RESEARCH NOTE

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Control of a Mushroom-infesting Fly, *Lycoriella mali*, with *Steinernema feltiae*[1]

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The sciarid fly, *Lycoriella mali* (Fitch), is the most important insect pest of the cultivated mushroom, *Agaricus bisporus* (J. Lange), in the United States (2). The larval stages of the flies feed on the mycelium and tunnel into the caps and stems of mushrooms. The nematode *Steinernema feltiae* (Filipjev) (= *bibionis* Bovien, 1937) occurs in nature on various dipteran hosts in Denmark and Australia. In laboratory tests in the United Kingdom, *S. feltiae* reduced the incidence of mushroom damage by *L. auripila* (Winn) by 79% (6). *Steinernema carpocapsae* Weiser, 1955 and *Heterorhabditis bacteriophora* Poinar, 1976 reduced *L. auripila* emergence by 67 and 83%, respectively (5). In this study, the ability of *S. feltiae* to control *L. mali* was evaluated in the laboratory. Infective-stage *S. feltiae* were obtained from Biosys, Inc. (Palo Alto, CA), stored at 4 C, and checked weekly to insure at least 90% viability. Sciarid fly populations were from a colony maintained by the Agricultural Research Service (Beltsville, MD).

Phase II mushroom compost was placed in plastic containers (22.5 cm × 13.5 cm × 7 cm deep, 500 g wet weight/container). Mushroom spawn containing the vegetative stage of the mushroom was added at the rate of 5 g/container and thoroughly mixed with the compost. The mixture had a moisture content of ca. 75%. The level was maintained by misting each container daily with 6 ml water. The containers were placed in an incubator held at 23 C and 90% RH.

To determine the relationship between numbers of *S. feltiae* added to the compost and control achieved, nematodes were introduced to the surface of the mushroom compost in 20 ml water at the rates of 0, 69, 207, 310, and 620/cm^2 when the larval sciarids were in the third instar. Approximately 100 or 200 fly eggs, extracted from infested compost with screens and differential sucrose solutions (4), had been introduced into each container. Fly emergence was monitored with a sticky pot label placed on the compost to catch emerging flies, and the container was covered with a fine nylon bag. The experiment was replicated three times.

The susceptibility of fly larvae of different developmental stages to *S. feltiae* infection was determined with a rate of 620 infective-stage juveniles/cm^2 of compost surface. This experiment was replicated five times. Timing of application was based on earlier studies (3) that indicated when the number of each instar or the pupal stage would be expected to be at the maximum. (It would have been desirable to use insects of a single developmental stage, but because individual insects do not develop at the same rate, they would have had to be extracted to obtain those of uniform development. This extraction process would have resulted in some mortality and would have posed a problem in returning the larvae to the optimum depth and environmental conditions for that instar. Also,

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TABLE 1. Relationship between number of *Steinernema feltiae* added to mushroom compost and control achieved of *Lycoriella mali*.

S. feltiae (no./cm²)	Fly eggs/ treatment (no.)	Adult emergence (%)	Adjusted mortality (%)†
0	506	99	0
69	522	45	55 c
207	508	37	62 c
310	511	27	72 b
620	511	15	85 a

† Mortality adjusted with Abbott's formula. Letters in a column followed by same letter are not significantly different according to Waller-Duncan *t*-test, k-ratio = 100.

returning the larvae to the compost would result in a major change in the physical structure of the compost.) Each container was infested with 100 fly eggs before inoculation with nematodes. On the day of each nematode inoculation, an additional container of fly-infested compost was extracted to determine the actual developmental stage of the insect at treatment time. Data were statistically analyzed using the Waller-Duncan k-ratio *t*-test (7) of mortality percentage adjusted by Abbott's formula (1).

To determine nematode movement in the compost, nematodes were extracted by a modified Baermann funnel technique from both the top half and the bottom half of the compost after allowing them 6–28 days to migrate.

A comparison of five nematode dosage levels with fly mortality showed a linear relationship with the adjusted mortality ranging from 55 to 85% and was directly proportional to the number of nematodes introduced (Table 1). A probit analysis of the data (7) indicated that 95% mortality would occur at a dose of 973 nematodes/cm² with 95% fiducial limits of 861 and 1,131. To obtain 99% mortality would require 1,376 nematodes/cm².

Infective-stage *S. feltiae* caused 72–81% mortality to the second-instar to fourth-instar larvae when drenched at the rate of 620/cm² onto compost infested with larval *L. mali* (Table 2). The more mature fourth instars had considerably lower mortality than the younger fourth instars. During these stadia, the insect larvae penetrate the deepest into the compost (3), suggesting that *S. feltiae* also penetrate the compost.

Counts were made to determine the depth of nematode dispersal into the 10-cm-deep compost. The initial inoculation was 620 nematodes/cm². At days 6 through 28, over 60% of the nematodes were in the bottom half of the compost.

The results of this experiment suggest that the use of nematodes is promising for this high value crop. The rate used in our experiment was low in comparison to Richardson (6) who obtained 67% of 79% con-

TABLE 2. Efficacy of *Steinernema feltiae* against immature stages of *Lycoriella mali*.

Expected stage at treatment	n†	Actual stage	Fly eggs/ treatment (no.)	Adult emergence (%)	Adjusted mortality (%)‡
Untreated			532	98	0
1st instar	38	Egg—8% 1st—92%	518	42	57 b
2nd instar	54	2nd—91% 3rd—9%	534	20	79 a
3rd instar	64	3rd—33% 4th—67%	526	18	81 a
4th instar	33	3rd—21% 4th—79%	532	27	72 a
Pupa	35	3rd—3% 4th—97%	523	65	33 c

† Number of immature *L. mali* extracted from single stage indicator sample.
‡ Mortality adjusted with Abbott's formula. Letters in a column followed by same letter are not significantly different according to Waller-Duncan *t*-test, k-ratio = 100.

trol of the British mushroom fly, *L. auripila,* with inoculations at the rate of 1,100/cm² and 1,850/cm², respectively. An additional advantage of this biological control agent is the possibility that the nematodes can survive and attack the next generation of flies.

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