Evaluation of two insect growth regulators for insect pest control in the Australian mushroom industry

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Summary

Two Insect Growth Regulators (IGRs), triflumuron (Bay Sir 8514) and diflubenzuron, were evaluated for use in casing and compost against the mushroom sciarid, *Lycoriella mali* (Fitch) and white cecid *Heteropeza pygmaea* (Winnertz). Both IGRs showed considerable activity against sciarids when used at 35 mg Kg^{-1} in casing and 10 mg Kg^{-1} in compost, resulting in higher yields and less damage. However, neither showed sufficient activity against cecids unless combined with 0.01% maldison watered on weekly. Use of triflumuron, either alone or with maldison, resulted in the least yield loss compared to an uninfested control.

Introduction

Effective pest control is an important factor in efficient production in commercial mushroom culture (Fletcher *et al.* 1986, Clift 1987, Rinker 1987). In Australia, the sciarid *Lycoriella mali* (Fitch) is the main pest species, but the white cecid, *Heteropeza pygmaea* (Winnertz) is also important (Clift 1987).

The organophosphate insecticide chlorfenvinphos was the main persistent insecticide used to treat mushroom beds until mid-1985, when increased microbial degradation reduced its time of effective protection from over 10 weeks to less than three (Clift 1987). Insecticide resistance has not yet occurred in Australian *L. mali* (Clift 1987), as it has in the English *Lycoriella auripila* (Winnertz) (Fletcher *et al* 1986, White 1986).

The Insect Growth Regulator (IGR) diflubenzuron was selected as the insecticide to control OP-resistant *L. auripila* in England (White 1986), retaining diazinon and maldison to control OP-susceptible pests, including *H. pygmaea,* not controlled by the IGR (Fletcher *et al* 1986). Diflubenzuron and a related IGR, triflumuron (formerly Bay Sir 8514), have been evaluated for use against *L. mali* in the USA (Cantelo 1979, 1983, Argauer and Cantelo 1984).

Because of activity against *Lycoriella,* low residues (Argauer and Cantelo 1984) and low fungitoxicity (White 1986), these two IGRs were evaluated for use in the Australian mushroom industry as a replacement for chlorfenvinphos. We report the results of the evaluation in this paper.

Table 1. Marketable and damaged mushroom yields, in Kg per tray, when two IGRs and OP insecticide were used as compost or casing treatments to protect against sciarids and cecids. Numbers in brackets after each treatment gives the numbers of trays used in each experiment.

Treatment	Experiment 1[A]		Experiment 2[A]	
	Marketable	Damaged	Marketable	Damaged
1. Sciarid Control (8)	4.16b*	0.686b	5.47a	0.427b
2. IGR 35 mg Kg^{-1} casing (8)	5.33a	0.060a	5.68a	0.109a
3. IGR 35 mg Kg^{-1} casing + 10 mg Kg^{-1} compost (8)	5.16a	0.087a	5.80a	0.134a
4. IGR 70 mg Kg^{-1} casing (4)	5.20a	0.055a	5.71a	0.195ab
5. IGR 70 mg Kg^{-1} casing + 20 mg Kg^{-1} compost (4)	5.36a	0.092ab	nt+	nt
6. Diazinon 50 mg Kg^{-1} casing + 0.01% maldison (8)	4.42b	0.592b	5.42a	0.353b
7. Diazinon 100 mg Kg^{-1} compost, 50 mg Kg^{-1} casing + 0.01% maldison (8)	4.68b	0.490b	5.47a	0.340b
8. Cecid Control (4)	2.78c	1.333c	3.66b	1.729c
9. Cecid Diazinon 100 mg Kg^{-1} compost, 50 mg Kg^{-1} casing + 0.01% maldison (4)	4.52b	0.607b	5.59a	0.134a
10. Cecid IGR 35 mg Kg^{-1} casing (4)	4.88ab	0.424b	3.89b	1.822c

[A] IGR is triflumuron in Experiment 1 and diflubenzuron in Experiment 2.
* Numbers in the same column not followed by the same letter are different at P<0.05 using Duncan's Multiple Range Test.
+ nt not tested

Methods and materials

Three experiments were done in the Mushroom R & D Unit (MRDU), BCRI, Rydalmere. MRDU provides, on a smaller scale, similar cultural conditions to those found on commercial farms. The experiments used the same mushroom strain, a commonly grown U3-Type hybrid of *Agaricus bisporus.* Experiment 1 evaluated the efficacy of triflumuron at two rates, Experiment 2 evaluated diflubenzuron at two rates and Experiment 3 evaluated maldison watered onto an existing IGR treatment.

The growing rooms at MRDU hold 64 plastic trays on four, four tiered shelves. Treatments were arranged so that there were equal replications on each tier. Inoculum of the mushroom strain was added to 16 Kg of commercially prepared compost as each tray was filled.

Experiments 1 and 2 included compost insecticide treatments, each in 1 L water, were incorporated into batches of compost, 72 Kg in weight, which was sufficient to fill four trays, before inoculation. Details of the compost treatments are given in Table 1 (Treatments 3, 5, 7, 9). The inoculated compost was held at 24–25°C until the mycelium had colonized the compost, usually after 12 days. The casing layer, composed of moist neutralized peatmoss, was then applied. Conditions recommended for optimal sporophore production, which suggested an air temperature of 17–20°C (van Gils 1988), were maintained.

Casing insecticide treatments, were usually applied by including the commercially prepared product in the water added to the peatmoss to ensure uniform incorporation. The exception was maldison, which was watered on weekly as a 0.01% emulsion at 2.5 L m^{-2}. Details of the treatments and numbers of replicates are given in Table 1 (Treatments 2 to 7, 9, 10) for experiments 1 and 2, and in Table 2 (Treatments 2 to 9) for experiment 3.

Infestation by *L. mali* was achieved by releasing several hundred adults into the room after all the trays had been filled. *H. pygmaea* infestations used five to 10 larvae added to the appropriate trays within two hours of casing. The sciarid control (Table 1, Treatment 1) and cecid control (Table 1, Treatment 8) were untreated, infested controls.

Harvesting of the sporophores started 18 days after application of the casing layer and was done three times per week over five weeks. The sporophores from each tray at each harvest were examined for the presence of sciarid and cecid larvae or larval tunnels and classified as marketable or damaged. Marketable and damaged yields for each tray over the five weeks

Table 2. Marketable and damaged yield when two IGRs or an OP insecticide, with and without maldison, were used as casing treatment against cecids. Numbers in brackets after each treatment gives the numbers of trays used.

Treatment	Marketable	Damaged
1. Uninfested Control (8)	6.26a*	0.128b
2. Triflumuron 35 mg Kg^{-1} casing (8)	6.03a	0.029a
3. Triflumuron 35 mg Kg^{-1} casing + 0.01% maldison (8)	6.05a	0.023a
4. Diflubenzuron 35 mg Kg^{-1} casing (8)	5.52b	0.014a
5. Diflubenzuron 35 mg Kg^{-1} casing + 0.01% maldison (8)	5.47bc	0.042a
6. Diazinon 50 mg Kg^{-1} casing + 0.01% maldison (8)	5.39bc	0.130b
7. Cecids + Triflumuron 35 mg Kg^{-1} casing + 0.01% maldison (4)	6.10a	0.056a
8. Cecids + Diflubenzuron 35 mg Kg^{-1} casing + 0.01% maldison (4)	5.07c	0.141b
9. Cecids + diazinon 50 mg Kg^{-1} casing + 0.01% maldison (4)	5.63ab	0.120ab

* Numbers in the same column not followed by the same letter are different at $P<0.05$ using Duncan's Multiple Range Test.

Table 3. Sciarid larval and pupal counts for the fifth week of harvesting, when two IGRs and OP insecticides were used as compost or casing treatments.

Treatment	Experiment 1 Triflumuron		Experiment 2 Diflubenzuron	
	Larvae	Pupae	Larvae	Pupae
1. Sciarid Control	33	2	34	8
2. IGR 35 mg Kg^{-1} casing	0	0	0	0
3. IGR 35 mg Kg^{-1} casing + 10 mg Kg^{-1} compost	0	0	0	0
4. IGR 70 mg Kg^{-1} casing	0	0	0	0
5. IGR 70 mg Kg^{-1} casing + 20 mg Kg^{-1} compost	0	0	0	0
6. Diazinon 50 mg Kg^{-1} casing + 0.01% maldison	23	1	10	2
7. Diazinon 100 mg Kg^{-1} compost, 50 mg Kg^{-1} casing + 0.01% maldison	21	1	16	2

Table 4. Cecid larval counts for the fifth week of harvesting, from three experiments where two IGRs and an OP insecticide were used alone or with maldison watered on weekly.

Expt. and Treatment	Cecid Larvae
Expt. 1	
Infested Control (Treatment 8)	1685
Triflumuron in casing (Treatment 10)	229
Diazinon in compost, casing (Treatment 9)	1
Expt. 2	
Infested Control (Treatment 8)	6760
Diflubenzuron in casing (Treatment 10)	870
Diazinon in compost, casing (Treatment 9)	3
Expt. 3	
Triflumuron in casing (Treatment 7) + maldison	31
Diflubenzuron in casing (Treatment 8) + maldison	26
Diazinon in casing (Treatment 9) + maldison	0

was determined, analysed using the one-way analysis of variance (AOV) and the significance of differences determined using Duncan's Multiple Range test. Weekly samples of casing were taken from each tray, combined for each treatment and mist extracted (Clift 1979) to determine the numbers of sciarid or cecid larvae present.

Results and discussion

Triflumuron (Expt. 1) at the two rates in casing or compost and casing increased yields ($P<0.05$) compared to both untreated control and diazinon/maldison treatments when sciarids were the pest species (Table 1). When cecids were present, the diazinon + maldison treatment (Treatment 9) was similar to the same treatment (Treatment 6), when sciarids were the only pest. The cecid infested triflumuron treatment (Treatment 10) produced less marketable sporophores than the same treatment (Treatment 2), when sciarids were the only pest, but the difference was not significant ($P>0.05$). The damaged yield was significantly ($P<0.05$) higher (Table 1). A similar pattern was observed for diflubenzuron in Expt. 2 (Table 1), except the differences in marketable yield between the sciarid infested treatments were not significant ($P>0.05$). The differences in the damaged yields (Table 1) were significant ($P<0.05$).

In Expt. 3, marketable yields from all IGR and diazinon treatments were less than the uninfested control (Table 2). Use of triflumuron did not significantly reduce marketable yields compared to the control ($P>0.05$), although diflubenzuron and diazinon did ($P<0.05$). Watering on maldison in addition to the initial casing treatments, with or without cecids, did not reduce yields ($P>0.05$) compared to the same insecticides used alone (Table 2). Use of triflumuron against cecids resulted in higher marketable yields and lower damage ($P<0.05$) than did diflubenzuron (Table 2).

Both triflumuron and diflubenzuron were very effective in eliminating sciarid larvae from the casing, whereas diazinon reduced the numbers by about 30% in Expt. 1 and by 50% in Expt. 2 (Table 3). Both IGRs on their own reduced cecid numbers by 85% (Table 4), but this was insufficient to prevent contamination of the sporophores (Table 1). In all three experiments diazinon in both compost and casing, with maldison watered onto the casing weekly, was the most effective treatment against cecids (Table 4), although this was not reflected in the saleable sporophore yields (Tables 1, 2). Watering on maldison with either IGR reduced the cecid numbers a further 8–10 fold (Table 4), with the level of contamination of the sporophores (Table 2) similar or better to the level obtained with diazinon (Table 2).

Our results show that both IGRs, triflumuron and diflubenzuron, are very effective against larvae of *L. mali* (Table 3) and this is reflected in higher marketable yields and a lower level of damage (Tables 1, 2). This is consistent with other work on the mushroom sciarids *L. auripila* (White 1981, White 1986) and *L. mali* (Cantelo 1979, 1983, Cantelo and Argauer 1984).

Diflubenzuron is not recommended in England for cecid control (Fletcher *et al.* 1986) and our results support this conclusion (Tables 1, 2, 4). We have shown that maldison, watered onto triflumuron in the casing, is as effective as a compost + casing treatment with diazinon (Tables 2, 4), which is the recommended treatment against cecids in England (Fletcher *et al.* 1986) and Australia (Clift 1987). Use of triflumuron + maldison increased marketable yields, compared to the diazinon treatment, although these were still slightly less than the uninfested control (Table 2).

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