Effect of Insecticide Treatment of Compost and Casing on Mushroom Yield[1]

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ABSTRACT Bendiocarb, carbosulfan, cyromazine, penfluron, Sumitomo 31183, and Sumitomo 4496 have proven efficacious for controlling a sciarid fly, *Lycoriella mali* (Fitch) (Diptera: Sciaridae), the principal insect pest of commercial mushrooms in North America. In this study, these compounds were evaluated for potential phytotoxicity to the mushroom *Agaricus bisporus* (Lange). Growth rate of the mycelium through the compost and through the casing; the weight, number, and size of mushrooms produced; and the time of each growth flush were measured. Penfluron was the only material that did not cause some yield reduction. Cyromazine and the low dosage of carbosulfan caused minor reductions in yield.

KEY WORDS *Lycoriella mali,* mushroom pest, insecticide, phytoxicity, pest control, *Agaricus bisporus..*

A fly, *Lycoriella mali* (Fitch) (Diptera: Sciaridae), is the major insect pest of the mushroom industry in the United States. Growers depend primarily upon treatments of the growing media with methoprene or diflubenzuron to control this pest (Cantelo 1989). The high cost of these compounds and the potential for development of insecticide resistance (Brewer and Keil 1989) indicate the need for additional control agents.

In the initial stage of this research, I compared the efficacy of several untested compounds vs. the fly (Cantelo 1989). The next stage, which is reported here, was to determine if any of these products affected production of the cultivated button mushroom, *Agaricus bisporus* (Lange) Imbach. San Antonio and Lambert (1962) had shown that many pesticides can lower mushroom production, if incorporated into the casing material.

Methods and Materials

Compost Treatments. The processing and pasteurization of phase II compost, consisting principally of horse manure and bedding straw, was done following conventional commercial procedures (San Antonio 1975), as were the spawning, casing, growing, and harvesting. Phase II compost (110 kg) was placed in a cement mixer and the chemical sprayed onto the compost as the mixer slowly turned. Subsequently, sufficient water was added to raise the percent moisture to 65%, followed by the addition of Amycel U-3 hybrid spawn at the rate of 2.5%

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by dry weight, and the mixer was turned for another minute. Then, 9 kg of the treated and spawned compost was placed in a plastic box (38 by 58 by 18 cm deep), which was placed in a room (9 by 5 by 4.9 m high) similar in design to a conventional bed house with temperature and humidity controls. Ten boxes were filled from each treatment, and the boxes were placed in a randomized complete block design in the growing room. Two treatments (20 boxes) that received no chemicals were used as controls. In none of the tests were there insect infestations.

Six chemicals, which had previously been shown to be efficacious in controlling L. *mali,* (Cantelo, 1989), were used – the insect growth regulators: Sumitomo 4496 = propionaldehyde oxime 0-2-(4-phenoxyphenoxy) ethyl ether, emulsifiable concentrate 10% wt/wt; Sumitomo 31183 = 2-(1-methyl-2-(-phenoxy-phenoxy)ethoxy)pyridine, emulsifiable concentrate 10% wt/wt; Armor (=cyromazine), emulsifiable concentrate 50 g/l; and penfluron = 2, 6-difluoro-N-((((4-trifluro-methyl)phenyl)amino)carbonyl) benzamide, pure compound emulsified with Tween-20 at the rate of 1:500; and the carbamates: Ficam W(= bendiocarb), 76% wettable powder; and Advantage (=carbosulfan) emulsifiable concentrate 480 g/l. These chemicals were used at concentrations that had previously produced about 95% fly control. Also, to better detect potential phytotoxicity, a concentration three times higher was used for each chemical. The chemicals and concentrations are given in Table 1.

Table 1. Effect of insecticide treatment of compost on mushroom production.

			Mushroom Yield		
Insecticide	Concentration (ppm)*	Number replications	Weight† g/m²	Number† /m²	Size† g/mushroom
Bendiocarb	66	20	5701 fg	359 cd	14.7 de
Bendiocarb	198	20	4638 g	263 d	14.0 e
Carbosulfan	26	20	6653 def	385 cd	16.5 abcd
Carbosulfan	78	10	8355 abc	519 abc	15.2 cde
Cyromazine	0.65	20	8417 abc	572 ab	17.1 abcd
Cyromazine	1.95	20	8956 ab	510 abc	18.8 a
Penfluron	0.11	20	9585 a	577 ab	17.4 abc
Penfluron	0.33	20	8753 ab	635 a	16.6 abcd
S31183	20	10	5823 efg	338 cd	17.1 abcd
S31183	60	20	7128 cde	448 bc	16.5 bcd
S4496	11	20	7416 cde	426 c	18.6 ab
S4496	33	20	8266 bc	495 bc	17.7 abc
Untreated	0	30	7446 cd	515 abc	15.1 de

* Concentration based on active ingredient per wet weight of compost.

† Data in a column followed by the same letter are not significantly different according to Fisher's LSD test, $P \leq 0.05$.

After the mycelium had grown through the compost for 13 days, the percentage growth on the surface was visually estimated to determine if the chemicals had affected mycelial growth. Mushrooms were harvested daily for 34 days beginning 24 days after casing, with the yield from each box weighed and counted. Plaster molds were common in some of the treatments, including one control set. Data from those treatments that contained any plaster molds were not used in the analysis. Table 1 indicates the number of replications used. The entire test was repeated, and the total yield data from the two tests were combined for analysis. The summary weight, number and size data were analyzed using analysis of variance (SAS Institute 1988a). The treatment structure was a 5 x 2 factorial with a detached control group. Data from the two untreated groups were combined for analysis. Fisher's LSD (least significant difference) at the 5% level was used for individual comparisons. Fisher's LSD was also used to determine if the treatments during the second crop had an effect on the time of growth flushes (the day within each flush having the heaviest yield of mushrooms).

Casing Treatments. The test design and analyses were identical to those of the previous test. However, the compost was not chemically treated, and the U-3 strain of spawn was applied at the rate of 1.4% of the dry weight of the compost. Casing, consisting of peat moss buffered with limestone equal in weight to the dry weight of the peat moss, was added to each box to obtain a depth of about 5 cm. This required about 1,870 g of casing per box with a 65% moisture content. The insecticides were applied on an area basis to five boxes at a time using a Solo Jet Pack sprayer. The chemicals and their concentrations are given in Table 3. Each box was treated with 155 ml of diluted chemical. Sixteen days after casing, I visually estimated the percentage of the casing surface with mycelial growth. The mushrooms were harvested for 30 days, beginning 22 days after casing.

Results and Discussion

Compost Treatments. The surface of the compost in the first compost test was rated for mycelial growth 13 days after spawning. The mean percentage of the surface covered with growth for each treatment follows: cyromazine 1x, 100%; cyromazine 3x, 100%; penfluron 1x, 100%; penfluron 3x, 99%; Sumitomo 4496 3x, 98%; untreated #1, 97%; Sumitomo 8311 3x, 95%; Sumitomo 4496 1x, 94%; bendiocarb 1x, 89%; untreated #2, 88%; bendiocarb 3x, 73%; carbosulfan lx, 67%; Sumitomo 3118 1x, 57%; and carbosulfan 3x, 41%. At the $P \leq 0.05$ level, LSD = 9.1. Mycelia in some of the treatments, including one of the controls, grew more slowly than in others. Mycelial growth rate among treatments in the second compost test appeared to be uniform, although growth of the entire crop was delayed, probably by two chlorothalonil applications (the first at 0.28 g AI per 0.203 sq m of the growing box; the second at half that rate) to control weed molds.

The weight and number of mushrooms, reported as least square means, in the highest yield treatment, penfluron 1x, were more than double those in the lowest yield treatment, bendiocarb 3x (Table 1). White (1986) reported a reduction in mushroom yield with bendiocarb compost treatments at dosages of 10 ppm and higher. Although the day of peak harvest varied significantly among treatments, the first and last treatments to flush were only 2 days apart in the first four flushes (Table 2).

Table 2. Effect of insecticide treatment of compost on time of first four growth flushes.

	Concentration	Days after casing*			
Insecticide	(ppm)	Flush 1	Flush 2	Flush 3	Flush 4
Bendiocarb	66	39 b	50 ab	56 ab	61 a
Bendiocarb	198	39 ab	49 abc	55 ab	60 abc
Carbosulfan	26	40 a	49 abc	56 ab	60 ab
Carbosulfan	78	38 b	48 abc	55 ab	60 abc
Cyromazine	0.65	40 a	49 abc	56 ab	59 bc
Cyromazine	1.95	39 ab	48 c	56 ab	60 abc
Penfluron	0.11	40 a	50 a	55 ab	59 abc
Penfluron	0.33	39 ab	48 bc	54 b	59 bc
S1183	20	38 ab	49 abc	55 ab	61 ab
S1183	60	40 a	48 c	55 ab	59 c
S4496	11	40 ab	49 abc	58 a	59 bc
S4496	33	39 ab	49 abc	57 ab	60 abc
Untreated	0	38 b	48 c	55 b	60 abc

* Data in a column followed by the same letter are not significantly different according to Fisher's LSD test, $P \leq 0.05$.

Casing Treatments. The surface of the casing was rated for mycelial growth 28 days after the casing layer was added. The mean percentage of the surface covered with growth for each treatment follows: penfluron lx, 30%; penfluron 3x, 28%; untreated, 25%; cyromazine 1x, 24%; carbosulfan 1x, 17%; bendiocarb lx, 17%; cyromazine 3x, 11%; carbosulfan 3x, 9%, Sumitomo 4496 lx, 6%; bendiocarb 3x, 5%; and Sumitomo 4496 3x, 3%. A log + 1 transformation of the data was used to improve the homogeneity of the residuals. The means reported are back transformations. At the P = 0.05 level, LSD = 1.5. It was apparent that several treatments inhibited mycelial growth.

The mean yields from the casing treatments (Table 3) indicated that only penfluron did not reduce mushroom yield. For all treatments, the higher concentration resulted in lower yield. Bendiocarb was the most phytotoxic at the concentrations used, followed by Sumitomo 4496, and cyromazine. The bendiocarb data are in agreement with White (1986) who reported phytotoxicity with bendiocarb casing treatments at concentrations of ca. 2.52 g/m^2 and 25.22 g/m^2 but not at 0.25 g/m^2. When White (1989) tested cyromazine as a casing treatment at 1 g/m^2, he observed a 4% reduction in mushroom number, which was compensated for by a 3% increase in mushroom size. My carbosulfan treatments had a large difference between the low and high concentrations, suggesting that the lower concentration may have been near the threshold of sensitivity to this compound. With casing treatments, fewer and heavier mushrooms were produced when treated with more phytotoxic compounds or rates. The time of growth flushes (Table 4) followed a similar pattern to yield reductions. There

Table 3. Effect of insecticide treatment of casing on mushroom production. Each chemical treatment replicated 10 times. Untreated replicated 20 times.

		Mushroom Yield		
Insecticide	Concentration g/m*	Weight* g/m^2	Number† /m^2	Size† g/mushroom
Bendiocarb	2.0	4021 fg	371 ef	11.2 c
Bendiocarb	6.0	2104 h	152 f	14.9 a
Carbosulfan	0.5	7075 bcd	887 bc	8.9 de
Carbosulfan	1.5	3718 g	342 ef	12.3 bc
Cyromazine	3.0	6864 cd	951 bc	7.5 e
Cyromazine	9.0	6355 de	882 bc	7.5 e
Penfluron	0.6	8352 ab	1273 a	7.0 e
Penfluron	1.8	8043 abc	1056 ab	8.0 e
S4496	1.0	6437 de	706 cd	10. 5 cd
S4496	3.0	5230 ef	518 de	13.6 ab
Untreated	0	8491 a	1271 a	7.1 e

* Data in a column followed by the same letter are not significantly different according to Fisher's LSD test, $P \leq 0.05$.

was no significant difference between the controls and penfluron treatments. The first flush from the boxes treated with bendiocarb 3x was nearly 5 days later than the first flush from the untreated boxes.

Any effect by the chemicals incorporated into compost was somewhat obscured by the moderate yield from untreated boxes. However, penfluron and cyromazine appear to have little effect on yield, whereas bendiocarb had an adverse effect. Hoffman et al. (1987) observed no phytotoxicity with cyromazine incorporated into the compost at concentrations as high as 5 ppm. *Agaricus* is usually more sensitive to casing treatment than to compost treatments, and here the distinctions between treatments were more clear. Penfluron was the only material applied to the casing that did not influence yield. The size of the mushrooms from the penfluron and cyromazine treatments, and perhaps the low concentration of carbosulfan, indicate a lack of phytotoxicity. The sensitivity of *Agaricus* to chemicals may vary among the different strains of spawn (Cantelo et al. 1982). Consequently, extrapolation of these results should be done only after the compatibility between the chemical and the strain of fungus to be used has been determined.

Table 4. Effect of insecticide treatment of casing on time of first three growth flushes.

Insecticide	Concentration g/m[2]	Days after casing Flush 1*	Flush 2*	Flush 3*
Bendiocarb	2.0	26 bc	34 a	43 a
Bendiocarb	6.0	28 a	32 abc	40 abcd
Carbosulfan	0.5	24 de	31 bc	38 cd
Carbosulfan	1.5	25 cd	33 ab	40 abcd
Cyromazine	3.0	24 de	31 bc	41 ab
Cyromazine	9.0	25 cd	32 ab	40 abc
Penfluron	0.6	23 e	30 c	38 cd
Penfluron	1.8	23 e	30 c	40 abcd
S4496	1.0	27 ab	33 ab	39 bcd
S4496	3.0	27 ab	35 a	40 abcd
Untreated	0	23 e	30 c	37 d

* Data in a column followed by the same letter are not significantly different according to Fisher's LSD test, $P \leq 0.05$.

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