Biological controls continued from page 3

tagonist establishment and growth are:

- THE ENVIRONMENTAL CONDITIONS (particularly temperature, moisture, nutrients, and pH)
- AND THEIR ABILITY TO COMPETE with the existing soil and plant micro-organisms.

Just as some organisms are antagonists of pathogens, antagonists have their own antagonists as well.

Biocontrol agents also must be compatible with other management inputs. In particular, biological control agents must be tolerant of fungicides, insecticides, herbicides and fertilizers currently in use. Their activities must also not be discouraged by cultural practices used in turfgrass maintenance. Just as pathogens are influenced by environmental conditions, so too are biological control agents. Therefore, biological control strategies must be employed primarily to control pathogens, but at the same time, maintain the associated antagonistic microbial communities. Organisms isolated from many different environments might be suitable biocontrol agents, but composts are perhaps the best sources of complex mixtures of antagonistic microorganisms. Incorporation of organic matter into turfgrass soils is one of the better ways of maintaining antagonistic microbial communities.

Disease suppression with composts

A NUMBER OF DIFFERENT APPLICATION strategies have been tested with composts used for the purpose of disease control. These have included the use of composts as:

- TOPDRESSING AMENDMENTS,
- TURF COVERS,
- ROOT ZONE MIX AMENDMENTS,
- TEAS PREPARED BY EXTRACTING THE COMPOST with water for various periods of time. Another approach that has as yet to be tested is the use of composts as seed coating or pelleting material.

Perhaps the most exciting results have been obtained when composts have been used as a topdressing amendment. For example, monthly applications of topdressings composed of as little as 10 lbs of suppressive compost/ 1000 ft^2 have been shown to be effective in suppressing diseases such as dollar spot, brown patch, Pythium root rot, Typhula blight, pink snow mold, and red thread. Reductions in severity of Pythium blight, summer patch and necrotic ring spot have also been observed in sites receiving periodic compost applications.

Root zone amendments of various composts (20% compost: 80% sand; v:v) have produced excellent control of *Pythium graminicola*-incited root rot on creeping bentgrass putting greens. This technique involves incor-

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Process is the key to disease-suppressive composts

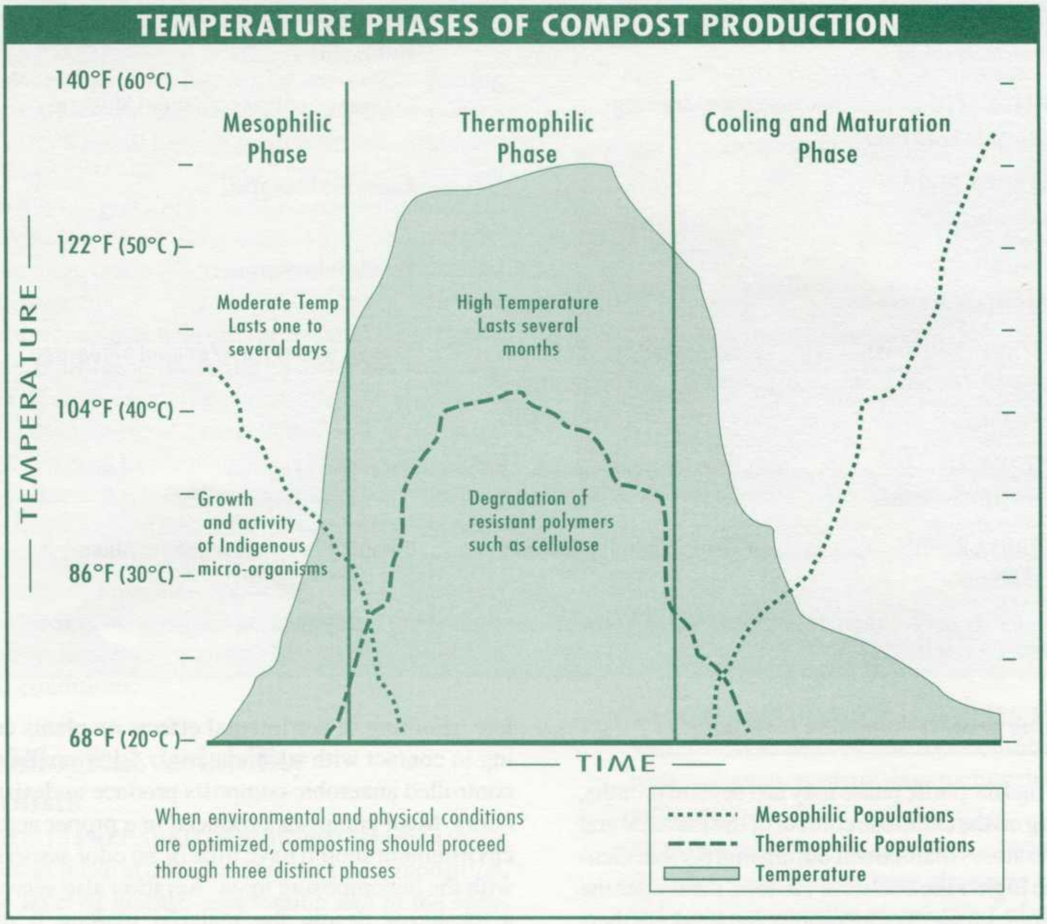
COMPOSTING CAN BE DEFINED as the "biological decomposition of organic constituents in wastes under controlled conditions". Since composting relies exclusively on microorganisms to decompose the organic matter, the process has biological as well as physical limitations. During composting, the environmental parameters (i.e. moisture, temperature, aeration) must be stringently controlled. This is necessary to maintain adequate rates of decomposition and to avoid the production of decomposition by-products that may be harmful to plant growth.

Compost "pile" design, construction, and maintenance play vital roles in the successful outcome of the process. For example:

- TO MAINTAIN PROPER TEMPERATURES, the composting mass must be large enough to be self-insulating, but not so large that compaction results in reduced air exchange.
- TO SUPPORT MICROBIAL ACTIVITY, the composting mass must be moist enough, but not excessively moist, so that the air exchange is limited.
- TO PROVIDE PROPER INSULATION, the particle size of the material must be small enough, but not too small—again to control air exchange.

When environmental and physical conditions are optimized, composting should proceed through three distinct phases (See the diagram of the composting process). The first stage of composting can last one or more days, depending on the type of starting materials used. During this phase, the temperature of the internal portions of the composting mass rise, as a result of the growth and activity of the indigenous mesophilic microorganisms associated with the starting organic material. During this self-heating phase, most of the soluble, readily degradable materials are broken down by these naturally-occurring microorganisms, precluding the

The activity ranges of the microbes involved in composting are relatively narrow in terms of temperature, so increases in temperature above 135°F (57°C) can limit decomposition.



▲ **THE COMPOSTING PROCESS**

Temperature plays a critical role in composting:

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

need for additional inoculum. At this stage of composting, populations of microorganisms increase in magnitude and activity.

The entire process is characterized by successions of both mesophilic (moderate-temperature) and thermophilic (high-temperature) microorganisms during various phases of organic matter decomposition. Each microbial community makes an important contribution to the nature of the final compost. Failure to maintain environmental conditions favorable for adequate microbial activity can jeopardize the quality of the final product.

As temperatures increase above 100°F (33°C), the mesophilic populations are replaced by thermophilic populations capable of degrading most resistant polymers, such as cellulose and hemicellulose. During this second stage of decomposition, microbial diversity decreases until only a few species of the bacterial genus, *Bacillus,* are active in decomposition processes.

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TURFGRASS DISEASES FOR WHICH COMPOSTS HAVE BEEN SUPPRESSIVE

DISEASE (PATHOGEN)	MODE OF APPLICATION	TURFGRASSES
▪ BROWN PATCH *Rhizoctonia solani*	topdressings	Creeping bentgrass/annual bluegrass Tall fescue
▪ DOLLAR SPOT *Sclerotinia homoeocarpa*	topdressings	Creeping bentgrass/annual bluegrass
▪ NECROTIC RINGSPOT *Leptosphaeria korrae*	topdressings	Kentucky bluegrass
▪ PYTHIUM BLIGHT *Pythium aphanidermatum*	topdressings	Perennial ryegrass
▪ PYTHIUM ROOT ROT *Pythium graminicola*	topdressings[a] and heavy fall applications[b] root-zone amendments[c]	Creeping bentgrass/annual bluegrass
▪ RED THREAD *Laetisaria fuciformis*	topdressings	Perennial ryegrass
▪ TYPHULA BLIGHT *Typhula spp.*	heavy fall applications	Creeping bentgrass/annual bluegrass

[a] Applied at the rate of ~10 lbs/1000 ft2; [b] Applied at the rate of ~200 lbs/1000 ft2; [c] Incorporated into sand at the rate of 20% compost, 80% sand (v,v)

***Composting process** continued from page 5*

The thermophilic phase may last several months, depending on the cellulose content of the material and the temperatures maintained during this period. Generally, the higher the cellulose content, the longer the thermophilic phase. Temperatures required for thermophilic decomposition range from 95–160°F (35–71°C). However, the highest rate of microbial activity and decomposition occurs at the lower end of the thermophilic range at temperatures of 95–135°F (35–57°C).

The activity ranges of the microbes involved in composting are relatively narrow in terms of temperature, so increases in temperature above 135°F (57°C) can limit decomposition. To overcome these constraints, most composts need to be aerated—either through repeated pile inversions or through forced air ventilation. Prior to placing in windrows, many composts are started in aerated vessel systems where temperatures can be precisely regulated and uniform decomposition can be established.

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

As the cellulose and hemicellulose components are exhausted, the compost enters a curing or maturation phase where temperatures decline, decomposition rates decrease, and the thermophilic microbial populations are again replaced by mesophilic populations. In general, the longer the maturation period, the more diverse the colonizing mesophilic microbial community.

It is this re-colonizing mesophilic microbial community that is most important in suppressing turfgrass diseases, since large proportions of the re-colonizing microbes are antagonists that render the compost disease-suppressive. Unfortunately, there is no reliable way to predict the disease-suppressive properties of composts, since the numbers and types of re-colonizing microbes are left to chance and determined largely by the types of microbes present at the composting site. ■