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Artillery Fungi (*Sphaerobolus* spp.) A Review of Horticultural Problems with Emphasis on Pennsylvania, USA

Review Article

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Abstract

Artillery fungi have been studied scientifically since 1729. For the nearly 3 centuries since, most publications dealing with artillery fungi were mycological studies. However, in the latter half of the 20th century, this mycological curiosity became of serious concern to homeowners in many parts of the USA, where artillery fungi grow on foundation landscape mulches, which are often comprised of shredded recycled wood. Such mulch is often colonized by artillery fungi, which can propel their sticky spore masses (gleba) towards sides of houses covered with highly reflective light-colored siding. The sticky gleba adhere tenaciously to vinyl siding and are very difficult to remove. If they can be removed, they often leave behind a brown stain. In this review, we examine the efforts to control this pest in landscape mulch, many of which have been ineffective in the USA. However, one promising “green” sustainable solution is to mix used recycled mushroom compost into the landscape mulch. Used mushroom compost may contain micro-organisms that are antagonistic towards artillery fungi. This control effort may result in a substantial reduction of artillery fungus populations, thus minimizing sporulation.

Keywords: Landscape molds; Mulch; Mushroom compost; Mycology

Introduction

History

In 1729, Micheli [1] first described artillery fungi, taxonomically placing them in the Basidiomycete genus *Carpobolus*, which means “fruiting-body thrower” in Latin. Fischer [2] documented the development of artillery fungi morphology in 1884, and Buller [3] described theartillery-like mechanism that shot the spore masses (gleba) in 1909. In 1927, Walker [4] placed artillery fungi in the genus *Sphaerobolus,* which contained *S. stellatus*, and named *S. iowensis* as a new species. A third previously unknown species, *S. ingoldii*, was named in 2005 [5] and a fourth unknown species is currently being studied by the authors and colleagues. Several other names for artillery fungi exist in herbaria, including *S. bombardioides, S. carpobolus, S. corii, S. crustaceus, S. epigaeus, S. minimus, S. minutissimus, S.rubidus, S. sparsus,* and *S. tubulosus*; however, the origin of these names could not be ascertained in the scientific literature and the names are thus considered scientifically invalid binomials [5,6].

Sphaerobolus is a cosmopolitan Basidiomycete found worldwide in temperate climates [5,6]. The genus has been reported from Europe (from Greece to Iceland), Asia (including Japan), Australia, New Zealand, and Africa. In the Americas, *Sphaerobolus* has been reported from Latin America, Canada, and most of the continental USA, where it is abundant in the eastern states, including Pennsylvania (PA).Whether this is the natural range of artillery fungi, or whether *Sphaerobolus* has been dispersed artificially, is unknown [5].

Numerous authors have studied the taxonomy, biology, life cycle,

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growth, and sporulation of artillery fungi [1-8]. However, artillery fungi were not considered to be a serious landscape pest in the USA until it was reported that they often colonized foundation landscape mulch and propelled their sticky spore masses (gleba) onto house siding.

Artillery fungi on plants and in landscape mulches

Early reports as pests on plants: In 1957, Birchfield et al. [9] reported that a small outdoor commercial planting of Chinese evergreen plants in Florida USA contained [thousands] of black *S. stellatus* gleba stuck to their foliage. The plants were growing in a mulch of pine and hardwood shavings, which apparently also served as a food source for the artillery fungus. As a result, sales of the unmarketable plants were delayed until a "clean-up" program was conducted by the nursery. In 1983, Bertus and Walker [10] reported *S. stellatus* as a 1982 nursery pest within a commercial glasshouse in Australia. Most plants had *S. stellatus* gleba on their leaves and retailers refused to buy the disfigured or contaminated plants. Discharged gleba were also noted on pots, benches, and glasshouse walls. The fungus appeared to be growing on the surface of the potting mix that had been fertilized with a dressing of dried blood, which apparently stimulated abundant growth of *S. stellatus.* In 1985, Lehman [11] published an outreach paper that accurately described the unknown (in the USA) "black spots", which were often misidentified as scale insects or insect excrement, on the sides of houses as"…masses of mature spores expelled from the fruiting bodies [spore masses, gleba] of the artillery fungus *Sphaerobolus stellatus*…" In 1989, Wolf [12] stated that the previously unknown "black spheres" observed among orchids (apparently grown in bark), as well as noted on pots, labels, nearby structures, and glass walls were *Sphaerobolus* fruiting bodies. These early reports of *Sphaerobolus* being a nursery/landscape pest were followed by a color brochure by Brantley et al. [13] entitled "What is growing in my landscape mulch?", which described landscape problems due to *Sphaerobolus* species in the USA.

The common name "artillery fungus" refers to the fungus' ability to orient its phototropic [14-16] spore-throwing device so that it will shoot its gleba towards the brightest light (direct or reflected) in its immediate environment. Relatedly, artillery fungi have evolved a dual-ecology strategy for spore dissemination and survival [17-19]. In an open field or pasture, the spore mass gleba is usually shot upwards towards sunlight but can become stuck on nearby grass or other vegetation. The gleba and spores may then be ingested along with vegetation by herbivores such as rabbits, deer, or cattle. Germinating spores and resultant fungal mycelium can survive on or in the animal's excrement, such as cow dung and rabbit or deer pellets, until the shooting mechanism is again formed by the new mycelium. The significance in this dual-ecology strategy is that grazing or browsing animals may act in both survival and dispersal/dissemination of artillery fungi gleba [18]. In contrast, within a forest the gleba may land on dead trees, logs, and branches on the ground, where the artillery fungus acts as a white-rot, wood-decay, Basidiomycete fungus, consuming cellulose, hemicellulose, and lignin as energy sources.

USA research papers

General: Within non-arid regions of the USA, such as PA, artillery fungi have been observed on dead trees, damp wood/bark products such as lumber, and landscape mulch [20]. However, in much of the USA, artillery fungi occur on landscape mulches placed next to house foundations in cool, moist locations. Such mulches are used extensively around urban and suburban houses, apartment residences, and office buildings in the USA to reduce weeds, maintain soil moisture, and enhance aesthetics in horticultural plantings [21]. The volume of mulches is currently increasing within the expanding residential and commercial developments that require extensive landscaping that use large volumes of landscape mulch [22,23]. In PA alone, more than~2M $m^3$of landscape mulch are sold annually to homeowners in the southeastern part of the state (Fidanza personal communication).

Mulches decompose over time as white-rot wood decay fungi (that often act as ecologically valuable "decomposers" or "recyclers" in nature), including artillery fungi, derive their energy by consuming the carbon-based compounds in the mulch. In past years, landscape mulches in the USA were comprised mainly of bark, usually obtained as sawmill waste products [24]. Bark contains toxic and hydrophobic compounds that inhibit fungi and is more resistant to decay than wood [25,26]. However, modern mulches currently used by horticulturalists and available at lawn-and-garden centers in the USA, are now often derived from wood rather than bark. The origin of the recycled wood may be old used "pallets"(flat portable wooden platforms used to pile, store, assemble, or transport goods), recycling facilities, and scrap wood from sawmills, as well as from land-clearing operations where stumps, soil, and rocks are ground and mixed in large tub grinders [27-31]. In addition, most landscape mulch in USA is double- or triple-ground to a fine texture to enhance the visual appearance and increase moisture-holding capacity. However, use of wood-based, finely shredded mulch favors growth and sporulation of nuisance fungi such as artillery fungi (Davis personal observations).

Artillery fungi have recently emerged from an interesting research topic to a problem of emotional stress and financial concern to USA homeowners, as well as related commercial enterprises such as insurance companies, mulch producers, and landscape contractors (Davis personal observations). Artillery fungi shoot their gleba towards direct sunlight and reflective objects [14-16] such as light-colored vinyl house siding, commonly used in the USA, peppering the surface with small sticky tar-like gleba. Once dry, the adhered gleba are very difficult to remove from smooth surfaces such as vinyl siding. If the gleba can be removed, they often leave a brown stain that is extremely difficult to clean from the surface. Disfigurement and discoloration of siding may result in homeowners filing claims to their insurance company to replace spotted house siding. However, if the homeowner's insurance policy specifically excludes artillery fungi, the insurance company may deny the claim and perceived liability may shift to the mulch producer, mulch sales yard, or contractor applying the mulch (Davis personal observations).

Artillery fungi most actively sporulate during cool moist weather in spring and fall, when temperatures are <25°C [14] becoming inactive during hot dry weather of mid-summer. However, during moist summers in PA, artillery fungi may actively shoot their gleba from April to November, becoming especially evident on the cooler, wetter sides of houses (often the north side in PA) (Davis personal observations). Many homeowners wage a continuous, stressful battle against the gleba of artillery fungi, and ultimately may change from attractive wood or bark mulches to stone or rubber artificial mulches that do not support the growth of artillery fungi in foundation mulches (Davis personal observations). Of note, those alternative mulch-types are often more economically expensive to purchase and install than traditional wood or bulk mulch (Fidanza personal observations). Such long battles have been described in the first author's web page entitled, "Artillery Fungus – Frequently Asked Questions (FAQ)" (http://www.personal.psu.edu/users/d/d/ddd2/).

Control of artillery fungi

One of the main concerns that stressed homeowners in the USA often pose on the first author's (DDD) artillery fungus webpage (see link immediately above) is, "How do I control artillery fungi in my landscape mulch?" The remainder of this review will deal with some of the published control solutions that have been attempted (successful or not) over the years.

Fungicides

As of 1985, fungicides had not been evaluated in the USA for control of artillery fungi in the landscape [11]. In 2005, Geml et al. [32] published results of a brief laboratory Petri dish study in which they evaluated the inhibitory effect of 14 fungicides on *in vitro* growth of *S. stellatus*, *S. iowensis*, and a previously undescribed *Sphaerobolus* species, which was later described as *S. Ingoldii* [5].

Captafol, epoxiconazole, thiophanate-methyl, triflumizole, and triphenyltinacetate were the most effective in controlling growth of *Sphaerobolus* spp. However, the authors caution that field studies are needed to evaluate whether mulch applications of any of these five fungicides would suppress the growth or sporulation of artillery fungi under outdoor environmental conditions. More importantly, none of the fungicides mentioned, were legally labeled in the USA, as of 2005, for control of artillery fungi in landscape mulch beds.

In a more extensive 2009 laboratory study, Fidanza and Davis [33] evaluated the influence of 26 fungicides on the *in vitro* growth of *S. stellatus*.*Sphaerobolus stellatus* was most sensitive topolyoxin-Dandazoxystrobin, followed by pyraclostrobin, triademifon, tebuconazole, propiconazole, thiophanate methyl, triticonazole, thiram, and fludioxonil. Many of these fungicides were commercially available at the time for use in USA turfgrass and ornamental markets, where they had proven effective in controlling a variety of fungi that caused foliar and root diseasesing green industry markets. Again, the fungicides evaluated had not been labeled for control of artillery fungi in landscape mulch beds.

Although fungicides may offer a possible solution to suppress artillery fungi, the numerous fungicides mentioned in these two studies need to be evaluated in field tests. If proven successful, the fungicide names may then be legally added to the product label. Nevertheless, these preliminary results [32,33] dealing with the effects of fungicides on artillery fungi can serve as a basis for justifying larger field studies to evaluate usefulness of fungicides to control artillery fungi.

Biocontrol

In a 2001 laboratory study, Brantley et al. [34] evaluated the use of the fungus *Trichoderma harzianum* and the bacterium *Bacillus subtilis* against *S. stellatus* growth and sporulation on agar within Petri dishes. Both *Trichoderma* and *Bacillus* have been reported to be general biocontrol agents [35,36]. Three formulations of the *Trichoderma* and two of *Bacillus* were evaluated, three of which were commercially available [34]. Although all five formulations had some antibiotic effect on *S. stellatus*, the fungus *T. harzianum* was more effective than the bacterium *B. subtillis*. However, that authors state that the suppressive nature of either biocontrol agents in Petri dishes may not be similar to findings in the field on common landscape mulches. Nevertheless, the authors suggest that a more intensive research effort dealing with sustainable, non-chemical biocontrol of artillery fungus is worth pursuing.

Types of Mulch

Landscape mulches vary widely in content and quality, being composed of various proportions of wood and bark derived from different species of trees, as well as from recycled materials and land clearing waste. In a 3-year study, Brantley et al. [37] evaluated 25 types of landscape mulches contained in dishes, on agar plates, or in the field to determine if any mulches inhibited *S. stellatus*. Results generated in the dishes or on agar were scientifically informative but did not offer any immediate practical controls. Therefore, only the results of the field study [37] are reviewed here.

Field study plots were inoculated with gleba in May 1996 and number of new gleba stuck to white targets counted annually through May 1999. Thirty months of post-inoculation data revealed that *S. Stellatus* eventually grew, at least to some degree, on most types of mulch as they decomposed over time, agreeing with Ingold [18] that most organic matter will support artillery fungi as the matter decomposes. However, the artillery fungus did not sporulate well (as measured by number of new gleba on the targets) on cypress, Atlantic white cedar, or large pine bark nuggets mulches. All three of these mulches appeared to be more water repellent, and subsequently less moist, than the other mulches (Davis personal observations). The hydrophobic nature of these mulches, possibly in conjunction with their natural fungicides, likely inhibited the artillery fungus. However, due to recent ecological sustainability issues with cypress, the authors of this review recommend that homeowners not use cypress mulch. By the end of the 3-year field experiment, the large pine bark nuggets remained hard and dry and supported very little artillery fungus, and were likely inhospitable to many relevant fungi, even after 3 years of weathering outdoors [37]. Results of this study indicate that large pine bark nuggets are an excellent option to use as a mulch in areas that have an existing or potential artillery fungus problem.

A similar but expanded field study was conducted [38]. To summarize, at the end of this study the large pine bark nuggets and cypress were again very resistant to *S. stellatus*. The authors of this review again recommend that homeowners use the large pine bark nuggets (but not cypress mulch due to sustainability issues) in areas that have existing or potential artillery fungus problems. In addition to the wood/bark mulches in the study, 100% used mushroom

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"compost"(recycled substrate used for the commercial production of the common edible "white button" mushroom) was added as a treatment, since aged, used mushroom compost has been reported to exhibit suppressive characteristics against fungi [13]. However, 100% mushroom compost is not an attractive landscape mulch (Davis personal observations). Most mushroom compost is aged (weathered outside for a year) prior to use, but there in increasing interest in using *fresh* (no aging) mushroom compost. *Fresh* compost would be used immediately upon removal from the mushroom house, an economical saving/year in space, time and labor for the mushroom grower, as compared to aged compost.

What is mushroom compost?

PA is the top producer of white button mushrooms in the USA, a crop valued at $500,000,000 [39]. White button mushrooms are grown on a substrate of raw materials in controlled environment houses. The substrate usually consists of horse manure, straw, corn cobs, and other agricultural plant wastes. After a mushroom crop is harvested, the substrate material is removed from the house and thereby is reclassified as "mushroom compost". Mushroom farms in PA produce more than 2 M m^3 of waste compost per year [41]. While considered an unwanted waste product by the mushroom industry, used compost is eagerly sought after by home gardeners and horticulturists as an excellent soil amendment with some fertilizer benefit [42,43]. In contrast, stockpiled used mushroom compost represents a disposal and regulatory problem in some areas of the USA, especially PA [41].

Blending mushroom compost with common wood mulch

As stated previously, a 100% aged mushroom compost inhibited *S. stellatus* sporulation [38]. This result is significant because there is increasing interest among homeowners to control artillery fungi without use of chemicals. Mushroom compost has physical and chemical characteristics that make it ideal for blending with landscape mulch to enhance growth of horticultural plants. 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. However, as stated above, 100% mushroom compostis not a visually attractive landscape mulch. Blends of compost with common landscape mulch would be more attractive than 100% compost. Therefore, the following studies are reviewed.

Blending landscape mulch with lower percentages (<100%) of mushroom compost

The suppressive nature of lower percentages (by volume) of aged mushroom compost, blended with a common wood-based landscape mulch in 5 treatments, were evaluated for control of *S. stellatus* sporulation [40]. Treatments consisted of 0% (control-landscape mulch only), 10%, 20%, 40%, or 100% mushroom compost blended with landscape mulch within a total of 30 field plots. Sporulation was recorded as number of gleba adhered to white targets in each plot on 5 different dates (Figure 1). Initial statistical analyses indicated a high level of variability that precluded statistical analyses of the individual effect of the five treatment levels on sporulation. Therefore, data from the 10, 20, and 40% mushroom compost were combined as one treatment (termed 10-40%). Data from 0%, 10-40%, and 100% mushroom compost were analyzed statistically.

Relevant to this review, the 10-40% combined data revealed significantly lower levels of artillery fungus sporulation (number of gleba) as compared to the control (0% = landscape mulch with no mushroom compost), and that sporulation increased with time over the study (Figure 1). This initial study [40] is the most promising control paper reviewed to this point, and revealed a possible sustainable, environmentally friendly, "green" control approach to control artillery fungi in landscape mulch. This paper also revealed that blending aged mushroom compost with common landscape mulch might solve a possible solution for both artillery fungi sporulation and the excess mushroom compost disposal problem.

Based the promising results of the previous study [40], a similar

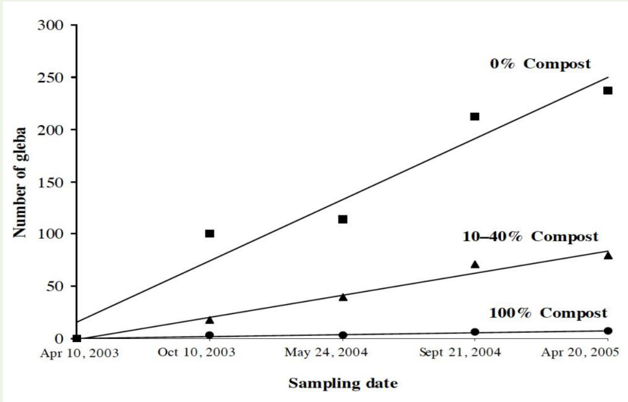

Figure 1: Linear regression lines based on average accumulation of gleba on targets over time for 0% (control), 10-40% and 100% (by volume) aged mushroom compost blended with a landscape mulch. Figure from Davis et al (2005) J Environ Hort 23: 212-215.

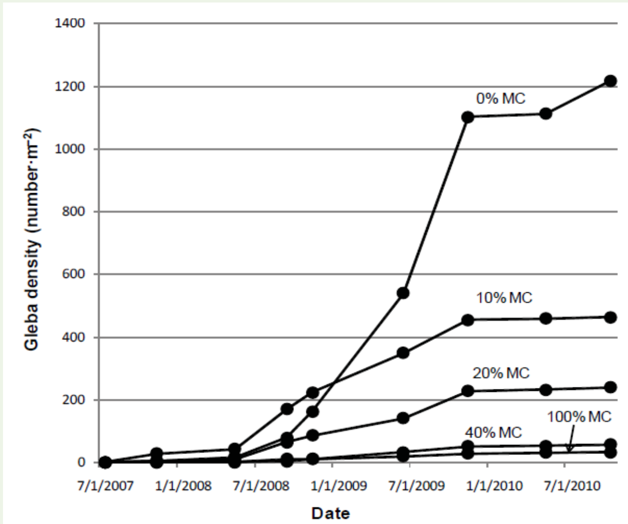

Figure 2: Mean number of glebam^{-2} on targets (white back walls of plots) for each treatment over time. The five treatments were 0% (control), 10%, 20%, 40%, and 100% (by volume) fresh mushroom compost (MC) blended with a landscape mulch. Figure from Davis and Fidanza (2011) J Environ Hort 29: 91-95.

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but more robust 4-year study [41]was conducted in field plots with 0% (control, no compost), 10%, 20%, 40% and 100% *fresh* mushroom compost blended (by volume) with a landscape mulch. Sporulation was recorded as number of gleba adhering to white targets at the back of each treatment plot (Figure 2). On the last data collection date, numbers of accumulated gleba in the 0% (control) and 10 % compost were statistically similar, but numbers of gleba in the 20%, 40% and 100% compost were significantly different from the controls (0% compost). Numbers of gleba in the 40% and 100% compost were statistically similar. Relevant to this review, these results suggest that blending ≥ 40% fresh mushroom compost with landscape mulch may be an environmentally friendly, sustainable, practice to reduce levels of artillery fungi in homeowners' foundation mulches, where they may be a current or potential serious pest. In addition, these results may offer at least a partial solution the excess mushroom compost disposal problem, if ≥ 40% mushroom compost (fresh or aged) is routinely blended with common landscape mulches.

As stated above, this study [41] was conducted using *fresh* mushroom compost, taken directly from the mushroom production house and blended with landscape mulch without "aging" (weathering outside for 1 or more years). Results of this study suggest that *fresh* compost, taken directly from the mushroom house and blended with landscape mulch without aging, also reduces artillery fungi sporulation. Commercial companies using *fresh* compost, rather than *aged* compost, need not invest additional time and money to conduct additional outside compost aging and processing, as is sometimes done.

Nevertheless, homeowners searching for an environmentally friendly, sustainable solution to controlling artillery fungi in their mulch beds may find that blending mushroom compost (fresh or aged) into their landscape mulch offers such a solution, as well as offering solution to the excess mushroom compost disposal problem.

We have also reported that mushroom compost inhibited growth and sporulation of a common bird's nest fungus in landscape mulch [42]. Field plots containing 0, 10, 20, 40, or 100% (by volume) mushroom compost blended with a common landscape mulch were naturally infested with a bird's nest fungus. Mushroom compost at percentages ≥ 40% significantly reduced growth and sporulation of the bird's nest fungus. It is likely that mushroom compost contains populations of beneficial microbes or helps to create a favorable microenvironment that facilitates the growth of those beneficial microbes that are antagonistic to, or feed on, various species of fungi. In addition, the first author (DDD) of this review also determined that used mushroom compost inhibited growth of a slime mold (unpublished). It may be that used mushroom compost contains or promotes populations of beneficial microbes that are antagonistic to several types of organisms. This is a fertile area for future study.

Conclusions

In the latter half of the 20th century, artillery fungi (*Sphaerobolus* spp) became a serious horticultural problem to homeowners in much of the USA. In these areas, artillery fungi often grow on wood mulch within foundation mulches and discharge their sticky spore masses (gleba) towards the sides of light-colored houses. The sticky gleba adhere tenaciously to house siding and are very difficult to remove, often leaving a brown stain on the house siding. In this review, we examine the efforts to control this pest in landscape mulch, many of which have been ineffective, unattractive, or not legally permitted. However, one promising solution is to mix used mushroom compost into the landscape mulch, which often results in a substantial reduction of sporulating artillery fungus populations. It is suggested that mushroom compost contains micro-organisms that are antagonistic towards artillery fungi.

Acknowledgements

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References

1. Micheli PA (1729) Nova Plantarum Genera. Florence Italy.
2. Fischer ED (1884) ZurEntwickelunggeschuchte der Gastromyceten. Bot Zeit 42: 433-470.
3. Buller AHR(1909) Researches on Fungi. Vol 5 Longmans Green & Co London.
4. Walker LB (1927) Development and mechanism of discharge in Sphaerobolus iowensisn. sp. and S. stellatus Tode. J Eli Mitch Sci Soc 42: 151-178.
5. Geml J, Davis DD, Geiser, DM (2005) Systematics of the genus Sphaerobolus based on molecular and morphological data, with the description of Sphaerobolus in goldiisp. nov. Mycologia 97: 680-694.
6. Geml J, Davis DD, Geiser DM (2005) Phylogenetic analyses reveal deeply divergent species lineages in the genus Sphaerobolus (Phallales: Basidiomycota). MolecPhylogenEvol 35: 313-322.
7. Dykstra MJ (1982) A cytological examination of Sphaerobolus stellatus fruiting bodies. Mycologia 74: 44-53.
8. Flegler SL (1984) An improved method for production of Sphaerobolus fruit bodies in culture. Mycologia 76: 944-946.
9. Birchfield W, Smith JL, Martinez A, Matherly EP (1957) Chinese evergreen plants rejected because of glebal masses of Sphaerobolus stellatuson foliage. Plant Dis Rptr 41: 537-539.
10. Bertus AL, Walker J (1983) Sphaerobolus stellatus as a nursery pest. Plant Dis Survey 26-27.
11. Lehman RD (1985) Black spots on houses – an insect or disease problem? PA Dept Ag Bur Pl Ind Reg Hort 11: 15-16.
12. Wolf K (1989) Those black spheres among orchids. Amer Orchid Soc Bull 58: 1012-1013.
13. Brantley EA, Davis DD, Kuhns, LJ (2009) What is growing in my landscape mulch? Penn State Univ College Agric Sci Coop Exten Bull 4.
14. Alasoadura SO (1963) Fruiting in Sphaerobolus with special reference to light. Ann Bot 27: 123-145.
15. Ingold CT, Peach J (1972) Further observations on fruiting in Sphaerobolus in relation to light. Trans Br Mycol Soc 54: 211-220.
16. Naraz M (1967) Phototropism in Sphaerobolus. Biologia 13: 5-14.
17. Ingold CT (1970) The glebal mass of Sphaerobolus. Trans Br Mycol Soc 56: 105-113.
18. Ingold CT (1971) Sphaerobolus, the story of a fungus. Trans Br Mycol Soc 58: 179-195.

19. Ingold CT (1971) Fungal Spores: Their Liberation and Dispersal.Claredon Press Oxford.

20. Brantley EA, Davis DD, Kuhns LJ (2001) Influence of mulch characteristics on growth and sporulation of the artillery fungus Sphaerobolus stellatus. J Environ Hort 19: 89-95.

21. Asquaah G (2005) Horticulture, Principles and Practices. Pearson Education Upper Saddle River NJ.

22. Relf D (2001) Mulching for a healthy landscape. VA Poly Inst State Univ Pub No 426-724 Blacksburg VA.

23. Stoefella PJ, Kahn BA (2001) Compost Util Hort Crop Sys. CRC Press Boca Raton FL.

24. Falk B (1997) Opportunities for the wood waste resource. Forest Prod J 47: 17-22.

25. Shivpuri A, SharmaOP, Jhamaria SL (1997) Fungitoxic properties of plant extracts against pathogenic fungi. Indian J Mycol Plant Pathol 70: 13-17.

26. Wösten HAB (2001) Hydrophobins: multipurpose proteins. Annu Rev Microbiology 55: 625-646.

27. Campbell AG, Tripepi RR (1992) Logyard residues – products, markets, and research needs. Forest Prod J 42: 60-64.

28. Falk B (1997) Opportunities for the woodwaste resource. Forest Prod J 47: 17-22.

29. Freedman D (1998) Sawmill thrives with mulch division. Bio Cycle 39: 74-75.

30. Glenn J (1997) Mulch at core of wood residuals use. BioCycle 38: 42-48.

31. Glenn J (1998) Pallet scraps yield mulch and compost. Bio Cycle 39: 30-31.

32. Geml J, Davis DD, Geiser DM (2005) Influence of selected fungicides on in vitro growth of artillery fungi (Sphaerobolus spp.). J Environ Hort 23: 63-66.

33. Fidanza MA, Davis DD (2009) In vitro screening of fungicides to control artillery fungi. J Environ Hort 27:155-158.

34. Brantley EA, Davis DD, Kuhns, LJ (2001) Biological control of the artillery fungus, Sphaerobolus stellatus, with Trichoderma harzianum and Bacillus subtilis. J Environ Hort 19: 21-23.

35. Bruce A, Highley TL (1991) Control of growth of wood decay basidiomycetes by Trichoderma spp and other potentially antagonistic fungi. For Prod J 41: 63-67.

36. Bernier R, Desrochers M, Jurasek L (1986) Antagonistic effect between Bacillus subtilis and wood staining fungi. J Inst Wood Sci 10: 214-216.

37. Brantley EA, Davis DD, Kuhns LJ (2001) Influence of mulch characteristics on sporulation by the artillery fungus Sphaerobolus stellatus. J Environ Hort 19: 89-95.

38. Davis DD, Kuhns LJ, Akina K, Harpster TL (2004) Sporulation by the artillery fungus on 27 different mulches - a field study. J Environ Hort 22:117-123.

39. Coles PS, Nogin G, Fidanza M., Roth, G (2020) Evaluation of fresh mushroom compost in a field corn production system. Compost Sci Util 28:76-86.

40. Davis DD, Kuhns LJ, Harpster TL (2005) Use of mushroom compost to suppress artillery fungi. J Environ Hort 24: 212-215.

41. Davis DD, Fidanza MA (2011) Fresh recycled mushroom compost suppresses artillery fungi sporulation – a 4-year field study. J Environ Hort 29: 91-95.

42. Fidanza MA, Beyer D (2009) Plant nutrients and fresh mushroom compost. Mushroom News 57: 4-9.

43. Fidanza MA, Sanford DL, Beyer DM, Aurentz DJ (2010) Analysis of fresh mushroom compost. Hort Technology 20: 449-453.

44. Fidanza MA, Davis DD (2009) Recycled mushroom compost suppresses bird's nest fungi in landscape mulch. J Environ Hort 27: 238-240.

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