Reports on HDC Project M9A

Control of mushroom flies with the predatory mite, *Hypoaspis miles*

by R J Chambers

Project Title: Control of mushroom flies with the predatory mite, *Hypoaspis miles*

Project Number: M9A

Final report date: 31 August 1994

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Location of project: HRI-Littlehampton and two commercial mushroom farms

Project coordinator: Mr A Hearne/Mr G Ganney

Date project commenced: July 1993

Date project completed: January 1994

Key words: biological control, mushrooms, predatory mites, sciarids, phorids, pesticides

Contents

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RELEVANCE TO GROWERS

Short summary of the project

The objective of this project was to assess the possibility of using the predatory mite *Hypoaspis miles* for control of mushroom sciarid flies. Successful biocontrol of sciarids was demonstrated in experimental conditions at HRI-Littlehampton on trays and bags with no marked difference between the two. Sciarid control was apparently achieved on a commercial farm which had suspended pesticide treatments, but an effect on sciarids was only achieved on a no-pesticides organic farm after introduction of the mites at ten times the standard dose. This was probably due to the higher background level of flies on the organic farm which quickly infested newly-laid beds. Further trials using *H. miles* are required on farms that normally use pesticides and practice a high standard of hygiene.

Detailed summary of the project

The aims of this project were fourfold. They were to: (i) determine whether *Hypoaspis miles* could control sciarid fly emergence from compost in semi-commercial conditions, (ii) establish if the biocontrol differed markedly between tray and bag growing systems, (iii) find if overhead watering would inhibit biocontrol by the mite and (iv) determine whether numbers of sciarid flies on a commercial holding would be limited by *H. miles* at a level acceptable to the grower.

The results are an advance on previous laboratory work (Project M9). Effective biological control of sciarids on commercial compost in bags and trays was achieved, with no important difference in the level of control between the two growing systems.

Earlier laboratory work did not check that overhead watering would not harm the mites; the trial reported here demonstrated that with typical rates of water application, biocontrol of sciarids was not inhibited. In fact, better control resulted where water was applied, probably as a result of drowning of sciarids emerging from the compost.

On the commercial farm using a bag growing system where pesticide usage had been suspended, sciarid fly numbers remained at low levels throughout the trial period. Although this is suggestive of an effect of *H. miles* on sciarid numbers, the result is not unequivocal because of the absence of an untreated house for comparison. On the farm using shelf growing systems where no pesticides were normally used (organic production), sciarids numbers were not affected until the dose of *H. miles* applied was ten times the standard rate. Many houses on this farm had high fly levels and the repeated infestation of newly-laid compost may have been the reason for the high dose required. In both growing systems, *H. miles* was found at the end of the cropping period.

Phorid numbers were high on both bag and shelf farms, an effect of the mite being evident only at ten times the standard dose. Although one laboratory test (Project M9) indicated a reduction in phorid emergence due to *H. miles*, no further testing has been done.

Reliable practical advice to growers cannot be given at this stage. Further trials on commercial premises are needed to determine whether *H. miles* released at the standard dose onto a farm normally using pesticides and practising a good standard of hygiene would control sciarids and phorids at a level comparable with pesticides. If necessary, supplementary control of phorids could be obtained by incorporating diazinon at reduced rates as it is now known that diazinon is unlikely to harm *H. miles* (MAFF-funded project). If successful biocontrol was achieved, trials comparing *H. miles* with nematodes would be necessary. These studies need to be supplemented by a more detailed look at the interaction of predator and prey within the compost as well as movement and migration. The effects of different types of compost and factors in the microenvironment may also influence biocontrol.

A future benefit of the mite to the industry would be that an alternative method of sciarid control would become available. With chemical options limited, and with resistance to diazinon known on some farms, biological control avoids any future risk of resistance developing. The biological option should also be affordable. If control of sciarids can be obtained at the standard rate (750 mites released per m^2 of bed at spawning) then treatment costs would be about £ 0.18 per m^2 of bed. (Current price of *Hypoaspis* is £6 per litre, each litre containing 25,000 mites). This might prove sufficient to control phorids as well, but if not, either a higher dose of *H. miles* or the additional cost of a low rate treatment of diazinon would be included.

Control of mushroom flies with the predatory mite *Hypoaspis miles*

EXPERIMENTAL SECTION

INTRODUCTION

1. Background and commercial objectives

Mushroom flies (sciarids, phorids and cecids) are a serious problem for the mushroom industry with an estimated 4% of the farm gate value of the UK crop being lost to attacks by pests, mainly sciarids. The chemical control options open to growers are now severely limited and there is also limited choice of biological control agents, with only entomophilic nematodes currently available. However, MAFF-funded research at HRI-Littlehampton has shown that the soil-dwelling predatory mite, *Hypoaspis miles*, released onto cyclamen or poinsettia pots, can control glasshouse sciarid flies effectively. The mite is simple and economic to mass-produce.

Earlier HDC-funded research (Project M9) demonstrated that *H. miles* attacks all three types of mushroom fly larvae, it reduces sciarid and phorid numbers emerging from compost, it penetrates mushroom compost (and to a lesser extent casing) and it can be applied by mixing or sprinkling into compost. The mite controlled sciarid numbers up to the third flush in the laboratory. Releases at spawning were more effective than releases at casing. In laboratory tests, a first estimate was obtained of the release rate required for sciarid control on commercial crops. *H. miles* did not harm mushroom mycelium or sporophores, it also moved between trays on a stack, but not rapidly.

HRI-Littlehampton has supplied four UK rearing companies with *H. miles*, and two companies (Natural Pest Control and Biological Crop Protection) have devised mass-production techniques and can supply growers.

H. miles is a soil-dwelling polyphagous predatory mite belonging to the family Laelapidae. The life cycle consists of an egg stage, a six-legged larval stage, protonymph, deutonymph, and adult males and females. The life cycle is completed in about 17 days at 20°C (Wright & Chambers, unpublished data). *H.miles* survives for up to seven weeks without food, providing a moist environment is maintained (Chambers, Wright and Lind, 1993).

2. Project objectives

Two scientific objectives were agreed for the project.

(i) Trials in controlled environment at HRI

An experiment was designed to determine the effectiveness of *H. miles* for sciarid control, compare its efficiency between bag and tray methods of production, and also compare efficiency between spawn-running and recently-cased compost.

A trial to test the effect of overhead watering on predatory efficiency was

substituted for the intended comparison of spawn-run and cased compost. This was because commercial trials (objective (ii)) were giving poorer control than expected at the time and watering was suspected as a causative factor.

(ii) Trials on commercial premises

The release of *H. miles* onto commercial mushroom crops grown in bag, tray and shelf systems without insecticides. Rates of release were adjusted in each crop according to the level of control obtained.

MATERIALS AND METHODS

1. Controlled environment trials

General methods

Two controlled environment rooms at HRI-Littlehampton were used at 24-26 °C for spawn-running and 17-18 °C for cropping. Each room was large enough to contain six experimental units, each made of two stacked wooden trays (each tray was 0.60 m wide x 0.90 m long x 0.18 m deep, with four legs 0.27 m above ground). The lower tray contained compost while the upper tray functioned as a cover.

The trays were made up into experimental units as follows. To prevent movement of mites between units they were isolated from one another by standing each of the four legs in pot plant saucers filled with water and detergent. The lower trays were also lined with thick polythene sheeting. To prevent adult flies on the compost surface moving between units, each was fitted with a cover made from a second wooden tray the floor of which had been removed. The cover tray was equipped with a roof of polythene sheeting and surrounded with walls of polyester netting to permit ventilation. After placing the cover tray over the lower tray, all gaps in the unit were closed with PVC tape.

Sciarid eggs were collected in the laboratory from female flies kept in small cages covered with polyester netting. Eggs were laid through the netting onto moist peat from which they were removed and counted under the microscope. After the units had been set up with compost, sciarid eggs were released by suspending the eggs in water and sprinkling over the surface of the compost.

Mites were released by sprinkling a measured volume of culture medium onto the compost surface. The density of mites in the medium was first estimated by taking at least six 2 cm^3 samples of the well-mixed medium and counting eggs and active stages under the microscope.

Each of the twelve units was fitted with one large sticky trap (0.40 m wide x 0.13 m tall, sticky both sides), held vertically by canes and pegs, with the lower edge in contact with the compost surface. Sticky traps were replaced weekly (except in the second run of the trial comparing trays with bags where only one set of traps was used throughout). All flies on the traps were counted in the laboratory.

Each run of a trial was continued for at least four weeks, sufficient for eggs released to become adult sciarids and appear on the sticky traps.

(i) Comparison of trays with bags

Lower trays of the units were filled with spawned compressed compost (without diazinon) obtained from a commercial source. Bags (0.26m diameter) were filled with the same spawned compost to a depth of approximately 0.38 m. These bags were smaller in diameter than those used commercially but the depth of compost was the same. Three bags were fitted into each experimental unit. Surface area of compost in

the trays was 0.52 m^2, the surface area of three bags was 0.16 m^2. Compost in all units was cased after approximately two weeks of spawn-running.

Six units containing bags were sited in one chamber and six units with compressed compost were set up in the second chamber. In each chamber, three units were treated with mites and three were left as experimental controls with no mites. Two runs of the experiment were performed.

Numbers of sciarid eggs and mites used are shown in Table 1. In both runs, all twelve units were infested with the same density of eggs. But in run 1, mite density was three times that used in run 2 which represented the 'standard dose' (750 per m^2) used in the commercial trials.

TABLE 1. Bags v. trays. Release rates of sciarid eggs and predatory mites.

(a) Run 1

	Compost area per unit (m^2)	Eggs per unit	Mites per unit
Bags	0.159	450	360
Trays	0.520	1472	1177

Sciarid egg density = 2830 per m^2. Mite density = 2264 per m^2

(b) Run 2.

Bags	0.16	450	120
Trays	0.52	1472	392

Sciarid egg density = 2830 per m^2. Mite density = 755 per m^2.

(ii) Effect of watering on predation by *H. miles*

All twelve units were filled with compressed spawned compost and the units set up for spawn-running. Sticky trapping began immediately. Mites were applied to the top surface of the compost in the treated units during the spawn-running period and allowed to establish. All twelve units were infested with sciarid eggs on the same day as the casing was applied, being washed onto the casing surface.

Eggs were released at 500 per unit (density = 960 per m^2), mites at 250 per unit (density = 480 per m^2).

Water was applied to the water treated units from the time of casing. Each application to each unit was 410 ml (a rate of 0.8 litres per m^2). Applications were

made from a watering can fitted with a rose, the flow rate of which had been measured. Water applications were then made for a fixed time period, rather than measuring each 'dose' of 410ml precisely.

The watering schedule, supplied by a commercial grower, is shown in Table 2.

The twelve units were divided into four treatments, with three replicate units for each:

A. Mites with watering
B. Mites with No watering
C. No mites with watering
D. No mites with No watering

Units were arranged between the two rooms in a randomised split block design. The entire trial was repeated with a second randomisation.

At the end of the second trial, samples of compost and casing (approximately 150 ml each) were taken from the six mite-treated experimental units and placed separately in Tulgren funnels for mite extraction.

TABLE 2. Watering schedule

Days after casing	1	2	3	4	15	16	19	20	21
No. of applications	1	1	3	3	2	2	1	3	3

METHODS cont'd

2. Trials on commercial premises

General methods

Hypoaspis miles was reared for the trials by Natural Pest Control Ltd in a peat culture medium. The density of mites in each new batch of medium received was measured in the laboratory and the volume of peat needed for the required release rate was calculated. After thorough mixing of the peat medium at least six 2 ml samples were removed at random and each was examined under a low power microscope. The mean number of mites per 2ml sample was calculated and multiplied by 500 to estimate the number per litre. The quantity of peat to be released on each mushroom bed or bag was calculated from the known surface area of compost and the mite density in the peat medium.

In earlier HDC-funded (Project M9) laboratory experiments the optimum dose of *H.miles* necessary to control the mushroom flies was estimated at 710 mites per m^2 of compost (Lind & Chambers 1993). To allow a margin for error, this figure was rounded up to 750 mites per m^2 and was designated as the 'standard dose' which was used on the first crops treated. Later crops were treated at rates that were multiples of the standard dose. A single introduction of *H. miles* in peat medium was made by sprinkling evenly over the surface of all the beds, or an equal amount was sprinkled into each bag. Second introductions were made in some cases.

Yellow sticky traps (10 cm x 13 cm sticky both sides) were positioned evenly throughout each crop to obtain an index of fly abundance. Traps were positioned approximately 10 cm above the compost surface supported by pegs, sticks or string. All traps were changed weekly and the flies on them were counted later in the laboratory.

To check on survival of the mites, small samples (approximately 150 ml each) of the compost and casing were taken from certain of the mite-treated crops. Samples were collected both post-casing and at the end of the cropping period and were placed into Tullgren funnels to extract the mites by heat.

(i) Shelf crop trials

H. miles was released into a total of eleven shelf-grown mushroom crops at Farm no. 1.

All growing rooms had twelve shelves in two stacks of six. Each shelf was 31.5m^2 in area; a total cropping area of 378 m^2 in each house.

Table 3 indicates doses used and room numbers at Farm no. 1. In addition, four rooms with no mites or pesticides (experimental controls) were monitored as were four rooms with nematodes only (applied at casing). Nematode treatments were normal practice at this farm, although it was recognised that they were only partially effective against sciarids.

Inoculation of the compost with *H. miles* was performed within 24 hours of the

compost being laid.

24 sticky traps were sited in each room with two traps on each shelf and were changed weekly. Most crops were removed after 7 weeks.

Diazinon and diflubenzuron were not mixed into compost or casing in these trials, but where fly numbers became excessive, farm staff applied pyrethrum to kill adult flies.

TABLE 3. SHELF crops: doses of *H. miles* applied

The letter 'b' indicates a second crop in a room used previously.

***H.miles* dose applied**	**Rooms treated**
Standard (750 m^{-2})	3, 5 and 17
Double (1500 m^{-2})	4, 6, and 12
Quadruple (3000 m^{-2})	3b, 13, 14 and 15
Ten-times (7500 m^{-2})	17b
Control (no mites)	1, 9, 9b and 12b
Nematodes	1b, 7, 8 and 8b

(ii) Bag crop trials

A total of ten bag-grown crops were treated with *H. miles* at Farm no. 2 (Brinsbury College of Agriculture, Pulborough). A system of ten-week crops set up at two week intervals in five houses was in use. Each house contained 172 bags in four rows, each bag being about 0.4 metre tall with a circular top surface of 0.152 m^2. By arrangement with the bag supplier, diazinon was omitted from the bags for the duration of the trial.

Farm practice was to stand out all the bags and close off the tops by twisting. This was to retain moisture during spawn-running. In order to inoculate each bag with *H. miles* at the start of the spawn-running period, the bag was opened, the mites sprinkled on the compost surface and the bag closed. Four crops (B2, B3, B4 & B5) were treated in this way, but the method was found to be too time consuming. Subsequently all remaining six crops were treated after casing when the bags were normally left open. Table 4 indicates treatments and house/crop numbers.

Standard doses were used initially, with the dosage increased after the first three crops. Where fly numbers appeared to be increasing excessively, a second dose (at the same rate) was applied. This was done in all houses except B5, B3b & B5b.

Twelve yellow sticky traps were positioned in each house and changed weekly.

TABLE 4. BAG crops: doses of *H. miles* applied

The letter 'b' indicates a second crop in a house used previously.

***H.miles* dose applied**	**Houses treated**
Standard, spawn-running (750 m^{-2})	B2, B3 and B4
Double, spawn-running (1500 m^{-2})	B5
Quadruple, after casing (3000 m^{-2})	B1, B3b and B4b
Ten-time, after casing (7500 m^{-2})	B1b, B2b and B5b

RESULTS

1. Controlled environment trials

(i) Comparison of trays with bags

Results are shown in Table 5 (next page). The numbers of sciarid flies caught in the control bags of run 2 (mean=1308.7 per unit) exceeded the number initially released as eggs (450 per unit). Therefore some contamination of the compost in the bags chamber must have occurred, possibly during spawn running.

Analysis of variance was performed using a square root transformation of the data to stabilise the residual variance (Table 6). There was a highly significant effect of the treatment (the effect of the mites), and also a strongly significant interaction between treatment and container type. This suggests that control was better in trays than in bags and the degree of control did not differ between experimental runs (the container.run.treatment interaction is not significant). However, the additional contaminating flies in bags may have contributed to this effect. Larger initial numbers of sciarids in the bags of run 2 would have presented the mites with greater difficulty in reducing sciarid density.

Even if the poorer reduction in fly density in bags was a real effect, substantial control benefits were still evident. Whereas in trays, fly numbers were reduced by 97% (from 916 in controls to 29 in treated), in bags a reduction of 87% was achieved (from 631 flies in controls to 84 in treated. Square root de-transformed means of both runs used).

TABLE 6. Analysis of variance - trays and bags trial

Source of variation	d.f.	var. ratio	F prob.
CONTAINER	1	0.28	0.606
RUN	1	46.20	<0.001***
TREATMENT	1	239.15	<0.001***
CONTAINER.RUN	1	29.95	<0.001***
CONTAINER.TREATMENT	1	11.36	0.004 **
RUN.TREATMENT	1	5.45	0.033 *
CONTAINER.RUN.TREATMENT	1	1.89	0.188
Residual	16		

TABLE 5. Sciarid adults caught on sticky traps - trays and bags trial

(a) Run 1

	Rep.	Mites	Control
TRAYS	1	21	872
	2	14	885
	3	51	728
	Mean	28.7	828.3

BAGS	1	26	212
	2	10	177
	3	5	251
	Mean	13.7	213.3

(b) Run 2

	Rep.	Mites	Control
TRAYS	1	50	997
	2	19	1002
	3	30	1029
	Mean	33.0	1009.3

BAGS	1	363	1917
	2	214	1155
	3	115	854
	Mean	230.7	1308.7

(ii) Effect of watering on predation by *H. miles*

Results are shown in Table 7 (next page). 500 eggs were released into each unit, therefore the contamination with wild sciarid flies was present throughout the experiment because the numbers caught in controls consistently exceeded this figure. Phorid contamination was present, but minimal. Assuming the contamination was not markedly different between units within a run, an analysis of variance was conducted using a square root transformation of the data (Table 8).

There was a highly significant effect of the mites on sciarid numbers and a similarly highly significant effect of watering on emerging sciarids. Sciarid numbers were reduced by 33% when no water was applied (1120 in controls, 749 in treated), and by 64% in the presence of water (872 in controls, 314 in treated. Square root de-transformed means used). Contrary to expectation therefore, the level of control achieved was greater when water was applied.

Because sticky traps were changed weekly in this trial, prematurely emerging sciarids could be identified as contaminants and separated from released flies emerging at the expected time. Separate analysis of variance for the two groups showed a highly significant effect of *H. miles* on sciarid numbers in both cases (contaminants; $p = 0.002$ and released; $p < 0.001$). There was a statistically significant effect of watering on contaminant flies ($p = 0.002$) but not on released flies ($p = 0.277$) although the trend was in the correct direction.

Mites were extracted from compost and casing collected at the end of the trial, showing that they had survived the watering regime.

TABLE 8. Analysis of variance - watering trial

Source of variation	d.f.	var. ratio	F prob.
MITES	1	27.79	<0.001 ***
WATER	1	17.27	<0.001 ***
MITES.WATER	1	3.07	0.098
Covariate	1		
Residual	17		

TABLE 7. Sciarid adults caught on sticky traps - watering trial

(a) Run 1

	Rep.	Mites	Control
WATER	1	256	573
	2	320	633
	3	67	794
	Mean	214.3	666.7

NO WATER	1	336*	876
	2	708	897
	3	820	1199
	Mean	621.3	990.7

(* trap omitted on one week in error)

(b) Run 2

	Rep.	Mites	Control
WATER	1	419	1678
	2	544	1036
	3	519	691
	Mean	494.0	1135.0

NO WATER	1	639	1170
	2	729	1505
	3	1085	921
	Mean	817.7	1198.7

2. Trials on commercial premises

Where there were very large numbers of flies caught on a trap, a representative sub-sample of each trap was counted (normally a half or quarter of the surface area) and multiplied up. Total fly numbers were calculated and tabulated for each week on each crop.

Separate totals of sciarid and phorid flies were calculated for each week's catch by identifying approximately 100 flies selected at random from each of four to six traps and calculating the percentages of sciarids and phorids present. The percentages were multiplied by the total catch to obtain estimates of sciarid and phorid totals.

Tabulated results for all commercial crops are given in the Appendix.

(i) Shelf crop trials

Weekly averages of fly catches were calculated across all cropping rooms treated at the same rate (Figs 1 & 2). The wave-like pattern of these graphs probably illustrates different phorid and sciarid generations. Therefore it is not possible to attribute particular week-to-week declines in adult density to predation; rather the overall population development must be examined.

Population trends in sciarid numbers appeared similar to the experimental control rooms in all standard, double and quadruple dose treatments (Fig. 1). Nematode treatment was also similar to controls, but the single room where mites had been applied at ten-fold rates was appreciably lower than controls and all other treatments.

Phorid numbers at lower rates were also little different from the average of the experimental controls (Fig. 2). At the ten-fold dose of *H. miles*, numbers appeared lower than controls, as did phorids in the nematode-treated houses.

(Statistical note: It was not possible to provide standard error bars for comparison between different treatments. This is because (i) the number of houses with the same treatment was small and (ii) the crops in the different houses were not started concurrently, and are therefore not true replicates. A purely visual analysis must be combined with correlation analysis of fly number and release rate.)

When peak sciarid numbers in each room was plotted against release rate of *H. miles*, a significant negative correlation resulted ($r = -0.514$, $n = 15$, $P < 0.05$). Correlation of peak phorid numbers against release rate was not statistically significant ($r = -0.365$, $n = 15$, NS). Area-under-the-curve analysis produced closely similar results.

H. miles was successfully extracted from both compost and casing samples of all crops sampled (four crops sampled soon after casing, and five crops at the end of the cropping period).

(ii) Bag crop trials

Weekly averages of fly catches were again calculated across all houses treated at the same rate (Figs 3 & 4).

Sciarid numbers were very low in all houses throughout the trials (Fig. 3).

Fig. 1 Sciarid flies at Farm 1 (shelves)

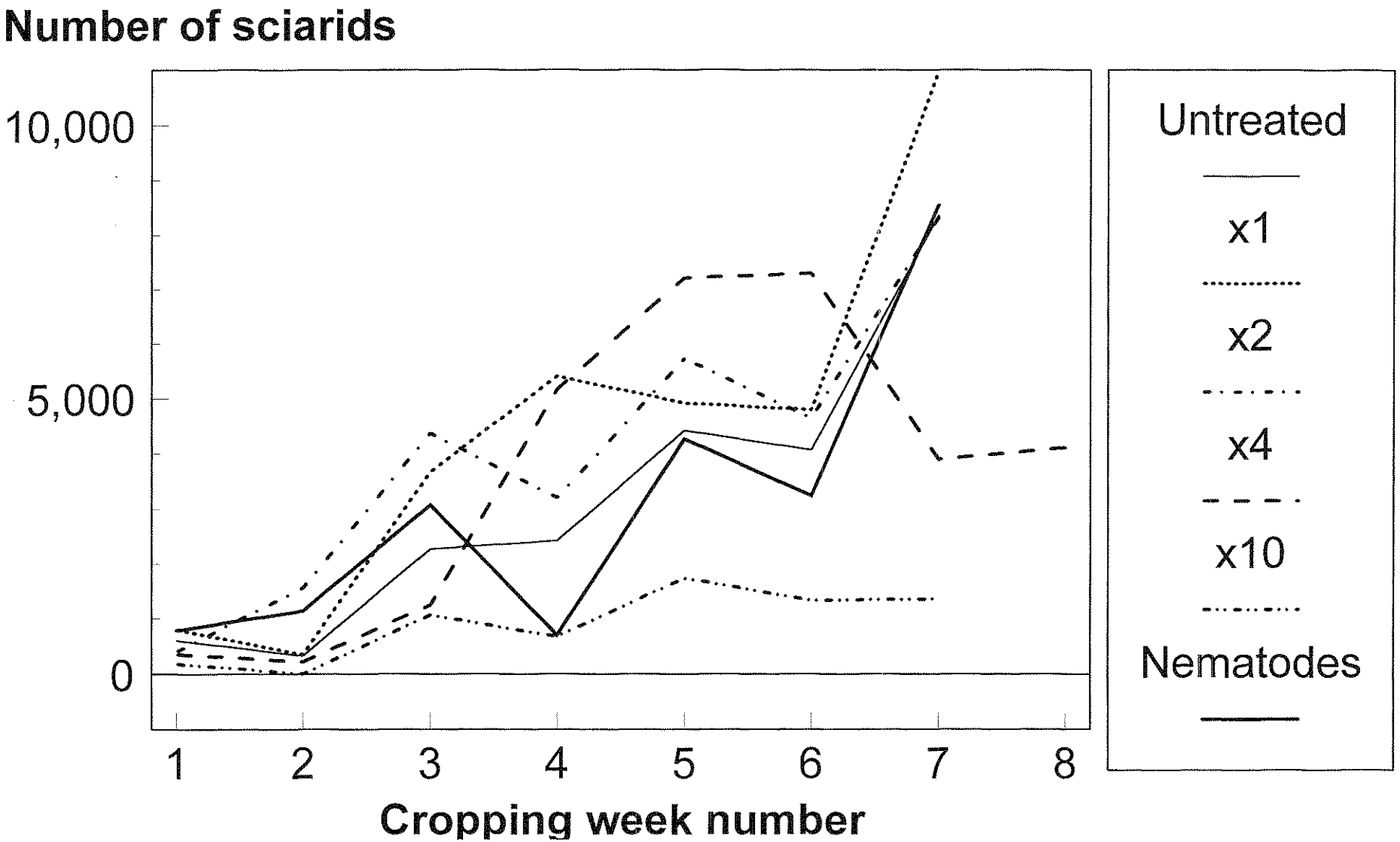


Fig. 2. Phorid flies at Farm 1 (shelves)

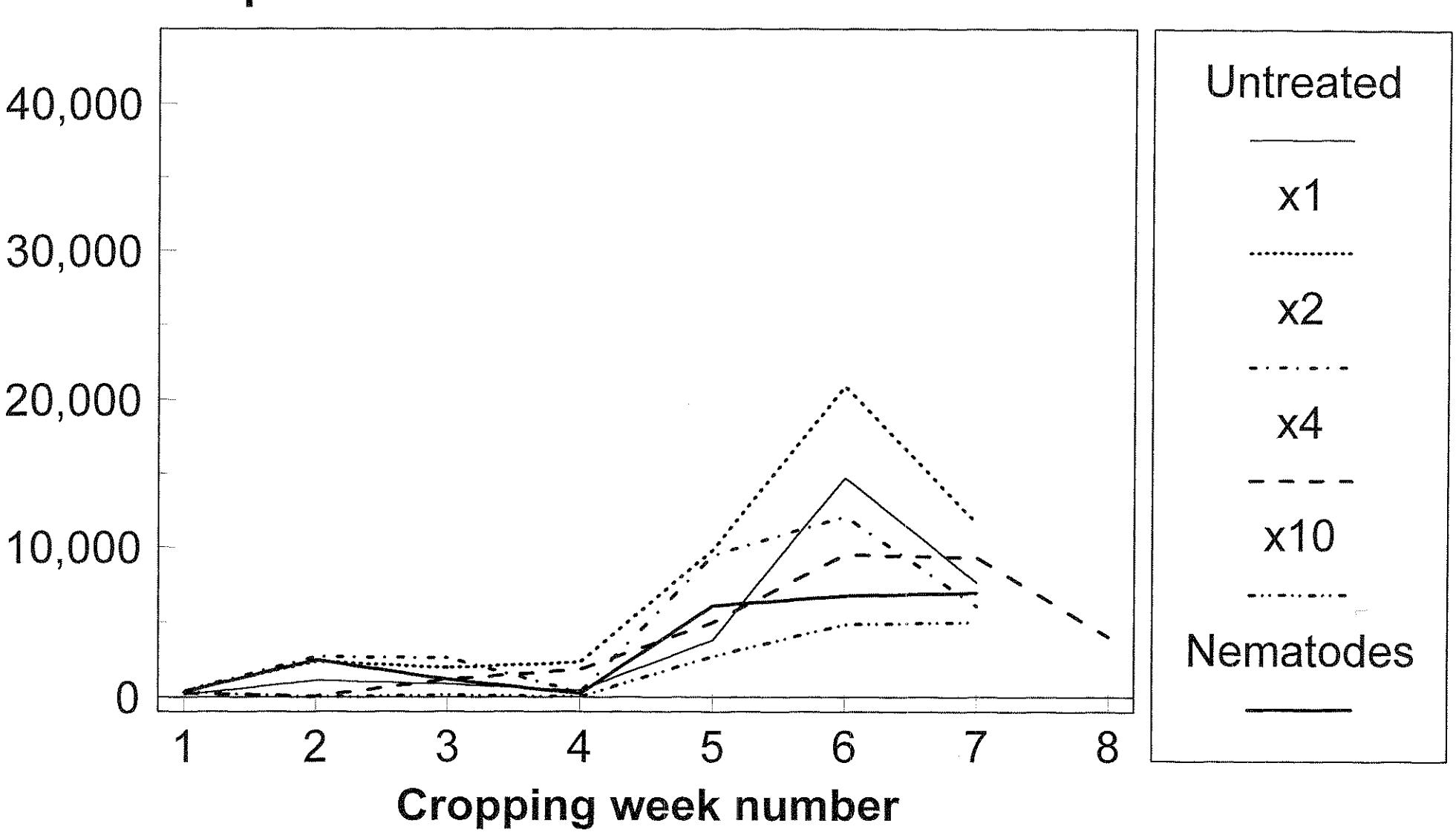


Fig. 3. Sciarid flies at Farm 2 (bags)

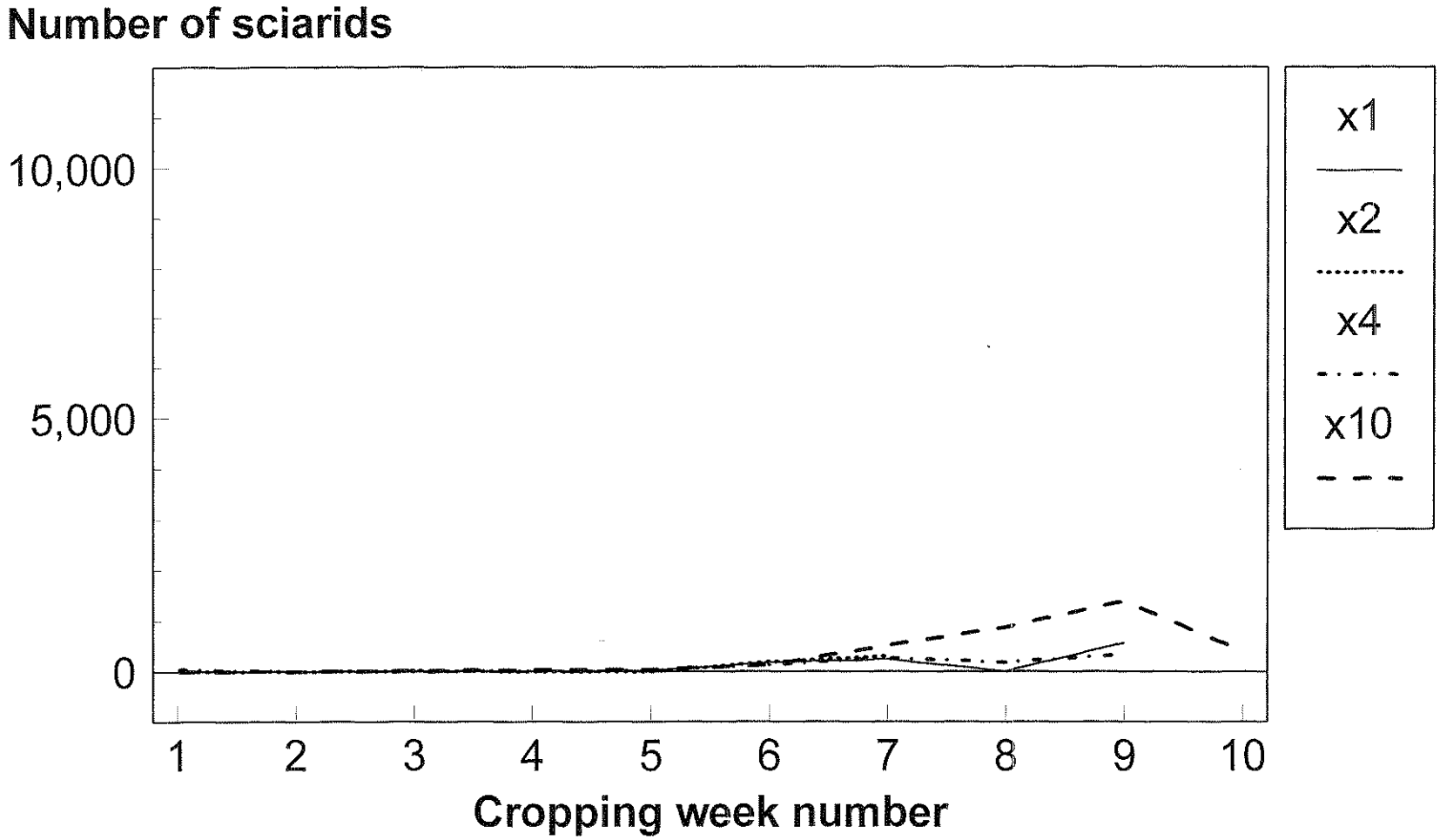
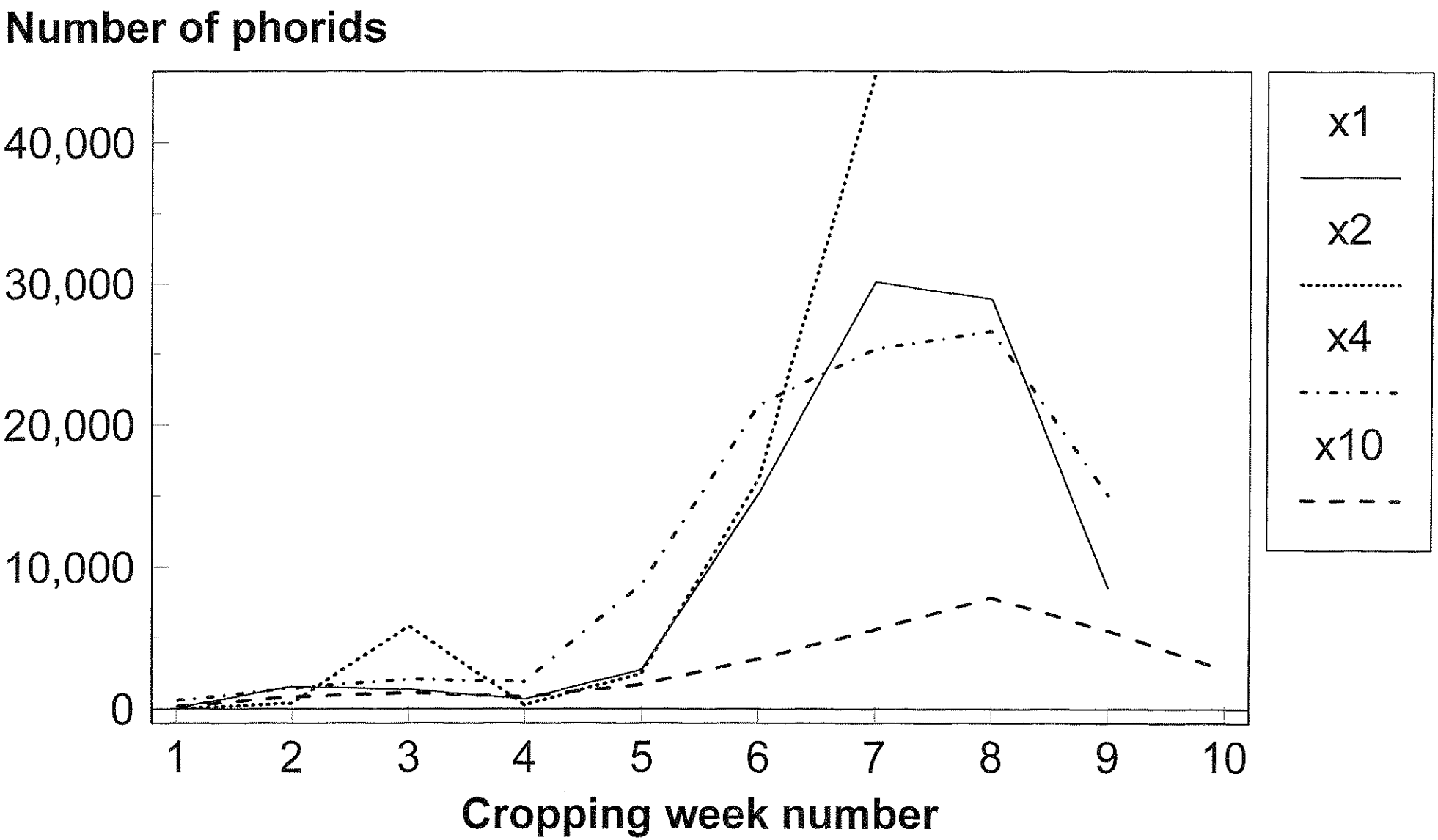


Fig. 4. Phorid flies at Farm 2 (bags)



Numbers in the ten-fold treatments were generally higher than in those with lower release rates. However, the difference was small compared to the sciarid numbers at Farm no. 1. Unfortunately there were no untreated (experimental control) houses for comparison on Farm no. 2.

In contrast, phorid numbers were conspicuously high (Fig. 4), probably exceeding fly densities in on the shelf farm (Fig. 2). However, the average of phorid numbers in the three ten-fold treatments was appreciably lower than in other treatments.

When peak sciarid numbers in each house was plotted against release rate, there was no significant correlation ($r = 0.248$, $n = 10$, NS). In contrast, phorid peak numbers in each house plotted against release rate show a significant negative correlation ($r = -0.738$, $n = 10$, $P < 0.02$). Area-under-the-curve analysis produced closely similar results.

H. miles was extracted from casing and compost in all crops sampled (four post-casing and three at the end of the cropping period). Samples at the end of cropping contained immature mites showing that not only had the mites survived since release but had also been breeding.

The farm manager reported an improvement in yield during the experimental period in comparison with normal commercial operation of the farm. This was probably due to removal of the phytotoxic effects of diazinon.

DISCUSSION

1. Controlled environment trials

(i) Comparison of trays with bags

A significant and marked effect of *H. miles* on sciarids was evident throughout the trial. There was a possiblity that the control in bags was not as efficient as in trays, but the possible effects of contamination in the bags of run 2 must be borne in mind. The result is contrary to what might be expected since uncompressed compost in bags could allow the mites better access to their prey. However, the percentage reduction in fly numbers in bags (87% bags, 97% trays) is still substantial and worth exploiting. Therefore, there was no evidence that *H. miles* was markedly less efficient in one growing system than the other.

(ii) Effect of watering on predation by *H. miles*

The possible effect of overhead watering on predatory efficiency of *H. miles* was not tested in earlier laboratory work (HDC Project M9). Nor was watering carried out in the above trial comparing trays with bags. Both showed sharp effects of predation on sciarids were possible. Therefore, when sciarids were found to be little affected by the standard and lower release rates used at Farm no. 1, overhead watering was suspected and the present trial was set up as an alternative to the planned experiment.

However, mites survived watering and surprisingly control was significantly better where water was applied, therefore this factor cannot explain poor control on commercial premises.

It is possible that watering drowns some sciarids as larvae or else as adults just emerging from pupae. The latter explanation is supported by the observation that watering had a significant effect on contaminant flies but not on released flies. Most watering was completed by the time released flies emerged, but contaminants were emerging during the watering schedule.

The lower level of control achieved by *H. miles* in this trial (33% reduction in the no water treatment) compared to the former bags versus trays trial (97% reduction on unwatered trays) may be explained by the lower mite density used; 450 per m^2, which is lower than the standard dose (750 per m^2). Fly numbers in the experimental controls of the two trials were comparable. Lower rates were selected deliberately in order that fly numbers were not reduced excessively, which might tend to obscure any effects of watering. These results lend support to the definition of 750 per m^2 as an effective standard dose.

These two controlled environment trials build on earlier laboratory work (Project M9) by providing strong evidence for the effectiveness of *H. miles* in the control of sciarid flies under conditions comparable with commercial systems.

2. Trials on commercial premises

(i) Shelf crop trials

In the room treated with a ten-fold dose of *H. miles*, numbers of both sciarids and phorids were appreciably lower. However, there was time to treat only a single room at this rate. The negative correlation of sciarid numbers with release rate is only just significant ($P < 0.05$) and is dependent upon the single ten-fold point. There is no significant correlation without this data point. There is no significant correlation of phorid numbers and release rate, although the trend is in the right direction.

The mushroom yield in the ten-fold house was low due to a poor spawn run. It is unlikely that the high mite introduction rate was the cause of this. While sciarids are unlikely to be affected by a poor spawn run (good spawn runs tend to deter them), fewer phorids might have been attracted to the crop.

(ii) Bag crop trials

The consistently low numbers of sciarids in houses on Farm no. 2 implies control by *H. miles*, but the absence of an experimental control and the absence of a negative correlation with release rate weakens the evidence.

Phorid numbers were noticeably lower in the three houses treated with ten-fold releases of *H. miles* and a significant negative correlation with release rate was found. This is more strongly suggestive of a predatory effect on phorids, although numbers were still at an unacceptable level.

There is no evidence that introductions made before or after casing have any effect on sciarid or phorid numbers.

FINAL CONCLUSIONS AND FUTURE WORK

The controlled environment tests showed clear-cut effects of *Hypoaspis miles* on sciarids in both tray and bag growing systems, advancing the proof of efficacy a step further from earlier laboratory tests. The absence of a convincing effect on sciarid flies at Farm no. 1 is dissapointing but may be due to the general high background level of sciarid infestation which may be readily transmitted from room to room as new crops are established. Higher input levels would demand high level releases of the predatory mite to make any impact. Low sciarid levels at Farm no. 2 were encouraging although not conclusive but it is possible that numbers in successive crops were kept at a low level due to the regular introductions of *H. miles*.

Phorid flies were generally numerous in 1993 (R. Gaze, pers. comm.) and were abundant at both farms. High immigrant levels and high general background levels may have prevented control except at the highest input rates on both farms. Unlike sciarids, there is no controlled environment evidence that phorids can be suppressed by *H. miles*, although a small-scale laboratory test (Project M9) indicated it was possible.

Recent laboratory tests at HRI-Littlehampton (under MAFF funding) have shown that *H. miles* is not killed by diazinon or diflubenzuron, insecticides commonly used against sciarids and phorids. This raises the possibility of integration of *H. miles* with chemical usage. Future trials need to be aimed at proving efficacy on commercial premises, but initial fly densities must be low when *H. miles* is first introduced to the farm. Applications of the mite made on farms using chemicals should be possible without harming predator numbers. Experimental phasing out or substitution of the chemicals may then be possible without raising fly densities.

ACKNOWLEDGEMENTS

The author would like to thank the following for collaborating on this project.

Mr Felix Posner - data collection
Mr Ivan Worrall and Ms Clare Lofts, Natural Pest Control Ltd
Dr Phil Walker and Dr Robin Penna, Biological Crop Protection Ltd
Dr Martin Emmett, Mr Alan Cade and colleagues, Brinsbury College of Agriculture
Mr Adrian Hearne, formerly of Hayes Farm, Cheltenham.
Mr George Pointing, Agricultural Supply Co (Fairford) Ltd
Dr Richard Gaze, ADAS
Dr Tim Elliott, HRI-Littlehampton
Mr Clive Penn and colleagues, HRI-Littlehampton
Mr Phil White, HRI-Littlehampton
Dr Rodney Edmondson - HRI-Littlehampton
Dr Rose O'Doherty - HRI-Littlehampton

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APPENDIX

Sciarids and phorids caught at Farms 1 and 2

Room 3 (x1 dose)

Week	Sciarids	Phorids
1	355	291
2	283	1407
3	2139	1253
4	5344	4168
5	2793	6699
6	7490	14002
7	11549	11335

Room 5 (x1 dose)

Week	Sciarids	Phorids
1	510	258
2	227	190
3	933	801
4	5467	474
5	4510	11181
6	-	-
7	9442	13034

Room 17 (x1 dose)

Week	Sciarids	Phorids
1	1555	624
2	535	5583
3	7938	3870
4	-	-
5	7452	11648
6	2113	27811
7	11940	10372

Room 4 (x2 dose)

Week	Sciarids	Phorids
1	182	92
2	1602	1151
3	-	-
4	2837	164
5	6234	1730
6	3924	9580
7	7016	4064

Room 6 (x2 dose)

Week	Sciarids	Phorids
1	281	83
2	2878	471
3	-	-
4	3556	428
5	5316	2750
6	7573	7735
7	9020	4688

Room 12 (x2 dose)

Week	Sciarids	Phorids
1	745	981
2	200	6536
3	4372	2628
4	-	-
5	5614	23814
6	2440	18828
7	8920	9388

Room 3b (x4 dose)

Week	Sciarids	Phorids
1	371	25
2	-	-
3	1017	124
4	8761	205
5	8611	1117
6	8501	1847
7		

Room 13 (x4 dose)

Week	Sciarids	Phorids
1	667	683
2	-	-
3	2088	1299
4	3140	848
5	6840	8596
6	4254	16890
7	2685	4267

Room 14 (x4 dose)

Week	Sciarids	Phorids
1	259	66
2	222	34
3	1447	187
4	6685	5291
5	8139	8139

Room 15 (x4 dose)

Week	Sciarids	Phorids
1	142	180
2	-	-
3	426	3078
4	2070	998
5	5214	1218
6	9117	9683
7	5108	14280
8	4107	4045

Room 17b (x 10 dose)

Week	Sciarids	Phorids
1	187	348
2	-	-
3	1063	137
4	682	16
5	1731	2737
6	1332	4865
7	1361	5022

Room 1 (No mites)

Week	Sciarids	Phorids
1	1603	227
2	419	2082
3	4439	1767
4	1435	226
5	7974	7672
6	1369	28455
7	5816	7932

Room 9 (No mites)

Week	Sciarids	Phorids
1	26	0
2	232	142
3	333	24
4	4679	1262
5	1343	3522
6	4258	2778

Room 9b (No mites)

Week	Sciarids	Phorids
1	-	-
2	-	-
3	2336	1226
4	1313	216
5	4764	2960
6	8544	13732
7	14276	7092

Room 12b (No mites)

Week	Sciarids	Phorids
1	199	179
2	-	-
3	1940	393
4	2243	0
5	3605	1093
6	2099	13800
7	4985	7796

Room 1b (Nematodes)

Week	Sciarids	Phorids
1	510	65
2	-	-
3	2330	2300
4	366	0
5	3809	825
6	2912	4522
7	10169	3855

Room 7 (Nematodes)

Week	Sciarids	Phorids
1	-	-
2	-	-
3	286	175
4	429	52
5	-	-
6	3935	1021
7	5587	7573

Room 8 (Nematodes)

Week	Sciarids	Phorids
1	1531	647
2	1139	2480
3	4142	1733
4	1439	765
5	3476	10697
6	2702	14422
7	4417	14019

Room 8b (Nematodes)

Week	Sciarids	Phorids
1	308	241
2	-	-
3	5505	463
4	580	66
5	5508	6704
6	3380	6948
7	14029	2371

House B2 (x1 dose, spawn-running)

Week	Sciarids	Phorids
1	3	29
2	2	60
3	9	1832
4	6	712
5	18	4401
6	0	25064
7	174	44810
8	0	28884
9	1038	15510

House B3 (x1 dose, spawn-running)

Week	Sciarids	Phorids
1	0	50
2	0	102
3	0	879
4	0	131
5	22	1204
6	459	10649
7	309	15403
8	105	1435

House B4 (x1 dose, spawn-running)

Week	Sciarids	Phorids
1	13	67
2	11	201
3	54	319
4	63	285
5	140	3988
6	2403	26093
7	486	18418
8	630	7956

House B5 (x2 dose, spawn-running)

Week	Sciarids	Phorids
1	0	372
2	15	5788
3	0	262
4	0	2476
5	188	16200
6	307	44973

House B1 (x4 dose, post casing)

Week	Sciarids	Phorids
1	0	594
2	0	2356
3	0	1496
4	19	3679
5	0	14632
6	0	35636
7	87	20137

House B3b (x4 dose, post-casing)

Week	Sciarids	Phorids
1	0	53
2	0	4538
3	0	2866
4	10	1123
5	0	2622
6	71	9817
7	79	30121
8	116	34620
9	145	13553

House B4b (x4 dose, post-casing)

Week	Sciarids	Phorids
1	125	1045
2	0	844
3	0	1848
4	0	1655
5	63	9110
6	71	22329
7	643	25741
8	243	18555
9	522	16502

House B1b (x10 dose, post casing)

Week	Sciarids	Phorids
1	0	62
2	0	240
3	3	180
4	28	342
5	20	1657
6	9	2156
7	0	1236
8	107	2441
9	424	1622
10	0	1417

House B2b (x10 dose, post casing)

Week	Sciarids	Phorids
1	0	171
2	0	1143
3	6	1273
4	70	1700
5	68	1974
6	49	2117
7	772	6569
8	2132	10300
9	3594	5763

House B5b (x10 dose, post-casing)

Week	Sciarids	Phorids
1	0	218
2	0	1128
3	26	1936
4	0	401
5	12	1491
6	312	6208
7	780	8818
8	396	10612
9	160	9076
10	818	4112