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Volatile chemical emissions at composting facilities are significantly below workplace guidelines

By Brian D. Eitzer

In the United States two-thirds by weight of municipal solid wastes (MSW) are materials that are potentially compostable. These materials include newspapers, cardboard, food wastes, and yard wastes. A second potentially compostable material generated in large quantities is sewage sludge, a byproduct of modern sewage treatment facilities. There are, however, potential pitfalls in the generation of compost at large composting facilities. One of these relates to the potential emission of pollutant chemicals from such facilities. Therefore, I have been studying the emission of volatile organic chemicals (VOCs) from MSW composting facilities.

The project was designed as a survey of eight composting facilities using different composting techniques and feedstocks. The project was not designed to determine the source of odorous chemicals (although some VOCs are odorous) nor would it determine the total quantity of VOCs emitted. The goal of the project was to determine which pollutant VOCs are present in the materials to be composted before composting starts, which pollutants are emitted during composting, where within the facilities the emissions would take place, and determination of the approximate concentrations in air of pollutant VOCs at different locations within the facility.

Figure 1. Brian D. Eitzer placing a sorbent resin tube into the thermal desorption oven of a gas chromatography/mass specroscopy instrument.

The method of determining volatile organic chemicals in the air at composting facilities was developed at The Connecticut Agricultural Experiment Station and tested at the Fairfield sewage sludge composting facility. The method uses a small portable pump to draw air though a material, called a sorbent resin, which is contained in a small tube and traps the VOCs as the air passes through the tube. A device was developed and used to isolate the air being sampled. Thus, different regions of the facilities had different air samples associated with them. Where possible, the sampling areas included the tipping floor, biofilters, different areas of active composting (differing in age of the compost), air near shredders, and curing compost piles.

Tubes were analyzed in the laboratory by the instrumental technique known as thermal desorption gas chromatography/mass spectrometry (GC/MS). This technique heats the resin, releasing all the trapped chemicals at the same time (thermal desorption), transfers the chemicals to a device (the gas chromatograph) which separates them and transfers each individual chemical to the mass spectrometer where its concentration can be determined.

Although this technique can detect many possible VOCs, better detection limits (lower observable concentrations) are observed in target compound analysis (determination of a selected set of VOCs, the "target compounds"). Thus a set of target compounds was developed for this study which included most of the volatile organic "priority pollutants" listed by the Environmental Protection Agency. Several other "man-made" VOCs which aren't on the priority pollutant list, and a series of terpenes (naturally occurring VOCs which were present in all samples) were also included as target compounds. Standards of all target compounds were analyzed to determine retention times and response factors, based on the most intense and/or most distinctive ion for each compound. All target compounds were screened for in every sample and quantified using the external response factors developed with the standards. The limit of detection for the target compound analysis was 1 µg per cubic meter of air.

A total of 161 samples from eight different composting facilities were examined. Table 1 lists the maximum observed concentration for each chemical found in at least one sample (only half of the target compounds were found), along with workplace exposure limits for that chemical as listed by the American Conference of Governmental Industrial Hygienists (ACGIH). Workplace exposure limits are higher than outdoor "ambient air" exposure limits.

It is important to note that even the highest concentrations found in the compost piles remain well below the exposure guidelines, in most cases by several orders of magnitude. Also, these maximum concentrations represent worst cases. Samples were taken directly from waste and compost piles so that the extremely high concentration might be localized, while workers would be exposed to a more mixed air sample, and off-site concentrations would be much lower as the air from the facility mixed with the ambient outdoor air. As an example of this worst case, a sample which came from a tipped pile of solid waste had an ethylbenzene concentration of 178 mg/m^3; while a sample from the indoor air in the building in which the pile was situated had an ethylbenzene concentration of only 3 mg/m^3. Total VOCs concentrations in these two samples were 425 and 85 mg/m^3, respectively.

The highest concentrations for most VOCs were in the tipping piles, near the shredders and in the most recently formed active composting region. This means that these chemicals are emitted early in the composting process. The VOCs are most likely present in the waste as it is dropped off at the facility. Shredding of the waste to prepare it for composting increases the surface area and exposes the surfaces to the atmosphere, allowing these compounds to volatilize rapidly. Thus, air from above the newly shredded material has some of the highest average concentrations for many chemicals as compared to the other sample types. For example, the maximum average concentration of priority pollutants such as *trimethyl*benzene, xylene, toluene, and carbon tetrachloride, or natural VOCs such as the terpenes, α-pinene and d-limonene all occurred in these shredder air samples.

The tests show that VOCs that remain after shredding continue to volatilize rapidly as the compost pile comes up to its operating temperature (approximately 150 C) in the active composting region. Once these initial VOCs are driven off, the air samples taken from the more mature compost piles show lower concentrations. There is another drop in concentration from the older active compost to the curing compost piles. It is possible that this drop is caused by the final screening, a process in which the finished compost is shaken through a fine mesh removing large particles and creating a pile of "sifted" compost. The screening process would once again expose all of the surfaces to air and possibly increase surface area which would allow for volatilization of VOCs which had remained in the old compost. In fact, the average concentrations in air above the curing compost piles are similar to background air concentrations except for a few selected chemicals, indicating the slight amount of VOCs emissions at this point.

The ketones (acetone, 2-butanone, 2-hexanone, 4-methyl-2-pentanone), are a group of compounds whose concentrations run counter to this trend. This group shows some increases in concentration from the shredder to the fresh compost or from the fresh to older compost. When the compounds in this group show a decrease in concentration, the decrease is much less than that for the other VOCs. One likely explanation for this type of behavior is that these compounds are being produced as volatile byproducts during the microbial aerobic digestion of large organic compounds such as lignins and proteins are being turned into humus there is a concomitant production of some smaller compounds of possible metabolic origin such as the ketones.

While the tests did not cover all potentially harmful VOCs, they did cover a broad range of pollutant chemicals which might be expected to be found at waste composting facilities. The results showed that worker exposure to those potentially harmful chemicals tested were well below exposure guidelines and therefore community exposure to those VOCs tested should be minimal.

Table 1. Maximum observed concentration and threshold limit value-time weighted average (TLV-TWA) for workplace air in µg/cubic meter, and maximum observed concentration as a percentage of the allowable amount. TLV-TWA values are from the American Conference of Governmental Industrial Hygienists.

	Maximum Conc.	TLV-TWA	Max as % TLV-TWA
Trichlorofluoromethane	914705	5620000	16
Acetone	166031	1800000	9
Carbon disulfide	154	31000	>1
Methylene chloride	262	174000	>1
1,1-Dichloroethane	10	400000	>1
2-Butanone	319445	590000	54
Chloroform	54	49000	>1
1,1,1-Trichloroethane	14722	1900000	>1
Carbon tetrachloride	292	31000	>1
1,2-Dichloroethane	2	40000	>1
Benzene	703	32000	2
Trichloroethene	1298	270000	>1
2-Hexanone	6598	20000	33
Toluene	66475	188000	35
Tetrachloroethene	5603	339000	2
4-Methyl-2-pentanone	16058	205000	8
Chlorobenzene	29	46000	>1
Ethylbenzene	178199	434000	41
m,o-Xylene	14877	434000[a]	3
p-Xylene	6982	434000[a]	2
Styrene	6091	213000	3
Isopropyl benzene	375	246000	>1
n-Propyl benzene	1225	*	*
4-Chlorotoluene	235	*	*
1,3,5-Trimethylbenzene	2216	123000[b]	2
1,2,4-Trimethylbenzene	1047	123000[b]	>1
sec-Butylbenzene	220	*	*
1,3-Dichlorobenzene	2	*	*
1,4-Dichlorobenzene	90	451000	>1
p-Isopropyl toluene	4774	*	*
1,2-Dichlorobenzene	1	150000	>1
n-Butylbenzene	207	*	*
1,2,4-Trichlorobenzene	9	123000[b]	>1
Naphthalene	1434	52000	3
Hexachlorobutadiene	4	210	2
1,2,3-Trichlorobenzene	6	*	*

* Value not listed

a Sum of all isomers of xylene.

b Sum of all isomers of trimethylbenzene

Growing healthy pumpkins requires proper nutrition and disease control

By Wade H. Elmer

Pumpkins have become increasingly popular as a fall crop for backyard gardeners, in part, due to the success of the breeders who have released many new varieties that vary in shape, size and color. Although pumpkins are thought to be a relatively labor-free crop, they require a modest amount of early, mid and late season care to ensure they grow vigorously and stay healthy.

Full sun and a well-drained soil, preferably a soil that has not been in pumpkins or other members of the squash family, such as melons, cucumbers, or squash, for at least 2 years are essential for growing quality pumpkins. Pumpkins respond well to soil containing a high degree of organic matter. Compost will increase the water-holding capacity and nutrient availability of the soil and enhance the growth of pumpkins.

Pumpkins are usually planted in small hills 6-10 inches high with 2-3 seeds per hill when the soil is warm, commonly in early to mid June. The gardener can get a head start by planting transplants. Pumpkins require more space than other vine crops so at least 6 feet must be allowed between hills spaced in rows approximately 6-10 feet apart. Their nutrition is very important, and I side-dress each hill with about one-fourth cup of 10-10-10 fertilizer after the true leaves have emerged. This is roughly equivalent to 3-5 lbs. of well rotted manure. Contact of fertilizer or manure with the leaves or the stem should be avoided. I repeat this fertilizer or manure application when the vines begin to run in mid July to ensure the plant has the proper nutrition when the fruits begin to form. Drought stress can compromise the size and number of the fruits, so plants should be irrigated. Pumpkins require at least 1 inch of water per week whether from rain or irrigation.

Pumpkin vines can be damaged by insects, such as the squash vine borer, squash beetle, and cucumber beetle. Although cucumber beetles do minor damage to pumpkins, they vector a bacterium called *Erwinia tracheiphila* which causes bacterial wilt. The latest information on ways to suppress these insects is available from our vegetable entomologists.

My research centers on diseases which can destroy pumpkins. A fungal disease called Phytophthora blight may damage pumpkins any time during the growing season when periods of heavy rainfall prevail. This pathogen requires free standing water for its spore-bearing structures to produce its swimming spores, called zoospores. The zoospores swim to the plant, infect, and cause disease. Proper soil drainage will discourage infection. Rotating pumpkins with crops including sweet corn and members of the cabbage family, such as broccoli and cauliflower, for at least 2 years can also reduce the amount of the fungus in the soil.

In late July or early August pumpkin leaves commonly develop whitish powdery spots called powdery mildew. These spots cause lesions which coalesce and cause the leaves to turn brown and die. Early infection of plants with powdery mildew in mid July may reduce the size and number of pumpkins. The disease is caused by two species of fungi, *Sphaerotheca fuliginea* and *Erysiphe cichoracearum.* Although the spores of these fungi are believed to be carried on the wind from southern regions, they may occasionally overwinter in Connecticut. The overwintering stage, called cleistothecia, contains spores which form when two opposite mating types of a species cross.

My colleague, Frank Ferrandino, and I have experimented with baking soda (sodium bicarbonate) mixed with horticultural oil as a potential spray to suppress powdery mildew. In 1993 we conducted a test at the Lockwood Farm on Howden pumpkins. In August, experimental pumpkin plots were sprayed with standard fungicides (Bayleton/Bravo) at normal rates and compared to pumpkin plots which received a spray containing baking soda (1%, w/v) mixed with horticultural oil (1%, w/v), and to pumpkin plots which received no sprays. During August and September the plots were visually rated for the percentage of leaf area diseased. The data indicated that the baking soda plus horticultural oil application was not as effective as the standard fungicides, but did suppress the disease when compared to the control plots (Figure 1).

There are several destructive fruit diseases of pumpkin caused by fungi. Black rot, the most common in Connecticut, is caused by the fungus, *Didymella bryoniae*. This disease causes dark water-soaked lesions on the rind of pumpkins and can be accompanied by an oozing fluid. This disease seems to be more damaging on the larger cultivars, such as Howden, but may also cause problems on smaller varieties if the fungus is present in the soil in high enough quantities and weather is conducive. Choosing land that has not been recently planted to pumpkins or to other members of the squash family can reduce the incidence of black rot.

Recently, a pumpkin fruit rot disease appeared in Connecticut that was distinctly different from black rot. This new disease caused small pitted lesions on the rind and was caused by species of a fungal genus called *Fusarium*. Four different species were isolated from the lesions and identified: *F. acuminatum, F. avenaceum*, *F. graminearum,* and *F. equiseti*. Greenhouse inoculations of healthy pumpkins revealed that the symptoms varied slightly with each *Fusarium* species. At present it seems that only the large pumpkins of the popular cultivar Howden are affected by the Fusarium fruit rots in the field. In greenhouse inoculation tests, however, mature pumpkins of other cultivars, such as Aspen, Wizard, Young's Beauty, Spooky, and Oz were also susceptible. I found that exposing pumpkin seedlings to spores of the *Fusarium* fungi did not cause disease, which indicates these fungi may only affect the fruit. I am now testing fungicides that are registered on pumpkin in the laboratory to learn if any can inhibit the fungus. Little is known about this disease, so many basic studies may be required to assist in developing alternate disease control strategies.

Late season virus symptoms are not uncommon in pumpkin. They usually appear as distorted shriveled leaves that exhibit a mosaic pattern. Most pumpkin viruses are believed to be spread by insects, although these viruses may also be seedborne. Infection early in the season during June or July is likely to prevent fruit from ripening normally and/or inflict disfiguring bumps on the pumpkin. Common viruses in Connecticut are papaya ringspot virus, squash mosaic virus, watermelon mosaic virus, and cucumber mosaic virus. A diagnostic assay using antibodies is needed to confirm the identity of the virus. Watermelon mosaic virus has been reappearing in the same area of Connecticut during the last few years and may be overwintering on an alternate host.

Pumpkins begin turning from green to yellow-orange in early to mid September and can be harvested any time prior to the first hard frost. Different varieties of pumpkins respond differently to frost damage, so more susceptible varieties may need to be covered during cold nights.

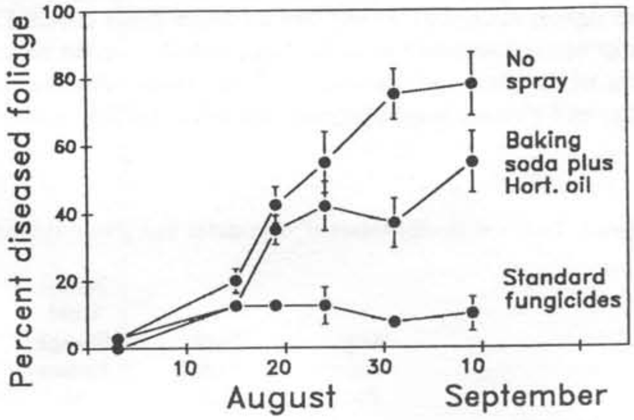

Figure 1. Comparison of baking soda plus horticultural oil with the standard fungicides (Bayleton 50WP/Bravo 720) for suppressing powdery mildew disease on pumpkin leaves.

Pumpkins offer many varieties and choices for growers

By David E. Hill

The lore of pumpkins includes the classic tale of Ichabod Crane in which Brom Bones, disguised as the headless horseman, carried a pumpkin under his arm and terrorized the countryside. More recently, around Halloween, the Peanuts comic strip character, Linus, spins tales of "The Great Pumpkin" rising out of the pumpkin patch. This lore contributes to the popularizing of the members of the genus *Cucurbita*.

The marketing of pumpkins for Halloween decoration and pie filling has increased substantially in the last decade. Virtually all roadside stands open through October have pumpkins to sell. The Conn. Agricultural Marketing Directory lists 29 farms that grow pick-your-own pumpkins and 32 other growers list pumpkins as a major item in their fall sales. The Connecticut Dept. of Agriculture estimated that 800-1000 acres of pumpkins were grown in Connecticut in 1993.

Most decorative pumpkins are selected by eye appeal. They must have good color, a consistent shape and a sound handle. Many open-pollinated cultivars are inconsistent in these qualities. Breeders have developed many new hybrid cultivars that are more consistent and are also resistant to some diseases.

In 1992, I began pumpkin trials that included cultivars with large, medium, small, and miniature fruit. The trials were conducted at the Valley Laboratory in Windsor in a sandy terrace soil and at Lockwood Farm in a loamy upland soil. All crops were grown according to accepted cultural practices of fertilization, cultivation, and insect and disease control as outlined in Station Bulletin 919.

Table 1 reports the yield and durability of unprotected fruit in 1993 at Windsor which received ample rain throughout the growing season. The extensive drought at Mt. Carmel from June through August caused early maturity of the fruit and severely reduced yield. At Windsor, the average fruit weight fell within the expected range reported by seed catalogues, but most fell in the lower part of the range for the large and medium size cultivars. The average fruit weight of small and miniature cultivars tended to fall in the upper part of their range. The total yield of most medium size cultivars exceeded 25 tons per acre (T/A). The heavy yield of Big Autumn was attributed to large average weight and prolific fruit production (7,200 fruit/A). The high yield of Oz, among miniature varieties, was due to high fruit yields (18,800 fruit/A) despite its small size. The yield of Autumn Gold and

Howden, reported from Mt. Carmel in 1992 were below average due to an infection of Phythophthora experienced in many Connecticut fields during a wetter-than-normal season.

During 30 days of unprotected storage, resembling conditions of pick-your-own operations, the fruit was subjected to two light frosts (30-32 F) and two moderate frosts (26-29 F). Frost damage appeared as water-soaked patches on the shoulders of the fruit and separation of the handle. Among the large and medium sized pumpkins, Howden and Big Autumn were damaged least. The miniature cultivar Oz had the least damage because its handle is disproportionately large for the size of the fruit. The post-harvest loss of unprotected fruit in the field indicates that proper storage requires placement of fruit in a dry, frost-free environment.

Among all cultivars Big Autumn, Howden, Oz, and Pro Gold 500 provided excellent yield and quality of fruit. High yield and quality were dependent upon weather and adequate control of diseases and insects.

Table 1. Yield and storage losses of unprotected fruit grown at Windsor, 1993.

Type/Cultivar	Avg. wt. lbs.	Total Yield T/A	30-day Field Storage Losses %
LARGE (>20 LB)			
Howden*	23.7	19.3	27
MEDIUM (10-20 LB)			
Aspen	14.8	24.2	64
Autumn Gold*	12.6	9.7	100
Big Autumn	16.0	58.8	33
Connecticut Field	18.2	31.6	78
JSS 9032	11.4	28.3	74
Pro Gold 500	15.5	35.6	53
Wizard	15.4	24.7	98
SMALL (5-10 LB)			
Ghost Rider	8.8	22.5	88
Lumina	7.5	16.7	45
Spirit	9.9	26.1	65
MINIATURE (<5 LB)			
Baby Bear	1.7	12.2	41
New England Pie	4.4	14.7	44
Oz	3.6	18.2	7

* Mt. Carmel, 1992

Use of synthetic pesticides on turf may have caused milky disease decline

By Douglas W. Dingman

Between 1939 and 1951, milky spore powder was used extensively to combat Japanese beetle (*Popillia japonica* Newman) infestations in Connecticut and other parts of the eastern United States. At least 5000 lbs. of spore powder were used in Connecticut during these years and infection rates exceeding 50% of a population were measured. Japanese beetle numbers reportedly declined during the 1940's and remained low for 25 years. In the early 1960's, the incidence of milky disease in Japanese beetles was reported as being impressively high. Because of this, milky spore powder was considered to be effective in combating Japanese beetles.

However, in 1975, the incidence of milky disease was reported to be low (0-20%) and this low incidence, also reported in 1988 and 1990, has not increased. The reason for this precipitous drop in disease incidence is unknown. I have been investigating the milky spore bacterium and possible reasons for its reduced effectiveness as a biological control agent.

The active ingredients of milky spore powder are endospores of the bacterium *Bacillus popilliae* and, to a lesser extent, the related bacterium *Bacillus lentimorbus*. Spores of these bacteria remain dormant in the soil for years. Following ingestion by larvae of the Japanese beetle or related scarab beetles [European chafer (*Rhizotrogus majalis*), Oriental beetle (*Anomala orientalis* Waterhouse), and Asiatic garden beetle (*Maladera castanea* Arrow)], spores germinate and the resulting cells penetrate through the intestinal epithelium, causing a septicemia (milky disease). There is massive release of newly-produced spores into the soil following death of the larvae. This cyclic, self-perpetuating characteristic makes *B. popilliae* ideal for use as a bioinsecticide.

Propagation of milky disease depends on the spores that

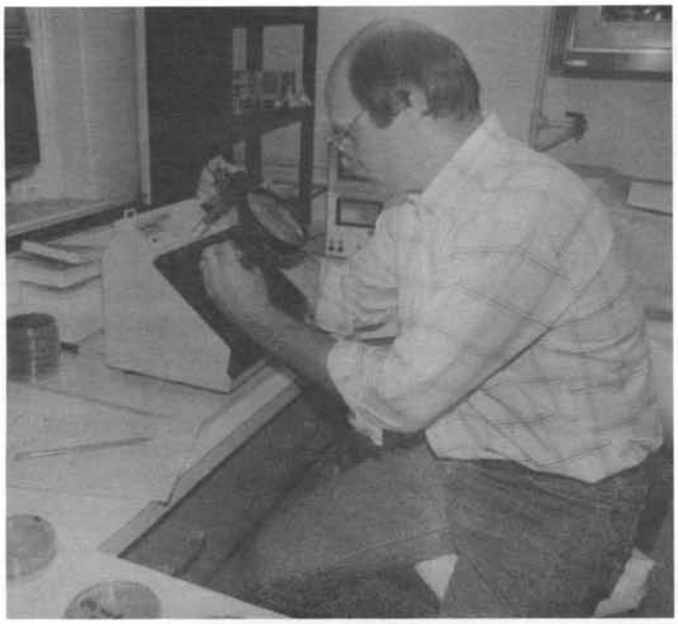

Figure 1. Douglas Dingman counts colonies of *Bacillus popilliae* growing in media in the laboratory.

remain in the soil and on the cycling of the bacterium through larval hosts. Any agent that upsets this delicate balance by killing spores or disrupting the disease cycle (i.e., spore germination and cellular growth) will curtail propagation and effectively lower the incidence of this disease.

I studied the effects of several chemical pesticides (Table 1) that are, or have been, used on lawns to determine whether they are harmful to *B. popilliae*. For this laboratory study, I used pesticides at rates and concentrations recommended by the manufacturers and followed information given on the pesticide spray guide labels. Pesticides are generally applied to turf as sprays or granules. Therefore, the initial application of pesticide to turf usually results in a high concentration of material in the upper soil layer even when used as recommended. Insufficient or uneven dispersal of pesticide throughout the soil will maintain this high concentration. All of the pesticides tested were detrimental to *B. popilliae* when aqueous concentrations of active ingredient exceeded 1000 parts per million (ppm). For these pesticides, 1000 ppm is far above the final soil concentration that results from even dispersal of the recommended amount of pesticide. However, application of these pesticides to turf is in excess of 1000 ppm.

Table 1. Pesticides tested.

Product Name	Active Ingredient
FUNGICIDES	
Bayleton 25	Triadimefon
Daconil 2787 Flowable	Chlorothalonil
Chipco* 26019 FLO	Iprodione
HERBICIDES	
Weedone DPC Amine	2,4-D & 2,4-DP
2 PLUS 2 (MCPP+2,4-D Amine)	MCPP & 2,4-D
Pre-M 60 DG	Pendimethalin
Dacthal W-75 AG	DCPA
Banvel	Dicamba
INSECTICIDES	
Dylox 80	Trichlorfon
Dursban* 4E	Chlorpyrifos
Chipco* Sevimol	Carbaryl
Tempo 2	Cyfluthrin
Oftanol 2	Isofenphos
Chlordane (tech. grade)	Chlordane

In soil studies, I found that when the fungicide chlorothalonil was present in soil at the concentration resulting from an even dispersal of the recommended application dosage the number of viable spores was significantly reduced (Table 2). The fungicide triadimefon and herbicides 2,4-D + 2,4-DP and pendimethalin significantly lowered spore numbers at five times the recommended application concentration. Therefore, I conclude that these four pesticides can lower *B. popilliae* spore numbers when used as recommended.

In general, the insecticides tested did not kill spores of *B. popilliae*. However, continued killing of the host by insecticides will disrupt the milky disease cycle and could result in its lowered prevalence in subsequent populations of Japanese beetle larvae.

Table 2. Effect of pesticides on spore numbers in soil as percentage of viable spores of *B. popilliae* remaining following exposure to pesticide at the recommended rate and five times the recommended rate.

	1X	5X
FUNGICIDES		
Triadimefon	139	57
Chlorothalonil	7	9
HERBICIDES		
2,4-D + 2,4-DP80	17	
Pendimethalin	81	24

1. The percentage of viable spores was calculated by determining the ratio of the number of spores germinating on experimental plates to the number of spores germinating on plates lacking pesticide.

Studies examining inhibition of *B. popilliae* cell growth revealed several harmful pesticides (Table 3). In culture, chlorothalonil, iprodione, and chlorpyrifos severely inhibited cell growth at concentrations below those recommended for application. Although not as dramatic, triadimefon, pendimethalin, and chlordane (studied because of its extensive use in the past) also inhibited growth of *B. popilliae* at concentrations less than or near those recommended for application. All pesticides tested in this study (Table 1) were found to repress cell growth at 1000 ppm.

Of the pesticides examined, the fungicides and the herbi-

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cide pendimethalin exhibited the greatest overall detrimental effect on *B. popilliae*. There are no accurate records of fungicide and herbicide use on turf in Connecticut for the past four decades. Therefore, correlation's between the decline in milky disease incidence and the extent of pesticide usage could not be made. However, triadimefon, chlorothalonil, iprodione, and pendimethalin became commercially available between the last report of high milky disease incidence and the first report of low incidence.

Many factors control the prevalence of a disease, and it is unlikely that the cause(s) of the decline of milky disease incidence will be determined with certainty. However, I suggest that use of certain pesticides on turf can decrease the incidence of milky disease and may be contributing to the continued low incidence of this bioinsecticide.

B. popilliae still has the potential to be effectively used as a bioinsecticide. Past history has shown that a high incidence of milky disease can be established in Japanese beetle populations and, in continued surveys of larval populations of scarab beetles, milky disease is still present. Research being done at The Connecticut Agricultural Experimental Station is striving to enhance the use of this bioinsecticide and, thereby, reduce our dependency upon synthetic pesticides.

Table 3. Inhibition of *B. popilliae* cellular growth by pesticides.

	Cellular growth (%) at pesticide concentration (ppm)[1]			
	1	10	25	50
FUNGICIDES				
Triadimefon	72	56	45	14
Chlorothalonil	<1	<1	<1	<1
Iprodione	61	<1	<1	<1
HERBICIDES				
Pendimethalin	75	60	15	6
INSECTICIDES				
Chlorpyrifos	87	4	4	3
Chlordane	137	111	76	2

1. The percentage of cellular growth was calculated by determining the ratio of cell titer in experimental culture tubes to cell titer in culture tubes lacking pesticide.