Project Title:	Non-chemical control of mushroom sciarids using compost or peat-based substrates as bait traps.
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PRACTICAL SECTION FOR GROWERS

BACKGROUND

In current MAFF funded work (HH1735SMU), experiments demonstrated that a large population of sciarids developed in those *Agaricus* species that did not strongly colonize the compost. It was hypothesized that the pots containing poorly colonized compost acted as bait sites. If this could be proved in small scale cropping experiments then, in a commercial situation, trays of poorly colonized compost could be used in a cropping house to 'lure' the egg-laying female sciarids away from the crop. Sciarids would be offered more 'tempting' egg-laying sites from spawning onwards, in an effort to catch the first and subsequent generations of female flies. Thus, successive generations of sciarids could be effectively removed from the crop and destroyed.

This project was aimed at determining whether sciarids would actually choose a bait substrate for oviposition in preference to the usual mushroom growing medium. Initial laboratory tests were aimed at evaluating different bait substrates, comparing two different sizes of bait pot and assessing the most effective bait to crop surface area ratio. Using the results from the laboratory investigations, the method was tested in a mushroom unit cropping trial.

It is intended that the attractive substrate should consist of materials readily available to mushroom growers. Thus, with the exception of regular replacement of the bait substrate, the scheme will be able to be operated at minimal cost. Reductions in chemical usage would be possible, thus reducing costs, health hazards and environmental damage. If successful, therefore, this method would offer a pragmatic, environmentally friendly adjunct to sciarid control that could be employed by all mushroom growers.

SUMMARY OF RESULTS

LABORATORY TESTS

Substrates

Four substrates were tested for their ability to lure sciarid female flies away from standard spawned compost: (a) moist moss peat; (b) a mixture of moist moss peat supplemented with soya flour (5% w/w); (c) unspawned compost; and (d) compost spawned with a species of *Agaricus* (W30B) (16% w/w spawn-run compost). W30B was chosen as being the most appropriate 'attractive' strain from MAFF funded work previously referred to. These substrates are known to be attractive to female sciarid flies and would be reasonably cheap to provide. The relative surface area of bait:crop was 1:7.

Results

- The moist peat and soya flour (peat+soya) bait reduced the first generation of sciarids by 43%
- The compost inoculated with *Agaricus* species W30B (compost+W30B) reduced the first generation of sciarids by 72%.
- The plain peat and plain compost baits were not effective.

Comparison of size of bait pots

Two sizes of bait pot were used to give surface areas of 18.1 cm^2 or 28.3 cm^2. The latter pot size is the same as that used in **Substrates**. The relative surface area of bait:crop in this experiment was 1:2 and the bait used was compost+W30B. The two bait pot sizes were compared for their efficiency in luring sciarid females away from standard spawned compost.

Results

- The crop boxes treated with the larger bait pot produced 42% fewer sciarids than those treated with the smaller bait pot.
- Over 3 times as many sciarids emerged from the larger bait pots.
- Results indicate that having a greater number of smaller bait sites did not improve the performance of the bait traps.

Comparison of different bait:crop surface area ratios

A range of bait:crop surface area ratios was tested to determine their effect on first generation sciarid control. Four ratios of bait:crop surface area were used - 1:2, 1:4, 1:8 and 1:16. For the 1:2 ratio, both peat+soya and compost+W30B were tested as baits. Only peat+soya bait was used for the tests on the three other ratios.

Results

- At a surface area ratio of 1:2, both types of bait substrate performed well producing over 80% control of the first generation.
- As the surface area ratio was reduced, so was the level of control.
- No control was shown at a surface area ratio of 1:16

MUSHROOM UNIT TRIAL

Mushrooms were grown on HRI F3 compost in three chambers on the mushroom unit at HRI. Immediately after spawning (Sinden A12), the trays were placed in the mushroom chambers. The crops were spawn-run, cased, watered and harvested according to HRI standard practice. There were three flushes of mushrooms. Two bait substrates were chosen to be tested further in cropping experiments: moist peat to which was added soya flour (5%); and pasteurized compost spawned with the *Agaricus* species W30B.

After the trays of compost were placed in the cropping chambers, bait substrate was placed in two of them (one type in each chamber), with the third chamber acting as an unbaited control. The bait substrate containers consisted of 0.64 m long pieces of standard 0.11 m diameter half-round uPVC rainwater guttering. A piece of guttering was placed on both long sides of each tray, held in place with simple metal hooked-shaped brackets. This was done in such a way as to ensure that the upper surface of each was at the same level. The open ends of each piece of guttering were sealed with masking tape. Before putting the lengths of guttering into the two chambers, they were each filled with 1 kg of one of two bait substrates.

Sciarid infestation and population assessment

Immediately after the bait traps had been placed in the cropping chambers, 240 gravid female sciarids (and some males) were released into each chamber (≡ 10/tray) from a point source near the door. Emergence traps were used in all three chambers to obtain an estimate of the number of sciarids developing in each tray. The number of sciarids caught on each trap was counted daily, where possible. The bait substrate in both chambers was changed twice during the period of the crop (*i.e.* 3 baits in total). Fresh bait substrate was placed in the chambers 0, 17 and 38 days after spawning. The used bait was removed on days 9, 38 and 55. The bait from each tray was put into separate microperforated polythene bags containing a sticky trap to catch subsequent sciarid emergence. The bags were kept in their respective cropping chambers for up to four weeks.

Results

Sciarid population development

- The peat+soya bait substrate caused reductions of 25.7% and 65.1% in the first and second generations, respectively - a 63.5% reduction overall.
- The compost+W30B bait did not cause a reduction in either sciarid generation.
- Large numbers of first generation sciarids emerged from the peat+soya bait samples.
- In the compost+W30B bait samples, very few first generation sciarids emerged.

Mushroom yield

- There were three flushes of mushrooms in all chambers.
- The peat+soya and compost+W30B baited crops both produced a greater yield than the unbaited control (12.8% and 8.4%, respectively).
- The peat+soya baited chamber produced a greater yield and proportion of button mushrooms than the other two chambers.
- The W30B-baited chamber produced the greatest yield and proportion of both open and damaged mushrooms.
- Sciarid-induced stress of the unbaited and compost+W30B baited chambers caused them to produce earlier flushes.
- The failure of the compost+W30B substrate was due to problems associated with the bulking-up of W30B.
- The temperamentality of W30B may obviate its commercial use as a bait substrate.

CONCLUSIONS

From the four bait substrates tested in the laboratory, the peat+soya and the compost+W30B proved to be the most effective. The bait:crop surface area ratio tests showed that the 1:2 ratio gave over 80% control with both of these bait substrates but, for logistical reasons, a surface area ratio of 1:4 was used in the cropping chamber tests.

In the cropping chamber tests, the peat+soya bait substrate proved successful with: a 63.5% reduction in flies; a 13% increase in yield; a higher proportion of buttons; and a lower level of damage. The compost+W30B bait substrate was ineffectual due to problems in bulking-up the compost inoculum.

There are a number of areas of work that would need to be done in order to refine this system of non-chemical sciarid control to make it acceptable for commercial use.

(1) A reduction in the soya flour content of the bait might be possible, which would reduce the cost of the bait substrate. The 5% level was chosen merely because it is the normal rate that is used for rearing sciarids in the laboratory. There was strong fungal growth through the peat substrate over the 2 weeks that it was in the crop - which might have reduced its attractiveness as an egg-laying site for the females.
(2) Controlling the moisture content of the bait was perceived as being a problem. The drier the substrate, the less likely are the female sciarids to lay their eggs.
(3) A reduction in the bait-to-crop ratio might be possible. Any reduction in the ratio would cause a *pro rata* reduction in the cost of using the system. For example, strategic placement of the bait traps - near doors to pasteurization and cropping houses - if proved to be effective, would reduce the amount of bait significantly.
(4) To save further on raw materials cost, it might be possible to cook-out the substrate and re-use it.
(5) The tests so far have been restricted to small-scale mushroom chamber work. For commercial acceptance of the system it would be necessary to carry out larger validation trials.

SCIENCE SECTION

INTRODUCTION

BACKGROUND

Pests are a constant threat to successful commercial mushroom production and about £3.5M/annum is being spent on control measures. In spite of this, losses through pest damage are still in the region of £7M/annum. Uncontrolled populations cause far greater losses, rejection of the crop at market and even total crop failure. Chemical control of sciarid fly larvae relies on just two similarly acting, insect growth regulators - diflubenzuron and methoprene. This is due to product withdrawal, problems of phytotoxicity and insect resistance. There are now cases in the United States of sciarid resistance to diflubenzuron. There is a similar dearth of approved adulticides. Reliance on a few active compounds leaves pest control extremely vulnerable to further resistance or product-withdrawal problems.

In current MAFF funded work (HH1735SMU), experiments are being carried out to determine natural resistance to pests by various *Agaricus* species. Numerous pots of compost, spawned with various *Agaricus* species, were exposed to a population of female sciarids that were then allowed a free choice where to lay their eggs. It was noticed that a large population of sciarids developed in those *Agaricus* species that did not strongly colonize the compost. The *Agaricus* species that had colonized the compost well - including a commercial strain of *A. bisporus* - produced very few flies. One species actually produced no flies at all. It is likely that the pots containing poorly colonized compost acted as bait sites. If this could be proved in small scale cropping experiments then, in a commercial situation, trays of poorly colonized compost could be used in a cropping house to 'lure' the egg-laying female sciarids away from the crop. Sciarids would be offered more 'tempting' egg-laying sites from spawning onwards, in an effort to catch the first and subsequent generations of female flies. Thus, successive generations of sciarids could be effectively removed from the crop and destroyed.

Mushroom sciarids (mainly *Lycoriella auripila* and *Lycoriella mali*) are attracted by the volatiles produced by compost where they will then lay their eggs. Usually the compost will support the development of the larvae through to adults although it is thought that composts vary in their capacity to do this (E.S.Binns 1975). However, a small quantity of mushroom mycelium aids the development of sciarid larvae, although the presence of large amounts of mushroom mycelium inhibits both oviposition and subsequent larval development.

After Phase II composting, an initial infestation by sciarids can occur from cool-down onwards. Depending on the compost temperature, the first generation of flies from this initial infestation can emerge any time from about the 14th day after spawning onwards. Thus the provision of a suitable attractive egg-laying substrate will lure the females away from the main bulk of the crop. Such bait sites would be replaced at suitable time intervals to ensure that sciarid recycling in the favourable substrate did not occur. The infested substrate would then be treated to destroy any developing sciarids. If such a process proved successful, therefore, the population increase within the cropping house will be severely curtailed. In addition, the crop itself becomes less attractive to sciarids with time, thus enhancing the process.

RELATED WORK

With the exception of the above-mentioned MAFF-sponsored research, no similar work is being carried out.

TARGET

It is intended that the attractive substrate should consist of materials readily available to mushroom growers. Thus, with the exception of regular replacement of the bait substrate, the scheme will be able to be operated at minimal cost. Reductions in chemical usage would be possible, thus reducing costs, health hazards and environmental damage. If successful, therefore, this method would offer a pragmatic, environmentally friendly adjunct to sciarid control that could be employed by all mushroom growers.

This project will determine whether sciarids will actually choose a bait substrate for oviposition in preference to the usual mushroom growing medium. Initial laboratory tests were aimed at evaluating different bait substrates, comparing two different sizes of bait pot and assessing the most effective bait to crop surface area ratio. Using the results from the laboratory investigations, the method was tested in a mushroom unit cropping trial.

LABORATORY INVESTIGATIONS

EXPERIMENT 1. EVALUATION OF BAIT SUBSTRATES

Four different substrates were chosen: moist moss peat; a mixture of moist moss peat supplemented with soya flour (5% w/w); unspawned compost; and compost spawned with a species of *Agaricus* (W30B) (16% w/w spawn-run compost). W30B was chosen as being the most appropriate 'attractive' strain from MAFF funded work previously referred to. These substrates are known to be attractive to female sciarid flies and would be reasonably cheap to provide.

Method

Two perspex fly chambers (800 x 470 x 530 mm) were set up on moist seep matting. Into each chamber were placed 24 plastic boxes (100 x 100 x 150 mm) containing 500 g of spawned HRI F3 compost (0.5% w/w Sinden A12). The boxes were arranged in three rows of four boxes, each on two levels. The upper level was supported on wire mesh shelves which allowed the flies free access. In one chamber, twelve small pots (60 mm diameter) each containing 90 g of a bait substrate were arranged equidistantly around the chamber. Six pots were suspended from the boxes on the upper level by wire loops and the remaining six were placed on the floor of the chamber. The relative surface area ratio of bait pots to spawned crop boxes was 1:7. The second chamber had no bait pots and acted as an untreated control. 72 female sciarid flies and some males were introduced into each chamber and allowed free choice of oviposition sites. The seep matting was watered daily to maintain a humid atmosphere. After 16 days the crop boxes were cased and then watered as required. On days 14, 28, 42 and 56 the bait pots and six of the crop boxes were removed from each chamber. The bait pots were covered directly with a vented sticky trap. With the crop boxes, a wire stem was inserted into the compost to support a sticky trap. The trap and box was then covered with a polythene bag, micro-perforated to allow gaseous exchange. The bait pots and crop boxes were incubated at 25°C for 28 days and the emerging flies caught on the traps counted. Sufficient fresh bait pots were introduced at each sampling date to maintain the original surface area ratio of 1:7.

This protocol was repeated four times, once for each of the different bait substrates.

Results

Bait 1 - Moist peat

Crop boxes. In all but sample 4, the number of flies emerging from the crop boxes taken from the baited chamber exceeded that from those taken from the control chamber (Table 1(a)). With the exception of sample 4, control chamber, a greater proportion of flies was caught in the upper layer in both chambers.

Bait pots. No flies emerged from the bait pots (Table 2(a)), as sciarid larvae cannot develop in moist peat alone.

	Bait type	Chamber	Layer	Sample 1	Sample 2	Sample 3	Sample 4
(a)	Moist peat	Baited	Upper	405	1540	1312	572
			Lower	305	1512	1272	516
			Total	710	3052	2584	1088
		Control	Upper	302	1485	1338	472
			Lower	135	1420	1242	1136
			Total	437	2905	2580	1608
(b)	Moist peat + soya	Baited	Upper	149	3106	2518	400
			Lower	691	2325	2811	1006
			Total	840	5431	5329	1406
		Control	Upper	735	2530	3049	948
			Lower	732	2603	2649	978
			Total	1467	5133	5698	1926
(c)	Unspawned compost	Baited	Upper	516	1058	1602	-
			Lower	372	969	1542	-
			Total	888	2027	3144	-
		Control	Upper	500	850	1836	-
			Lower	159	1190	1787	-
			Total	659	2040	3623	-
(d)	Compost spawned with W30B	Baited	Upper	46	700	1888	-
			Lower	209	600	1936	-
			Total	255	1300	3824	-
		Control	Upper	561	408	1680	-
			Lower	338	690	2000	-
			Total	899	1098	3680	-

Table 1. Evaluation of bait substrates. Sciarid emergence from the crop boxes in the four bait tests. Upper, data from the upper layer of boxes; Lower, data from the lower layer of boxes; -, tests terminated before fourth sample.

Bait 2 - Moist peat and soya flour (peat+soya)

Crop boxes. In sample 1, which represents the first generation, the number of sciarids from the bait chamber was 42.7% lower than that from the control chamber (Table 1(b)). There was no real difference between the upper and lower level emergence in the control chamber. In the baited chamber, first generation (sample 1), 82.3% of the total emergence came from the pots on the lower level. No reductions were demonstrated in subsequent generations.

Bait pots. Large numbers of flies emerged from all samples, especially the first three (Table 2(b)). In the first generation (sample 1), emergence from the upper level bait pots was much lower than that from the lower level pots, producing only 29.5% of the total number in this sample. In subsequent samples, there was little difference between the layers.

	Bait type	Layer	Sample 1	Sample 2	Sample 3	Sample 4
(a)	Moist peat	Upper	0	0	0	0
		Lower	0	0	0	0
		Total	0	0	0	0
(b)	Moist peat + soya	Upper	576	803	735	428
		Lower	1374	817	860	515
		Total	1950	1620	1595	943
(c)	Unspawned compost	Upper	60	812	1259	-
		Lower	55	473	1443	-
		Total	115	1285	2702	-
(d)	Compost spawned with W30B	Upper	716	496	23	-
		Lower	1180	1118	46	-
		Total	1896	1614	69	-

Table 2. Evaluation of bait substrates. Sciarid emergence from the bait pots in the four bait tests. Upper, data from the upper layer of boxes; Lower, data from the lower layer of boxes; -, tests terminated before fourth sample.

Bait 3 - Compost

Crop boxes. The general pattern of emergence from this bait was similar to that from the moist peat bait (Table 1(c)). In the first generation (sample 1) more sciarids emerged from the baited chamber than from the control chamber. With one exception (sample 2, control) more flies came from the upper level samples. The chambers were dismantled after the third sample due to the excessive number of sciarids in both.

Bait pots. Few sciarids emerged from the bait pots in the first generation (Table 2(c)), although a large number emerged from the next two samples. In samples 1 and 2 there were more flies emerging from the upper layer.

Bait 4 - Compost spawned with W30B (compost+W30B)

Crop boxes. The sciarid emergence from this bait followed a similar pattern to that from the peat+soya bait (Table 1(d)). In the first generation (sample 1), emergence from the baited chamber boxes was 71.6% less than that from the control chamber boxes, with the upper level producing only 18% of the total number of flies. After the first generation, the fly numbers emerging from the boxes taken from both chambers were similar.

Bait pots. A large number of flies emerged from the first two samples (Table 2(d)). Emergence from the upper level samples was always less than from the lower level pots. Few flies emerged from sample 3.

Discussion

The results indicate that, despite apparent initial over-infestation of the chambers with sciarids, the provision of bait sites can influence crop infestation by sciarids in the first generation. The two bait substrates to have a positive effect were peat+soya and compost+W30B (42.7% and 71.6% reduction, respectively), the latter giving the best result. In both these tests in the first generation (sample 1), both the crop boxes and bait pots which had been on the upper levels in the bait chamber produced fewer flies than those that had been on the lower level. The bait pots on the upper level were suspended by wire loops from, and in intimate contact with, the crop boxes. Thus the surfaces of the bait substrate and crop boxes were at the same level. On the lower level, the bait pots were placed on the floor of the chamber, which resulted in their surfaces being 7 cm lower. It is possible that the sciarids were lured away more effectively when the bait and compost surfaces were at the same level.

After the first generation, there was no positive effect from these two baits and the numbers emerging from the baited and control chambers were similar. There are two reasons that might help to account for this result, both concerned with the inherent carrying capacity of the various substrates available to the sciarids. Despite the increasing numbers of flies, with time, that occurred in the chambers, the number of flies emerging from the bait pots did not similarly increase. This indicates that, due to the sheer volume of flies in the second and subsequent generations the carrying capacity of the 'effective' baits been either reached or exceeded. In a similar manner, the crop boxes themselves had also probably reached their carrying capacity in later samples such that it was not possible to demonstrate any reductions due to the presence of the bait.

EXPERIMENT 2. COMPARISON OF SIZE OF BAIT POTS

Method

Six crop boxes (100 x 100 x 150 mm) containing 500 g of spawned HRI F3 compost (0.5% w/w Sinden A12) were put into a perspex fly chamber set up on moist seep matting. The crop boxes were arranged in two rows 50 cm apart, each of three boxes. Bait pots, containing compost+W30b (as in Experiment 1), were hung onto the side of the crop boxes. Two sizes of bait pot were used giving surface areas of 18.1 cm^2 or 28.3 cm^2. The latter pot size is the same as that used in Experiment 1. Eight of the smaller bait pots were hung on one row of three crop boxes and five of the larger bait pots hung on the other row of three crop boxes. This gave a relative surface area in each case of approximately 1:2 (bait:crop).

Immediately after putting the bait pots into the fly chamber, 18 gravid female sciarids were released from a central position in the chamber. As this experiment was only concerned with the initial infestation generation, after the four day infestation period, all the bait pots and crop boxes were removed from the chamber and the number of sciarids developing through to flies determined as in Experiment 1.

Results and Discussion

Table 3 shows the total number of sciarids emerging from the crop boxes and the two sizes of bait pots. The crop boxes treated with the larger bait pot (also used in Experiment 1) produced 42% fewer sciarids than those treated with the smaller bait pot. In addition, over 3 times as many sciarids emerged from the larger bait pots.

Total sciarid emergence from:	Surface area of bait pot (cm^2)	
	18.1	28.3
Crop boxes	1064	619
Bait pots	36	120

Table 3. Comparison of size of bait pots. Sciarid emergence from crop boxes and bait pots filled with compost+W30B.

These results indicate that having a greater number of smaller bait sites did not improve the performance of the bait traps. The compost in the smaller bait pots did dry out quicker than that in the larger ones and this may have affected the performance of the bait. From these results it was decided to continue using the larger bait pot size in the remaining laboratory investigations.

EXPERIMENT 3. COMPARISON OF DIFFERENT BAIT:CROP SURFACE AREA RATIOS

Method

A range of bait:crop surface area ratios was tested to determine their effect on first generation sciarid control. Four ratios of bait:crop surface area were used - 1:2, 1:4, 1:8 and 1:16. For the 1:2 ratio, both peat+soya and compost+W30B were tested as baits. Only peat+soya bait was used for the tests on the three other ratios.

Fly chambers were set up in a similar manner to Experiment 1, with 12 crop boxes of spawned compost in each, set out in three rows on two levels. Where necessary, bait pots were hung from the crop boxes to give the required surface area ratio. Into each chamber, 36 gravid female sciarids and some males were introduced and, after the four day infestation period, the chambers were dismantled and the bait pots and crop boxes assessed for sciarid emergence as outlined in Experiment 1. The effects of the different surface area ratios on sciarid emergence were done over three experiments.

1. Surface area ratio of 1:2

Three fly chambers were used. Twenty peat+soya bait pots were suspended from the crop boxes in one chamber, with the same number of compost+W30B bait pots used in another. The third chamber was set up without any bait and used as an unbaited control.

2. Surface area ratios of 1:4 and 1:8

Three fly chambers were used. In one chamber, ten bait pots of peat+soya were hung from the 12 crop boxes to give a surface area ratio of 1:4. In another chamber, five bait pots of peat+soya were hung from the 12 crop boxes to give a surface area ratio of 1:8. The third chamber acted as an unbaited control.

3. Surface area ratio of 1:16

Two fly chambers were used. In one chamber, the equivalent of 2½ peat+soya bait pots were hung from the 12 crop boxes to give a surface area ratio of 1:16. The second chamber acted as an unbaited control.

Results and Discussion

The fecundity of the 36 sciarids introduced in each of the three tests varied considerably. The number of progeny produced ranged from 100/female in the 1:2 ratio tests to just 7.8/female in the 1:4/1:8 ratio tests (Table 4). The former figure is an extremely good level of fecundity for this sort of test, while the latter figure is very poor and can be traced back to a general 'malaise' in the sciarid culture used. However, in each of the three tests the bait chamber was set up at the same time as a control chamber. Therefore comparisons between the various surface area ratio tests are still valid.

Surface area ratio	Sciarid emergence from crop boxes		Sciarid emergence from bait pots	Percent control
	Baited chambers	Control chambers		
1:2 W30B	639	3598	2621	82.2
1:2 P+S	454	3598	2926	87.4
1:4 P+S	156	276	162	43.5
1:8 P+S	207	276	17	25.0
1:16 P+S	1043	768	86	Nil

Table 4. Comparison of different surface area ratios. Sciarid emergence from crop boxes and bait pots filled with either peat+soya (P+S) or compost+W30B (W30B).

At a surface area ratio of 1:2, both types of bait substrate performed well producing over 80% control of the first (and only) generation (Table 4). As the surface area ratio was reduced, so was the level of control. No control was shown at a surface area ratio of 1:16.

CROPPING HOUSE INVESTIGATION

EXPERIMENT 1. MUSHROOM UNIT TRIAL

Method

General

Mushrooms were grown on HRI F3 compost in three chambers on the mushroom unit at HRI. After pasteurization, the compost was spawned into standard wooden mushroom trays (50 kg/tray, 0.5% Sinden A12, 0.9 x 0.6 m). Immediately after spawning, the trays were placed in the mushroom chambers. In each chamber there were 24 trays of compost arranged in two rows of three stacks, 4 trays to a stack. The crops were spawn-run, cased, watered and harvested according to HRI standard practice. There were three flushes of mushrooms. 48 days after spawning, permethrin smokes were used in the control and W30B bait chambers as sciarids from these chambers were infesting other areas of the unit.

Bait substrates

Two bait substrates were chosen to be tested further in cropping experiments: moist peat to which was added soya flour; and pasteurized compost spawned with the *Agaricus* species W30B.

After the trays of compost were placed in the cropping chambers, bait substrate was placed in two of them (one type in each chamber), with the third chamber acting as an un-baited control. The bait substrate containers consisted of 0.64 m long pieces of standard 0.11 m diameter half-round uPVC rainwater guttering. A piece of guttering was attached to both long sides of each tray, held in place with simple metal hooked-shaped brackets. Each was filled with 1 kg of one of two bait substrates. This was done in such a way as to ensure that the upper surfaces of the bait and crop were at the same level. The open ends of each piece of guttering were sealed with masking tape.

Peat+soya substrate. 35 kg of baled moss peat was broken up to remove lumps, before thoroughly mixing into it first 20 kg water and then 3 kg autoclaved soya flour (= 5.1% of total weight).

Compost+W30B substrate. Prior to the experiment, 8 kg lots of HRI F3 pasteurized compost were spawned with W30B which was allowed to colonize it. When needed, 8 kg of W30B-spawn-run compost was thoroughly mixed into 42 kg of HRI F3 pasteurized compost (W30B inoculum = 16% of total weight).

Sciarid infestation and population assessment

Immediately after the bait traps had been placed in the cropping chambers, 240 gravid female sciarids (and some males) were released into each chamber (≡ 10/tray) from a point source near the door.

Cropping trays. Emergence traps were used in all three chambers to obtain an estimate of the number of sciarids developing in each tray. These consisted of 200 x 100 mm curved sticky traps which were placed, sticky side down, on the surface of the casing. The curvature of the trap ensured that the adhesive was not fouled by the casing. The number of sciarids caught on each trap was counted daily, where possible.

Bait substrate. The bait substrate in both chambers was changed twice during the period of the crop (*i.e.* 3 baits in total). Fresh bait substrate was placed in the chambers 0, 17 and 38 days after spawning. The used bait was removed on days 9, 38 and 55. The bait from each tray was put into separate microperforated polythene bags containing a sticky trap to catch subsequent sciarid emergence. The bags were kept in their respective cropping chambers for up to four weeks.

Results

Sciarid population development

Sciarids started to emerge from the trays 24 days after spawning. The first generation lasted for about 11 days. The second generation started to emerge from about 43 days after spawning and numbers then increased steadily until the end of the experiment (55 days after spawning). The treatment of the control and compost+W30B-baited chambers with permethrin smokes 48 days after spawning cause a temporary slowing down in the number of sciarids caught but fly emergence continued to increase after a few days. In the unbaited control chamber, more first generation flies emerged from the trays nearest to the point of initial sciarid release. 53% came from the nearest double stack of trays, with 28% and 19% coming from the next two. In the compost+W30B-baited chamber, 38% emerged from the double stack nearest to the point of fly release, then with 28% and 34% coming from the next two. In the peat+soya baited chamber, the number of sciarids emerging from each stack was almost identical.

Cropping tray population. The number of sciarids emerging from cropping trays in the three chambers is shown in Table 5. In the peat+soya chamber, there were reductions of 25.7% and 65.1% in the first and second generations, respectively, compared to the unbaited control chamber, giving a 63.5% reduction overall. The compost+W30B bait did not cause a reduction in either sciarid generation – a 48% increase in total sciarid numbers being evident.

Generation	Number of sciarids			Percent control	
	Control	Peat+soya	Compost+W30B	Peat+soya	Compost+W30B
1	35.1	26.1	138.5	25.7	Nil
2	835.3	291.3	1150.8	65.1	Nil
Total	870.3	317.3	1289.3	63.5	Nil

Table 5. Sciarid emergence from cropping trays. Data is the mean number/tray of sciarid flies caught on the emergence traps.

Bait substrate population. The number of sciarids emerging from the three separate bait placements is shown in Table 6. In the peat+soya bait samples, large numbers of first generation sciarids emerged from the first sample. The number coming off from the second sample was much lower, with the third sample producing a high number of sciarids. In the compost+W30B bait samples, very few first generation sciarids emerged from the first sample. The second and third samples produced large numbers of sciarids, the number from the third sample being about the same as that from the peat+soya bait.

Sample	Number of sciarids	
	Peat+soya	Compost+W30B
1	606.3	5.9
2	188.0	428.1
3	2405.9	2471.3

Table 6. Sciarid emergence from bait substrate. Data is the mean number of sciarids to emerge from each trays' substrate.

Mushroom yield

The flushing patterns for the three cropping chambers are shown in Figure 1. These patterns are obtained by subjecting the raw data to weighted moving average analysis. The yield data are shown in Table 7.

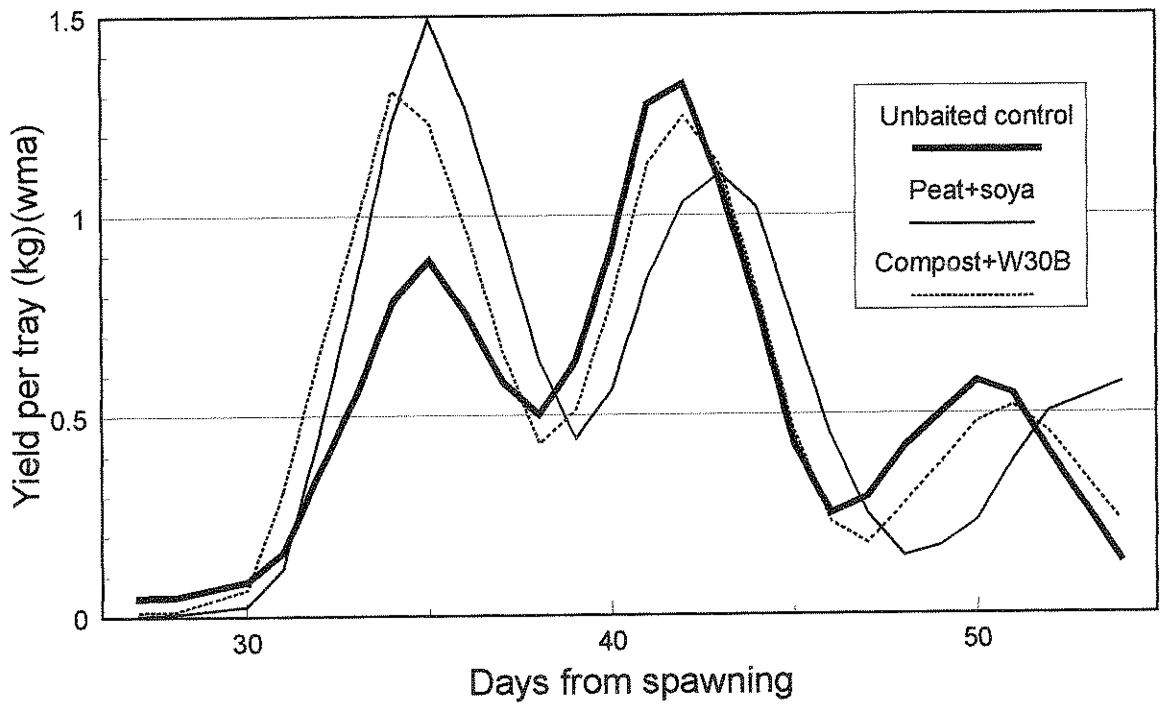

Figure 1. The flushing pattern of all three cropping chambers. The smooth graphs are produced by subjecting the raw data to weighted moving average analysis.

In the W30B-baited and unbaited control chambers, the first mushrooms were picked 27 days after spawning. The peat+soya baited chamber started two days later with all successive flushes also being produced later. The peat+soya and compost+W30B baited crops both produced a greater yield than the unbaited control (12.8% and 8.4%, respectively). The peat+soya baited chamber produced a greater yield and proportion of button mushrooms than the other two chambers. It also produced a greater yield of closed mushrooms. The W30B-baited chamber produced the greatest yield and proportion of both open and damaged mushrooms.

Mushroom grade	Unbaited control	Peat+soya	Compost+W30B
Buttons	1.93 (13.1)	3.56 (21.4)	1.33 (8.3)
Closed	7.88 (53.4)	8.04 (48.3)	7.03 (43.9)
Open	4.77 (32.3)	5.00 (30.0)	7.34 (45.9)
Damaged	0.18 (1.25)	0.05 (0.28)	0.30 (1.86)
Total (1)	14.76	16.65	16.00
Total (2)	295	333	320

Table 7. Mushroom yield. Mushroom grade data is kg/tray (% of total yield). Total (1), total yield per tray in kg; Total (2), total yield in kg per tonne of compost at spawning.

Discussion

Peat + soya bait substrate

Effect on sciarid population development. Of the two bait substrates tested, peat+soya was the only successful one, causing a 63.5% reduction in sciarid numbers overall. The initial bait placement was very effective as the number of flies that emerged from the bait itself was very high. Although peat+soya is known to increase the development capacity of sciarid larvae, large numbers of female sciarids must have laid their eggs in the bait instead of in the crop compost. The initial bait remained moist as the relative humidity during the spawn-running period was high. For the second and third bait placements, however, the normal reduction in the relative humidity in the cropping chamber caused the peat+soya to dry out to a degree. This might have inhibited both egg-laying by females and larval development. The generation time of the sciarids in the peat+soya bait substrate was longer than that in the compost+W30B bait substrate, again reflecting the effect on larval development.

Effect on yield. As well as the 13% increase in overall yield compared to the unbaited control chamber, there was a higher proportion of buttons - 21% compared to 13% - and a lower level of damage. All these effects were due to the lower level of sciarids in the peat+soya chamber.

Compost + W30B bait substrate

Effect on sciarid population development. The compost+W30B substrate did not cause any reduction in the number of sciarids developing within the crop. The failure of this substrate to perform in the mushroom chamber test, compared to the good result in the laboratory, is due to problems associated with the bulking-up of W30B. From previous experience, both in the laboratory work in this project and in the previously mentioned MAFF one, growing W30B either as a grain spawn or through compost was difficult. Despite the best attention to detail, bulking-up sufficient quantities of this *Agaricus* species for use in the mushroom unit tests was beset with problems. In consequence, there was barely any mycelial growth through the compost when the first bait was put into the crop after spawning. However, the logistics of the cropping programme meant that the experiment could not be postponed.

That there was little W30B growing through the compost bait was confirmed by the results from the first bait sample emergence, where a mean of only 6 flies per tray was caught. This result is very similar to the laboratory result with the pasteurized compost alone bait substrate (Table 2(c)). It was apparent that there was some W30B in the second and third baits but, by this time, the fly numbers had started to increase substantially.

Because of the poor growth of W30B, therefore, the mushroom chamber results are not necessarily indicative of its value as an effective bait substrate. However, it may well be that the temperamentality of this species of *Agaricus* may obviate its commercial use as a bait substrate.

Effect on yield. Compared to the unbaited control chamber, there was an 8% increase in yield. However, this was mostly due to an increase in lower grade open mushrooms. The proportion of higher grade buttons was lower in the compost+W30B chamber. The flushes in both the unbaited control and compost+W30B baited chambers were earlier than those from the peat+soya chamber. This was probably due to both these crops being 'stressed' by the high number of sciarids present in these chambers causing the yield to be produced quicker than would normally be the case.

CONCLUSIONS

From the four bait substrates tested in the laboratory, the peat+soya and the compost+W30B proved to be the most effective. The bait:crop surface area ratio tests showed that the 1:2 ratio gave over 80% control with both of these bait substrates but, for logistical reasons, a surface area ratio of 1:4 was used in the cropping chamber tests.

In the cropping chamber tests, the peat+soya bait substrate proved successful with: a 63.5% reduction in flies; a 13% increase in yield; a higher proportion of buttons; and a lower level of damage. The compost+W30B bait substrate was ineffectual due to problems in bulking-up the compost inoculum.

There are a number of areas of work that would need to be done in order to refine this system of non-chemical sciarid control to make it acceptable for commercial use.

(1) A reduction in the soya flour content of the bait might be possible, which would reduce the cost of the bait substrate. The 5% level was chosen merely because it is the normal rate that is used for rearing sciarids in the laboratory. There was strong fungal growth through the peat substrate over the 2 weeks that it was in the crop - which might have reduced its attractiveness as an egg-laying site for the females.
(2) Controlling the moisture content of the bait was perceived as being a problem. The drier the substrate, the less likely are the female sciarids to lay their eggs.
(3) A reduction in the bait-to-crop ratio might be possible. Any reduction in the ratio would cause a *pro rata* reduction in the cost of using the system. For example, strategic placement of the bait traps - near doors to pasteurization and cropping houses - if proved to be effective, would reduce the amount of bait significantly.
(4) To save further on raw materials cost, it might be possible to cook-out the substrate and re-use it.
(5) The tests so far have been restricted to small-scale mushroom chamber work. For commercial acceptance of the system it would be necessary to carry out larger validation trials.

REFERENCES

MAFF HH1735SMU: Determination of the variation in the development and multiplication of mushroom sciarids when reared on various cultivable fungi. Project Leader P F White, HRI Wellesbourne.

Binns, E S (1975). Mushroom mycelium and compost substrates in relation to the survival of of the larva of the sciarid *Lycoriella auripila*. *Annals of Applied Biology* **80**:1-15.