill organisms. In most cases it is best to have a dedicated sprayer for biological sprays. They can be done through conventional spray equipment, if it is cleaned properly, but usually this becomes a hassle and then gets neglected or forgotten altogether.

Biological inoculants don't need sophisticated spray equipment.

The equipment used to spray inoculants doesn't have to be sophisticated. Liquid inoculants don't have to be sprayed with the precision of pesticides and less filtration and larger nozzle sizes are preferable since what we are trying to do is get the maximum amount of biology out there. Older used sprayers are fine in most instances, or if needed a small pull behind trailer can be put together such as the one shown above.

It is important to note that spraying inoculants is much more like spraying hydro mulch than insecticides. One of the best nozzles to increase efficiency of sprayed materials is made by Tee Jet (see picture on the following page). This nozzle can allow a spray width of as much as 75 feet, making it very convenient for spraying both fairways and greens. Again, the fine tuned accuracy of conventional sprayers is not necessary. The water you are using is the carrier and the idea is to just make sure you get good coverage. The force and friction of pumps and spray pressure are also important considerations.

SPRAY EQUIPMENT

PUMPS - When selecting a pump for use with liquid inoculants, the more passive the action of the pump the better. Pumps that have impellers or fins will be rough on the organisms. For example, the impellers will shred longer fungal hyphae. Piston pumps can also be rough and will have a tendency to mash some of the organisms. The pumps that do the least damage are diaphragm pumps and air blast type sprayers.

FILTERS – The filters on pumps can also affect organisms. SFNY studied the difference in sprayer filters with compost extracts. Extract was sprayed through a 20-mesh screen and a 50-mesh screen. Between 2 and 8% of the bacteria and fungi were filtered out using a 20-mesh line strainer. A very noticeable difference occurred with the 50 mesh as over 20% of the bacteria and fungi were lost. Most tree and turf spray equipment can use screens of 20 mesh, or can be used unfiltered.

There are two potential ways of losing organisms by filtering. First: a percentage of the organisms themselves can be removed, and second, minute pieces of organic matter (which provide a physical surface for bacteria and fungi to attach to) can also be trapped. Since organic matter fines can continue to feed the organisms and provide shelter, they should not get held up on the screens. To prevent this liquid is usually filtered as it is drained from its holding tank.

In most cases the filter basket on most sprayers will do that. Then the in line filter is removed so that organisms pass through easily. Particulate matter can damage piston pumps, so when these are used more restrictive filters may be necessary. With diaphragm pumps or roller pumps filters are usually not needed.

NOZZLES – The boom jet type nozzles as mentioned earlier are excellent for applying beneficial organisms. As a rule, nozzle openings need to be at least 80 microns in size to allow organisms to pass through, but should be as large as possible to avoid clogging.

Boom Jet Nozzle (Tee Jet #5880-34-2T OC 80)

SPRAY PRESSURE - Typically sprayers with less than 100 psi work well. Venturi sprayers are fine if you can crank them down below 100 psi. 300 psi will push them out of the nozzle so fast that the velocity of impact on the leaf anywhere within a short radius will turn the organisms into protoplasm.

When spraying across distances such as with the BoomJet nozzle, then velocity will be reduced by the time the organisms hit the leaves that far away (and then a higher pressure can be used). When spraying through a typical spray boom inoculants should not be applied with greater than 40 to 80 PSI of pressure (at the nozzles), and should be applied during weather when plants are active.

TIME OF APPLICATION- Liquid inoculants should be applied as a mist before 10 am or after 3 pm on sunny days because ultraviolet rays can kill organisms. If applied with larger droplets, impact from UV is reduced. Do not apply biological liquids when it is raining hard, but a light mist often helps the organisms establish in the soil.

4. Cultural Practices

As a biological tool, cultural practices that are used are those that reduce plant stress while stimulating growth. Rather than having a program that reacts to problems, the goals is to do as much preventive measures as possible.

DIVOT REPAIR – Divot mix is an excellent place to re-introduce beneficial organisms. When quality compost is part of this beneficial organisms are returned to the soil along with their food substrates and “homes”. This allows for greater survival of microbes and helps increase their populations in adjacent soils.

MOWING - It is well known that maintaining sharp mower blades enhances mowing efficiency and reduces stress on the grass. This also enhances decomposition of the grass clippings and provides an additional food source for beneficial organisms. In areas where grass clippings can be returned to the soil, mulching mowers can add from 2-5 pounds of nitrogen per 1000 square feet on an annual basis. This can be very important if you are trying to reduce your nitrogen applications to reduce runoff or ground water contamination.

WATERING - Watering in the morning puts less stress on turf and reduces spread of fugal disease. Over watering has the potential to increase soil borne disease and can stimulate growth of certain weeds such as annual bluegrass. This is because as soils become water logged they become anaerobic. Under these conditions, disease organisms actually have an advantage over beneficial organisms (which prefer aerobic soil conditions). A beneficial by-product of the biological approach is that improved soil structure and aggregation will improve moisture retention in the soil, while allowing excess water to drain. Watering less frequently will improve the population of beneficial microbes and in turn encourages greater rooting depth. Deep-rooted turf can withstand dry conditions better and has less thatch. With less thatch there is better soil aeration, which promotes deeper turf roots. This allows turf is to compete better with shallow rooted weeds.

OVERSEEDING – This practice also effects soil biology. Not only does it allow us to replace unwanted or disease prone varieties with new ones, but it can also be done in conjunction with additions of beneficial organisms by mixing with compost or mycorrhizal fungi. With a good thick stand of turf, weeds can be handled by spot treating. This is why many will agree that if you do it right, grass seed is the cheapest herbicide.

HEAT STRESS – As with other problems, the idea is to be proactive. Good monitoring of soil moisture is essential and reducing water just prior to the onset of summer heat can help prepare the turf to become dormant. Applications of seaweed extract can also help reduce heat stress by stimulating antioxidant production in turf. Researchers have found that when turf has the proper amount of antioxidants during times of stress, photosynthesis and metabolism will often be maintained at more normal levels. This allows plants to be stronger and less susceptible to disease. Both humates and humic acids have also been shown to increase antioxidant production.

DISEASE MANAGEMENT

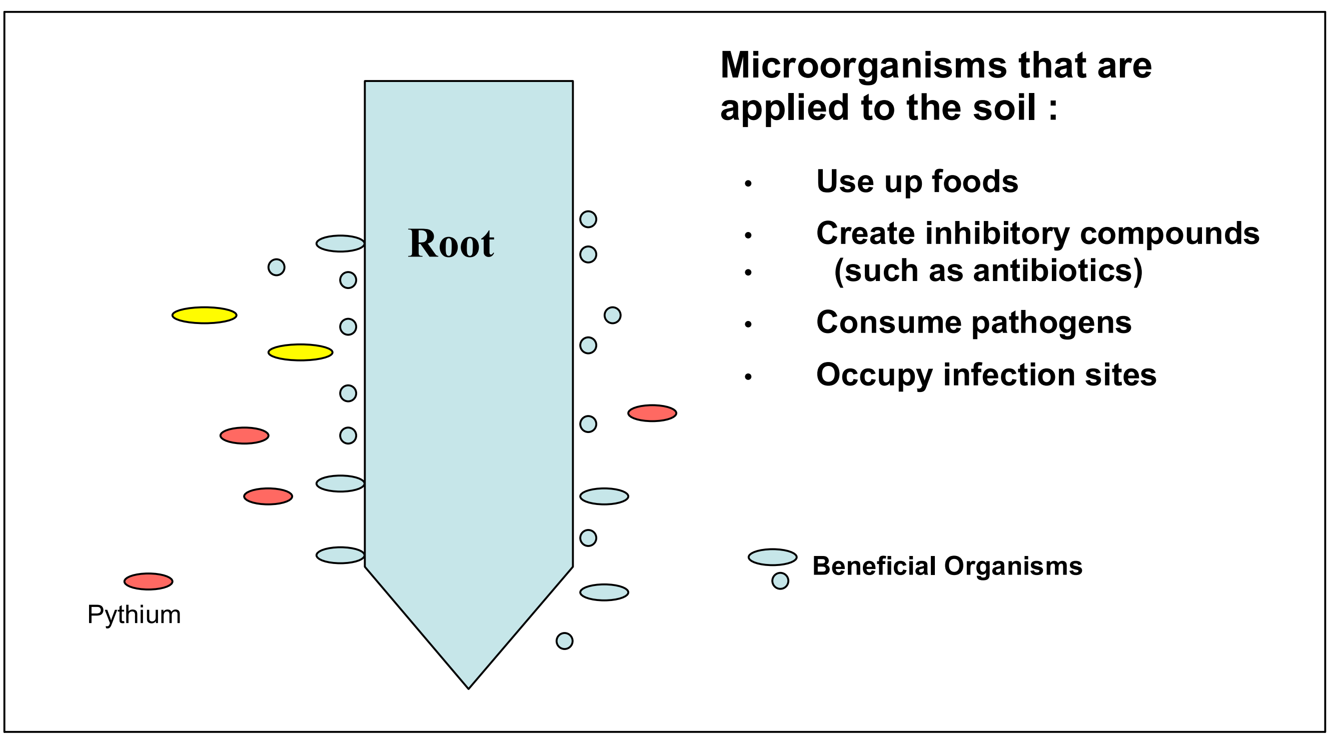
Prevention

This is one the most important aspects of a biological turf management. Regular application of composts and liquid inoculants are extremely important. This can reduce the amount of fungicide needed for disease control and can increase the time interval between disease outbreaks. Some courses have been able to reduce annual fungicide use by as much as 70% using this approach. Covering leaf surfaces and infection sites with beneficial organisms makes it difficult for disease organisms to get established (see diagram on the following page).

Research has shown that once a leaf has beneficial organisms on 70% of it surface area, diseases no longer cause economic damage. This has been shown even when the disease was identified on 70% of the leaf surface. As shown in the diagram below, a similar affect occurs below ground when the beneficial organisms supplied in liquid drenches come in contact with root surfaces. Again, what is important is to get good coverage of organisms on plant surfaces. Studies have also shown that best results occur when 60 – 80% of root surfaces are colonized by mycorrhizal fungi. As explained earlier these fungi not only ward off disease but also are extremely important in drought tolerance and making nutrients available to turf.

Use of Fungicides

The next level of control in a biological program is the use of microbial fungicides and products that kill over wintering organisms on leaf surfaces. The goal in a biological program is to put off the use of chemical fungicides for as long as possible because these materials have the most detrimental affect on beneficial microbes. What we are doing is to save the “big guns” for later and use the cheaper less invasive tools at the first onset of disease. Just as in other forms of integrated pest management, scouting is very important. The goal is not to spray just because the conditions are there, but to actually scout and work with preventative measures and spray only where needed. In the project at Timber Point Country Club we recognized that with the weather conditions present on Long Island, it would be nearly impossible to avoid all fungicides.



When using fungicides, it is important to be selective as to what materials are used. One of the best materials in this regard is the fungicide trade named Zerotol. This product (which is hydrogen dioxide) is a potent contact fungicide and a strong oxidant. It kills organisms on leaf surfaces and oxidizes out of the environment quickly. It is non-selective and kills both beneficials and disease causing organisms. This can leave the leaf surfaces open to new infection.

With a biological approach, Zerotol can be used to "clean up" disease. Then liquid biological inoculants can be applied to re-establish beneficials on leaf surfaces. This helps provide protection when disease conditions arise again. In a biological program this has been found to be most useful when applied early in the spring, when it can be used to kill over wintering disease.

During the growing season, bio-fungicides are another tool that is used when disease pressure builds. These products are usually very selective and therefore don't affect beneficials as much. In this regard they are much more compatible with biological methods. A typical bio-fungicide or microbial fungicide is usually made of a certain species of microbe that is antagonistic toward another species of microbe. One of the best examples is a product called EcoGuard. This is a bacterium that has been found to be effective against Dollar Spot disease.

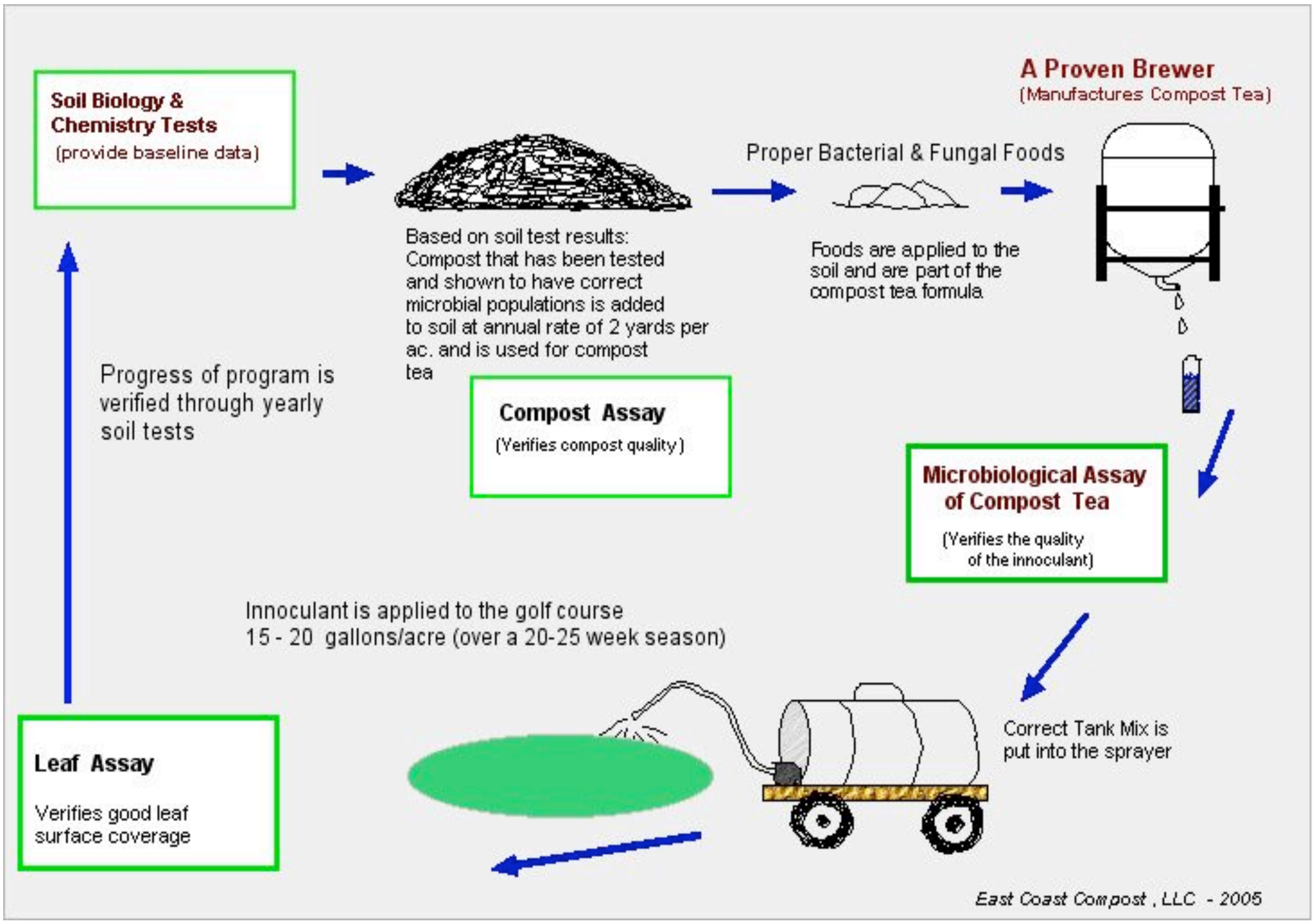
An important aspect of using fungicides in a biological program is to re-build the biology as soon as possible after you control the target disease. Following the use of a chemical fungicide, compost tea is recommended at double the rate and ample foods for building soil microbial populations are included in the follow up sprays.

Application of liquid biological inoculants does not require the precision of conventional sprays.

This same type of strategy would be used to follow up application of a microbial fungicide as well. The idea is to get the beneficials back out there as soon as possible following a fungicide application. The goal is to be as biologically friendly as possible and work with the materials that the superintendent is comfortable with. Therefore for this report we are limiting our discussion to those that we used. There are numerous options for other products that could be used in conjunction with a biological program. Additional information on Zerotol, Ecoguard and other microbial fungicides can be found at: http://www.ippc.orst.edu/biocontrol/biopesticides

5. Methods to Verify Results

The diagram below shows some of the ways lab testing is used to verify the quality of ingredients and changes in soil biology. In addition to lab results, studying disease incidence, rooting depth and resistance to compaction are all indicators of biological soil health. In the lab reports on the following page, a before and after biological soil test is shown for the 9th green at Timber Point Country Club.



…………………THE SAME GREEN AFTER 1 YEAR ON A BIOLOGICAL PROGRAM……………

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Soil Foodweb Analysis

Fall 2004

Before

Organism Biomass Data

Sample #	Unique ID	Dry weight	Active Bacterial Biomass (µg/g)	Total Bacterial Biomass (µg/g)	Active Fungal Biomass (µg/g)	Total Fungal Biomass (µg/g)	Hyphal Dia (µm)	Protozoa Numbers/g Flagellates	Amoebae	Ciliates	Total Nematode Numbers #/g	Percent Mycorrhizal Colonization of Root	Plant Available N Supply fromPredators (lbs/acre)	Root-feeding Nematode Presence
3969	**# 9 Green**	0.79	33.6	288	66.4	**169**	2.5	**3,503**	**3,503**	**0**	**1.7**	**6%**	**25-50**	**Multiple species**
Bold Means Low														
Desired Range		0.45 - 0.85	1 - 5	175 - 300	1 - 5	175 - 300	2.5 +	5000 +	5000 +	50 - 100	10 - 20	40% - 80%	75lbs/ac+	None

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Soil Foodweb Analysis

Fall 2005

After

Organism Biomass Data

Sample #	Unique ID	Dry weight	Active Bacterial Biomass (µg/g)	Total Bacterial Biomass (µg/g)	Active Fungal Biomass (µg/g)	Total Fungal Biomass (µg/g)	Hyphal Dia (µm)	Protozoa Numbers/g Flagellates	Amoebae	Ciliates	Total Nematode Numbers #/g	Percent Mycorrhizal Colonization of Root	Plant Available N Supply fromPredators (lbs/acre)	Root-feeding Nematode Presence
4961	**# 9 Green**	0.80	33.6	793	37.2	440	2.5	5,740	5,740	57	**8.5**	**10%**	75-100	**Multiple species**
Bold Means Low														
Desired Range		0.45 - 0.85	1 - 5	175 - 300	1 - 5	175 - 300	2.5 +	5000 +	5000 +	50 - 100	10 - 20	40% - 80%	75lbs/ac+	None

After 1 year ……..

- Bacterial and Fungal biomass tripled
- Protozoa numbers reached optimal levels
- Nematode population increased 4-fold
- Mycorrhizal colonization increased
- Plant available nitrogen supply doubled

Being able to verify this type of biological change allows the superintendent to comfortably reduce some inorganic inputs since the soil is responding to treatments. During routine scouting, rooting depth and soil compaction can be monitored by looking at soil cores or by using a soil penetrometer. Over the course of the Timber Point project, rooting depth doubled in many greens.

Economics Benefits

The 2003 NY Turfgrass Survey collected data on total fungicide and fertilizer expenditures for 860 New York golf courses. The following table was developed using the survey results combined with an expense history of the Timber Point project. . In this study Timber Point already had an older sprayer that was used for the project and therefore this cost was not figured in. In Table 5., the expenditures of the 2005/2006 biological program on 9 holes were compared to an average 9-hole New York State course.

	Timber Point 2005 / 2006 Average	Average New York State Course [1]
Fungicide cost	$ 2,256	$ 12,279
Fertilizer cost [2]	$ 4,778	$ 8,186
Biological program cost	$3014	N/A
Total cost	$ 10,048	$ 20,465

[1] 2003 New York State Turfgrass Survey, New York Agricultural Statistics Survey. www.nass.usda.gov/ny

[2] Fertilizer Cost does not include micronutrient additions (data not available)

Compared with an average New York golf course, this analysis showed that after adding in the costs of the biological program, the average 9-hole golf course could save $10,417 per year; an 18-hole course could save $20,834. While no two courses and seasons are exactly alike (and therefore expenditures will fluctuate), it is obvious from this data that biological soil management can be a cost-effective tool for turf managers. More detailed studies of this nature should be conducted to develop more accurate data for other courses.

Getting Microbes into Your Work Schedule

Growing a good golf turf is not that much different than growing any other crop. All the tools must be integrated with current management practices. As discussed earlier, the value of any practice is not only in how it relates to turf health but also how well it fits into the work schedule. In this regard, the use of biological techniques is no different than other practices. Fertilizer application, core aeration, top dressing, irrigation and other techniques used to influence the chemical and physical aspects of golf turf are all very important. These practices also affect microbiological populations and can be excellent times to add beneficial microbes to your turf. Since these are tasks that are done already, adding biology can be done without having a negative effect on labor costs.

Fertilizers can improve or damage soil biology. Many inorganic fertilizers have higher salt levels that damage microbes to some degree. Organic fertilizers can be selected to address the fertility while also feeding the correct soil microbes to balance the biology. When compatible with compost teas or other inoculants, liquid organic fertilizers can be applied within the same spray. This reduces travel time across the course and allows both biology and nutrients to be applied at the same time. Since soil microbes will retain the nutrients in the fertilizers and prevent leaching, less fertilizer can be applied with the same ultimate boost in selected nutrients.

Core aeration will help maintain a good aerobic environment for beneficial microbes to colonize. Typically, bacterial biomass will bloom following aeration, but this spike can be offset with fungal food resources that can be applied during aeration. Also, while holes are open and materials can be easily applied to the root zone, mycorrhizal spores can be applied if needed.

Top dressing is a good opportunity to inoculate a wide diversity of beneficial microbes. Blending 5% – 10% compost with sand and then topdressing into aeration holes is a great way to get all the benefits of compost, without the layering that can be problematic. This is a good practice for sand based greens and tees. A dusting of compost on the fairways can typically be performed without blending.

Irrigation In some instances where fertilizers are applied through irrigation or fertigation systems, microbial inoculants can be added. This has been successful on some golf courses that are using worm casting extracts.

The “Take Home” Message

By utilizing the natural life processes in the soil, researchers are now showing that it is possible to “dial back” the amount of fertilizers and pesticides used on golf turf. This doesn’t have to be a separate project but can work in conjunction with regular management practices. Once established, beneficial organisms can help reduce input costs.

Additional education is needed on the roles/functions of beneficial soil organisms; the practices that promote and destroy microbial life and the methods to monitor and manage biological populations. To make biological tools more useful, additional research and successful examples are also needed to allow turf managers to develop a “comfort zone” for this technology.

The take home message from the use of biological turf management is fairly simple. If you keep the biology alive in the soil, it will work for you and help grow healthy turf.

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APPENDIX I.

THE FUNCTIONS OF SOIL ORGANISMS

Functions of Soil Organisms

Type of Soil Organism		Major Functions
Photosynthesizers	• Plants • Algae • Bacteria	**Capture energy** • Use solar energy to fix CO_2. • Add organic matter to soil (biomass such as dead cells, plant litter, and secondary metabolites).
Decomposers	• Bacteria • Fungi	**Break down residue** • Immobilize (retain) nutrients in their biomass. • Create new organic compounds (cell constituents, waste products) that are sources of energy and nutrients for other organisms. • Produce compounds that help bind soil into aggregates. • Bind soil aggregates with fungal hyphae. • Nitrifying and denitrifying bacteria convert forms of nitrogen. • Compete with or inhibit disease-causing organisms.
Mutualists	• Bacteria • Fungi	**Enhance plant growth** • Protect plant roots from disease-causing organisms. • Some bacteria fix N_2. • Some fungi form mycorrhizal associations with roots and deliver nutrients (such as P) and water to the plant.
Pathogens **Parasites**	• Bacteria • Fungi • Nematodes • Microarthropods	**Promote disease** • Consume roots and other plant parts, causing disease. • Parasitize nematodes or insects, including disease-causing organisms.
Root-feeders	• Nematodes • Macroarthropods (e.g., cutworm, weevil larvae, & symphylans)	**Consume plant roots** • Potentially cause significant crop yield losses.
Bacterial-feeders	• Protozoa • Nematodes	**Graze** • Release plant available nitrogen (NH_4^+) and other nutrients when feeding on bacteria. • Control many root-feeding or disease-causing pests. • Stimulate and control the activity of bacterial populations.
Fungal-feeders	• Nematodes • Microarthropods	**Graze** • Release plant available nitrogen (NH_4^+) and other nutrients when feeding on fungi. • Control many root-feeding or disease-causing pests. • Stimulate and control the activity of fungal populations.
Shredders	• Earthworms • Macroarthropods	**Break down residue and enhance soil structure** • Shred plant litter as they feed on bacteria and fungi. • Provide habitat for bacteria in their guts and fecal pellets. • Enhance soil structure as they produce fecal pellets and burrow through soil.
Higher-level predators	• Nematode-feeding nematodes • Larger arthropods, mice, voles, shrews, birds, other above-ground animals	**Control populations** • Control the populations of lower trophic-level predators. • Larger organisms improve soil structure by burrowing and by passing soil through their guts. • Larger organisms carry smaller organisms long distances.

APPENDIX II.

DESIRED RANGES OF MICROBIAL POPULATIONS

FOR GOLF TURF SOIL

Desired Ranges of Microbial Populations

For Turf Soil

<table>
<tr><td colspan="6">Microbial biomass/Number of organisms per gram of turfgrass soil</td></tr>
<tr><td rowspan="3">Total bacterial biomass</td><td rowspan="3">Total fungal biomass</td><td colspan="4">Protozoa numbers</td></tr>
<tr><td>Flagellates</td><td colspan="2">Amoebae</td><td>Ciliates</td></tr>
<tr><td>5,000-10,000</td><td colspan="2">5,000-10,000</td><td>50-100</td></tr>
<tr><td rowspan="3">150-300 micro-grams</td><td rowspan="3">150-300 micro-grams</td><td colspan="4">Nematode numbers</td></tr>
<tr><td>Bacterial feeders</td><td>Fungal feeders</td><td>Predatory</td><td>Root feeders</td></tr>
<tr><td>>5</td><td>>5</td><td>>2</td><td>None</td></tr>
<tr><td colspan="6">40-80% Mycorrhizal colonization of roots</td></tr>
</table>

APPENDIX III.

STANDARDS
For
COMPOST AND COMPOST TEA

COMPOST STANDARDS

For Turf Applications

Characteristic	Analysis
Appearance	few recognizable components of original material remain. Structure is light and crumbly.
Color	dark brown to black (but not dark black, which indicates overheating during the composting process)
Texture or particle size	fine texture, particles smaller than 1/2 inch for incorporation, smaller than 1/8 for topdressing
Odor	earthy aroma, no smell of ammonia or sulfur
Temperature	not warm to the touch
Moisture content	30 to 50%
Carbon to nitrogen ratio (C:N ratio)	15:1 to 20:1
Organic matter	more than 25%
Ammonium	0.2 to 3.0 ppm
Nitrate	< 300 ppm
Sulfides	zero to trace
pH	6.5 to 8.5; pH 7 optimal
Heavy metals	lower than allowable limits
Soluble salts	Conductivity less than 3 millimhos/cm
Microbial Profile	Active Bacterial Biomass 15 - 25 micrograms/gram Total Bacterial Biomass 100–3000 micrograms/gram Active Fungal Biomass 15 - 25 micrograms/gram Total Fungal Biomass 100- 300 micrograms/gram Hyphal Diameter 2.5 micrometers or greater Flagellates 10,000 per gram or greater Amoebae 10,000 per gram or greater Ciliates 50 – 100 per gram Nematodes 20 – 30 per gram or greater

COMPOST TEA STANDARDS

For Turf Applications

Characteristic	Analysis
Odor	Earthy aroma, no smell of ammonia or sulfur
Ammonium	15 - 20 ppm
Nitrate	15 - 30 ppm
Sulfides	Zero to trace
pH	6.5 to 8.5; pH 7 optimal
Soluble salts	Conductivity less than 1.6 mmhos/cm
Microbial Profile	Active Bacterial Biomass 10 - 50 micrograms/milliliter Total Bacterial Biomass 10 – 150 micrograms/milliliter Active Fungal Biomass 2 - 10 micrograms/milliliter Total Fungal Biomass 2- 50 micrograms/milliliter Hyphal Diameter 2.5 micrometers or greater Flagellates 1,000 per milliliter or greater Amoebae 10,000 per milliliter or greater Ciliates 20 – 50 per milliliter Nematodes 2 – 10 per milliliter or greater