# Use of Mushroom Compost to Suppress Artillery Fungi[1]

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## Abstract

Mushroom compost (spent mushroom substrate, SMS, mushroom soil) exhibits suppressive characteristics against various fungi, as well as against plant diseases caused by fungi. In addition, mushroom compost has physical and chemical characteristics that make it ideal for blending with landscape mulch to enhance growth of horticultural plants. There is currently an oversupply of used compost in mushroom-growing areas, where it represents a major disposal and regulatory problem. Concurrently, artillery fungi (*Sphaerobolus* spp.), which commonly live in landscape mulch, have recently become a plague for many homeowners due to the sticky spore masses they expel onto houses and cars. There is increasing interest among homeowners to control artillery fungi without the use of chemical fungicides. Therefore, we have explored the use of aged mushroom compost as a biocontrol agent for artillery fungi. The abundance of mushroom compost, as well as its antagonistic nature to fungi, made it an ideal candidate to blend with landscape mulch to suppress artillery fungi without the use of fungicides. We previously reported that 100% aged mushroom compost suppressed artillery fungi. In the current 3-year field study, we examined the suppressive nature of lower percentages of aged mushroom compost blended with wood landscape mulch. Lower percentages of compost did suppress artillery fungi, but the high variability in the data precluded detailed statistical analyses. Nevertheless, blending mushroom compost with landscape mulch may yield a possible solution for both the compost disposal and the artillery fungi problems.

**Index words:** *Sphaerobolus stellatus, Sphaerobolus iowensis*, mulch, spent mushroom substrate, black spots.

### Significance to the Nursery Industry

In recent years, artillery fungi have become of increasing concern because they colonize landscape mulch along house foundations, where they shoot sticky spore masses (gleba) towards light-colored, reflective house siding. The attached gleba turn dark and stain the siding. Disgruntled homeowners often file insurance claims for painting or replacing the damaged house siding (power washing usually does not work). However, homeowner insurance policies may exclude coverage of damage caused by fungi such as artillery fungi. In this case, the perceived liability may shift to the mulch producer, mulch sales yard, or contractor applying the mulch. Our previous field research, involving the relative sporulation of artillery fungi on 27 different mulches, revealed that 100% aged mushroom compost suppressed sporulation. The objective of the present study was to repeat this previous study, but to include lower percentages of aged mushroom compost blended into landscape mulch. Results of this 3-year field study supported our previous results. Mushroom compost, even at low percentages, suppressed artillery fungi, affording a possible solution for both the compost disposal problem by the mushroom industry and the artillery fungi problem by the landscape industry. In addition to suppressing artillery fungi, blending mushroom compost with landscape mulch adds beneficial nutrients later released from the compost as it decomposes.

### Introduction

Artillery fungi include two previously described basidiomycetes in the genus *Sphaerobolus* (*S. stellatus* (Tode) Pers. and *S. iowensis* (Walker)) (6) and one recently named species (*S. ingoldii* (Geml, Davis, *et* Geiser)) (8). Artillery fungi have evolved a dual ecology; they commonly live as saprophytes on excrement, such as cow dung, but also exist as white-rot, wood-decay fungi (13). It is this latter ecological niche that is of interest to us, since landscape mulch is now comprised mainly of wood. White-rot fungi are those species capable of removing the three major plant cell wall components (cellulose, hemicellulose, and lignin) of wood at approximately equal rates during the decay process (1). Since they can consume all three structural components of the cell wall, white-rot fungi can grow on a variety of substrates, including various landscape mulches.

We reported that artillery fungi favor landscape mulches composed of wood as opposed to bark (5), and grow and sporulate most abundantly on those mulched landscapes located along the cool, moist, north side of a house. Artillery fungi produce sticky spore masses (gleba) that are shot towards sunlight, or towards light-colored reflective objects, by a phototropic spore-release mechanism (13, 22). The gleba adhere tightly to surfaces such as house siding (14) or automobiles (23), darken, and are difficult to remove without leaving a permanent, unsightly stain. Homeowner complaints and resultant lawsuits regarding this staining have been the impetus for our series of studies to determine factors that suppress artillery fungi within landscape mulch.

Within the United States, artillery fungi appear to be common in the Northeast, where the cool, moist climate favors their growth and sporulation during the spring and fall (5). That is, artillery fungi are considered to be cool, wet weather fungi in terms of sporulation. Based on complaints received, artillery fungi were especially evident in the Northeast during the wet years of 2003 and 2004. However, we have also received complaints regarding artillery fungi problems from Alaska, as well as from various locations along the East Coast from Connecticut to Florida. In fact, these cosmopolitan fungi are found in many other parts of the world, in such varied places as Australia, Europe, and Japan (3, 6).

In recent years, increased use of landscape mulch, as well as increased publicity about artillery fungi, have led to greater

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public awareness of the problem. More importantly, we believe that recent changes in mulch composition from bark to wood have contributed to the increases in these white-rot, wood decay fungi (5).

Microorganisms in natural, organic substrates, such as compost, can suppress a variety of plant pathogenic fungi, and possibly bacteria (4, 9–12, 16–19, 21, 24). Apparently, organic substrates such as mushroom compost encourage a population of antagonistic microorganisms that interfere with the activity of plant pathogens; compost is especially replete with microorganisms antagonistic to pathogenic fungi (19). Romaine and Holcomb (19) reported that the percentage of compost in the growing medium affected the relationship between tomato (*Lycopersicon esculentum* Mill. 'Ace 55') seedling survival and damping-off disease caused by the fungus *Pythium*. They reported a general trend for increasing seedling survival as the proportion of compost increased up to 100%, and that compost at a level of 50% or greater provided highly effective disease control.

Our projects involving artillery fungi have been concerned mainly with suppressing growth and sporulation. In the lab, we have shown that biocontrol agents within the bacterial genera *Bacillus* and the fungal genus *Trichoderma* suppressed growth of artillery fungi in Petri plates (2), as did certain fungicides (7). In the field, we reported that different types of landscape mulches support different levels of sporulation by artillery fungi (3, 5). In these latter studies, one of the most suppressive mulches was 100% mushroom compost (5); this latter result led to the study reported herein. The main goal of our research was to investigate whether concentrations of mushroom compost less than 100%, when blended with landscape mulch, would suppress sporulation of artillery fungi.

## Materials and Methods

*Artillery fungi inoculum.* Gleba of *S. stellatus* were originally collected on the campus of The Pennsylvania State University, University Park, PA (2, 3) and plated onto oatmeal agar. One isolate, based on abundant sporulation, was selected from the resulting cultures. This isolate of *S. stellatus* has been maintained, used in subsequent experiments (5), and was used in the study reported herein. New gleba from this isolate were subcultured and resultant mycelium placed in flasks containing a sterilized rye-grain, oak-sawdust mixture. The inoculated medium was cultured in the dark at 22C (72F) for 3 weeks, during which time the mycelium had grown throughout the flask material. This grain-sawdust material served as inoculum for our experiments.

*Compost-mulch substrate.* Used mushroom compost, consisting of steam-pasteurized horse and chicken manure, gypsum, and a proprietary nutrient supplement, was obtained directly from a commercial mushroom house in southeastern Pennsylvania (Georgi Mushroom Co., Temple, PA) and trucked to our research site. This compost had been used to grow the common button mushroom (*Agaricus bisporus* (Lange (Imbach)). Landscape mulch, consisting of kiln-dried, double-ground oak-hickory wood chips, was obtained locally from a commercial dealer (Pennwood Corp., Pleasant Gap, PA). In June 2001 the two substrates were blended outside in 7 $m^3$ (9.2 $yd^3$) piles, each consisting of 0 (control), 10, 20, 40, or 100% compost (vol/vol). To further compost the blended material, piles were irrigated weekly with the equivalent of 5 cm (2 in) rainfall throughout the summer until November 2001. During this time, the internal temperature of each pile was monitored weekly and piles were turned once each week or when internal temperatures reached 65C (149F).

*Field plots.* Thirty treatment plots were constructed at The Russell E. Larson Agricultural Research Farm of The Pennsylvania State University, Rock Springs, PA. Each plot was approximately 0.7 m wide × 1 m long (*ca*. 2 × 3 ft) with a 0.7 m high back wall covered with white aluminum. Plywood walls, attached at right angles to the back wall and separating individual treatments, were 0.7 m × 0.7 m, and painted white. The sides and back of each plot were considered to be the 'targets' for discharged gleba. During November 2001, grass and weeds were removed from each plot, and mulch treatments applied to a depth of 12–13 cm (*ca*. 5 in) onto bare soil. Each of the five mulch treatments was established in a randomized block design (two blocks, at slightly different locations). Each block contained three replications of the five treatments. Treatments were allowed to age in place for an additional 12 months before inoculation, to allow leaching of possible harmful salts from the compost (19).

Each plot was inoculated in October–November 2002, by placing 25 ml (*ca*. 5 tsp) of the grain-sawdust inoculum at three evenly spaced locations per plot each time. Mulch from the plot was lightly sprinkled on the inoculation point. Plots were maintained until April 2005 (*ca*. 30 months after inoculation) under prevailing environmental conditions and were not irrigated.

*Data collection and analyses.* Sporulation was recorded as number of gleba attached to the targets (back wall and two sides) of each field plot. Numbers of new gleba were recorded five times: April 10, 2003; October 10, 2003; May 24, 2004; September 21, 2004; and April 20, 2005. Numbers of accumulated gleba at the end of the experiment (April 20, 2005) were calculated. Data were subjected to a $\log_{10}$ transformation. Transformed data were used to evaluate statistical differences between blocks and among the five treatments using Analysis of Variance (ANOVA) with a General Linear Model; differences among means were determined using Tukey's Mean Separation test. To illustrate trends in gleba production over time, data were analyzed using linear regression (15, 20). For clarity in interpretation, only non-transformed data are illustrated.

## Results and Discussion

*Influence of percentage compost.* Five individual treatments, consisting of 0 (control), 10, 20, 40, and 100% compost, were tested within two blocks to determine the effect of treatment level on sporulation. The ANOVA, based on the average number of gleba accumulated on the targets at the end of the experiment (April 20, 2005, 30 months after inoculation), revealed that the level of sporulation did not differ significantly ($P \leq 0.05$) between blocks. Therefore, data from the blocks were combined.

Initial analyses revealed extreme variability in the data among treatments. To increase number of observations per treatment, data from the 10, 20, and 40% compost were combined as one treatment (termed 10–40% compost), transformed, and re-analyzed. The overall ANOVA revealed that significant differences ($P \leq 0.05$) occurred among the mean number of gleba at the end of the experiment, with the targets of the 0, 10–40, and 100% compost having 236.8, 26.4, and 7.2 mean gleba, respectively, which were significantly different ($P \leq 0.05$) from each other.

As in our previous reports (3, 5), additional statistical analyses (i.e., comparing data among the 10, 20, and 40% compost treatments) were limited by the high degree of variability. This variability was likely related to the different microbe populations that became established in the various field treatments. Many interactions between artillery fungi and antagonistic microbes, including other fungi and bacteria antagonistic to artillery fungi (2), can occur under field conditions. Nevertheless, these results support our previous findings (5) that mushroom compost suppresses artillery fungi. Suppression is likely due to the populations of antagonistic microbes (2, 4, 10, 19) within the mushroom compost.

*Sporulation over time.* The mulch was inoculated in November 2002; gleba were not observed on the targets during the first data collection on April 20, 2003, approximately 6 months after inoculation. Small numbers of gleba were observed by the second sampling on October 10, 2003, indicating that approximately 1 year was needed for the artillery fungi to colonize the mulch and sporulate under the conditions of this experiment. Regression analysis revealed that the time-trend in accumulated gleba was linear and significant ($P \leq 0.004$) for each of the three treatments (Fig. 1). Slopes of the three linear regressions were significantly ($P \leq 0.001$) different from each other.

Although not revealed by the linear regression, examination of the raw data revealed that the rate of sporulation began to decline towards the end of the experiment in April 2005. This decreasing trend in sporulation over time was similar to our previous findings (3, 5). Since artillery fungi are white-rot wood decay fungi, they consume cellulose, hemicellulose, and lignin (1) within the mulch and one might assume that these food bases become limiting with time. However, we observed that most of the wood substrate had not been visibly colonized by artillery fungi in any treatment, even by the end of the experiment. Therefore, depletion of food (wood) substrate was not likely the reason for the diminishing sporulation over time. It is more likely that compost contains many microorganisms antagonistic to fungi, and that the totality of this antagonistic microflora contributes to the suppressive nature of mushroom compost against artillery fungi (19). As mulch aged, it is likely that populations of competitive antagonistic microflora such as *Bacillus* and/or *Trichoderma* (2), likely derived initially from the mushroom compost, increased to levels that interfered with growth and sporulation of artillery fungi.

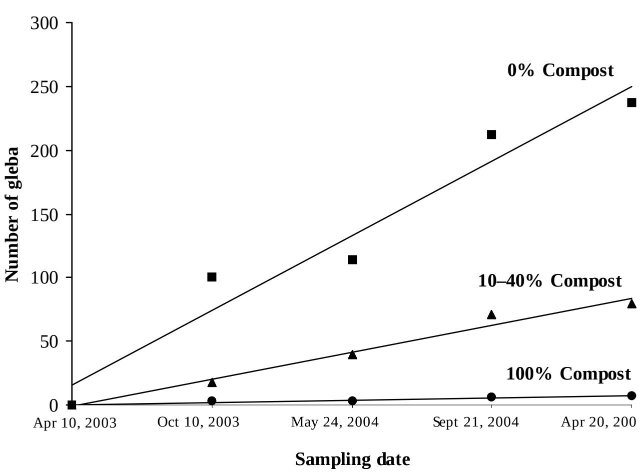


**Fig. 1. Linear regression based on average accumulation of gleba on targets over time for the three treatments: 0 (control), 10–40, and 100% compost.**

In summary, our overall findings support our previous report (5) that aged mushroom compost suppresses sporulation of artillery fungi. Romaine and Holcomb (19) reported that 50% or greater levels of compost were needed to provide effective disease control in tomato seedlings against the pathogenic fungus *Pythium*. Their results indicate that initial levels of mushroom compost, within blended growth medium or landscape mulch, must be high enough to establish populations of antagonistic microorganisms that successfully compete with unwanted fungi. However, in our study, it appeared that lower percentages of aged mushroom compost could suppress artillery fungi.

It is likely that mushroom compost contains initial populations of antagonistic fungi at fairly high levels. However, populations of microbes in compost are likely to be variable. Until this high level of variability can be understood and controlled, it is difficult to make firm recommendations regarding the percentage of compost to blend with landscape mulch in an attempt to suppress artillery fungi.

Any commercial-scale production of compost-mulch blends should be carried out at the mulch producer site. Fresh compost could be trucked directly from the mushroom house to the landscape mulch yard, where the two components could be blended, composted, and turned until the following spring, when most landscape mulch is sold. At that time, the blended mulch product could be delivered in bulk to mulch sales yards or to mulch applicators. The length of time during aging would also allow time for leaching of possibly harmful salts within the compost component (19). The economic feasibility of producing compost-based, blended landscape mulch cannot be determined at this time, but the potential is great. Use of such a blend would reduce the over-supply of used compost within the mushroom industry, and create an environmentally friendly method to reduce the artillery fungi problem for the landscape industry without the use of chemical fungicides.

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