Effectiveness of insecticides against larvae of *Inopus rubriceps* (Macquart) (Diptera: Stratiomyidae) in sugarcane ratoons

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Summary

Insecticides were evaluated for treatment of sugarcane ratoons infested with larvae of the sugarcane soldier fly *Inopus rubriceps*. Aldicarb and carbofuran were more effective than ethoprophos and fenamiphos against *I. rubriceps*. Larval numbers were reduced in trials using both surface application and subsurface application with paired coulters. However, results were inconsistent, even with aldicarb which we judged the most effective compound. Aldicarb was more effective when applied using coulters than when applied to the soil surface when both methods were compared in the same trials. In two further trials, terbufos, oxamyl, isofenphos and bifenthrin were not effective when surface-applied, but aldicarb and carbofuran were also unsuccessful. A suitable treatment was not developed.

Introduction

Larvae of the sugarcane soldier fly *Inopus rubriceps* (Macquart) feed on the roots of sugarcane in Australia. Damage is usually seen several years after planting, with affected plants failing to ratoon after harvest. Crops must then be ploughed out prematurely and replanted.

No insecticides are available for control of *I. rubriceps* in sugarcane. This paper reports on trials to test the effectiveness of insecticides applied to infested ratoon crops. We first tested four chemicals presently registered for use as insecticides or nematicides in sugarcane in Queensland and which have established maximum residue limits. These compounds, aldicarb, carbofuran, ethoprophos and fenamiphos, showed medium to high activity against larvae of *I. rubriceps* in laboratory bioassays (Samson 1992). The best two of these were then tested to compare the suitability of two application techniques. Third, we compared the effectiveness of a range of other compounds.

Materials and methods

General trial details

Nine trials were carried out, all near Bundaberg, southern Queensland. Several soil types were included, with particle size analyses of: sand, 24–55%; silt, 19–36%; clay, 26–56%. About 25 mm of water was applied by overhead irrigation not more than three days after insecticide application in all trials.

Comparison of compounds registered in cane

The chemicals were granular formulations of aldicarb (150G Temik), carbofuran (100G Furadan), ethoprophos (100G Mocap), and fenamiphos (100G Nemacur). Target application rates for each were 4 and 8 kg a.i. ha^{-1}.

In Trials 1 to 3, granules were distributed by hand-held applicator on to the soil surface in a band 20 cm wide over the cane row. The treated band was then covered with about 5 cm of soil on the day of application. Plots measured 3 rows × 5 m or 4 rows × 6 m.

In Trials 4 and 5, granules were delivered from a tractor-mounted microfeed applicator into two slots cut 10 cm deep and spaced 20 cm apart in the rows. Slots were cut using twin coulter discs. Plots measured 3 or 4 rows × 13 m. The microfeed applicator was calibrated to deliver the target application rates; actual application rates were subsequently calculated from the weight of unused granules after treatment of all plots. Actual rates were:

- Trial 4: aldicarb 5.3 and 9.0, carbofuran 4.1 and 8.4, ethoprophos 3.6 and 8.5, fenamiphos 4.5 and 4.8 kg a.i. ha^{-1};
- Trial 5: aldicarb 5.2 and 8.0, carbofuran 3.3 and 6.2, ethoprophos 4.3 and 7.7, fenamiphos 4.1 and 4.3 kg a.i ha^{-1}.

Comparison of application methods: aldicarb and carbofuran

The effectiveness of aldicarb and carbofuran was compared between surface and coulter application in Trials 6 and 7. Target application rates were 2 and 4 kg a.i. ha^{-1}, but the low rate of carbofuran was used in only one trial.

Insecticide granules were delivered from a microfeed applicator, either on to the soil surface in a band 20 cm wide over the row, or into two slots 10 cm deep and spaced 20 cm apart cut with paired coulter discs. Surface-applied granules were incorporated by rakes running behind the delivery tubes. Plots measured 4 rows × 10 m. Actual application rates were:

- Trial 6: aldicarb 2.4 and 4.9, carbofuran 4.9 kg a.i. ha^{-1};
- Trial 7: aldicarb 2.0 and 4.1, carbofuran 2.9 and 3.5 kg a.i. ha^{-1}.

Comparison of other compounds

In Trials 8 and 9, we compared the insecticides aldicarb (150G), carbofuran (100G and 360SC), terbufos (150G Counter), oxamyl (240EC Vydate), isofenphos (500EC Oftanol), and bifenthrin (100EC Talstar). Application rates were 4 kg a.i. ha^{-1}, except for the pyrethroid bifenthrin which was applied at only 0.4 kg a.i. ha^{-1} to maintain a similar cost.

Insecticides were applied to the soil surface in a band 20 cm wide over the row. Granules were sprinkled on from a hand-held applicator. Liquids were diluted in two litres of water per plot and sprayed from a gas-pressurized knapsack. The rows were then covered with about 5 cm of soil. Plots measured 4 rows × 6 m.

Table 1. Number of living larvae of *Inopus rubriceps* per 4-core soil sample, following surface application of insecticides on 31/8/90 in Trial 1, 29/8/90 in Trial 2, and 4/12/90 in Trial 3. Back-transformed means are given with means of transformed data in parenthesis.

Insecticide	Rate kg a.i. ha^{-1}	Trial 1 (19/11/90)	Trial 2 (29/11/90)	Trial 3 (22/2/91)
aldicarb	4	0.5 (0.19)	3.6 (0.66)	9.5 (1.02)*
	8	1.0 (0.31)	6.6 (0.88)	3.2 (0.62)*
carbofuran	4	3.0 (0.60)	3.8 (0.68)	14.1 (1.18)
	8	2.7 (0.57)	4.4 (0.73)	14.8 (1.20)
ethoprophos	4	2.1 (0.49)	8.5 (0.98)	27.2 (1.45)
	8	1.2 (0.35)	4.4 (0.73)	23.5 (1.39)
fenamiphos	4	2.0 (0.48)	3.9 (0.69)	19.9 (1.32)
	8	1.8 (0.44)	1.4 (0.38)	21.9 (1.36)
control		1.4 (0.38)	2.0 (0.48)	24.7 (1.41)
se of mean[1]		(0.102)	(0.107)	(0.088)
P[1]		0.137 ns	0.011	<0.001

Means followed by * significantly lower than untreated control by lsd test (P = 0.05)
[1] By analysis of variance of data transformed as log (x+1); ns, P > 0.05

Trial sampling and analysis

All trials were set out as randomized complete-block designs with seven replications.

Larvae of *I. rubriceps* were sampled in each trial at least nine weeks after treatment. Samples were taken from the middle one or two rows of each plot, no closer than 1 m to each end. Single soil cores (20 cm × 6.5 cm diameter) were taken beside each of four stools and combined. Soil samples were wet-sieved using a 1 mm mesh screen (Robertson 1984), and living soldier fly larvae counted.

Larval counts were transformed as $\log_{10}(x+1)$ to stabilize the variance. Treatment means were compared with means in untreated control plots in each trial using the least significant difference (lsd) test, provided that there was a significant (P=0.05) treatment effect by analysis of variance. In addition, means were compared within groups of similar trials using data pooled over locations, provided that there was no interaction between treatments and locations in the analysis of variance (P=0.05).

Results

Comparison of compounds registered in cane

Following surface application of insecticides, there was no significant difference in numbers of larvae between treatments in Trial 1 (Table 1). Analysis of variance indicated a significant treatment effect in Trial 2, but no insecticidal treatments significantly reduced larval numbers in comparison with the control. In Trial 3 both rates of aldicarb significantly reduced numbers of larvae. A combined analysis showed that the effect of treatment varied between trials (P<0.001), so pooled means were not calculated.

Following application of the same insecticides using coulters in two trials, a significant difference between treatments was observed only when trial results were combined (Table 2). Both rates of aldicarb and carbofuran and the high rate of fenamiphos significantly reduced larval numbers relative to the control. The high rate of fenamiphos was under-treated due to intermittent blockages in the feeder tubes, and efficacy of this treatment is probably underestimated.

In sum, plots treated with aldicarb and, to a lesser extent, carbofuran had the lowest number of living larvae in most trials (Tables 1 and 2).

Table 2. Number of living larvae of *Inopus rubriceps* per 4-core soil sample, following coulter application of insecticides on 11/10/90 in Trial 4 and 17/10/90 in Trial 5. Back-transformed means are given with means of transformed data in parenthesis.

Insecticide	Rate[1] kg a.i. ha^{-1}	Trial 4 (11/1/91)	Trial 5 (2/1/91)	Combined
aldicarb	4	0.9 (0.27)	2.4 (0.53)	1.5 (0.40)*
	8	0.7 (0.24)	1.2 (0.35)	1.0 (0.30)*
carbofuran	4	1.2 (0.34)	2.3 (0.52)	1.7 (0.43)*
	8	1.2 (0.34)	2.4 (0.53)	1.8 (0.44)*
ethoprophos	4	2.4 (0.53)	5.2 (0.79)	3.6 (0.66)
	8	2.2 (0.51)	3.5 (0.65)	2.8 (0.58)
fenamiphos	4	2.4 (0.53)	3.2 (0.62)	2.7 (0.57)
	8	1.1 (0.33)	2.8 (0.58)	1.8 (0.45)*
control		2.1 (0.49)	6.2 (0.86)	3.8 (0.68)
se of mean [2]		(0.099)	(0.116)	(0.077)
P [2]		0.231 ns	0.121 ns	0.008

Means followed by * significantly lower than untreated control by lsd test (P = 0.05)
[1] Target rate; calculated rates given in text
[2] By analysis of variance of data transformed as log (x+1); ns, P > 0.05

Table 3. Number of living larvae of *Inopus rubriceps* per 4-core soil sample, following surface or coulter application of insecticides on 19/9/91 in Trial 6 and 4/10/91 in Trial 7. Back-transformed means are given with means of transformed data in parenthesis.

Insecticide	Rate[1] kg a.i. ha^{-1}	Method	Trial 6 (10/4/92)	Trial 7 (14/2/92)	Combined
aldicarb	2	surface	1.4 (0.38)	1.7 (0.43)	1.6 (0.41)
		coulter	0.7 (0.24)	0.3 (0.13)	0.5 (0.18)*
	4	surface	0.1 (0.04)	1.1 (0.33)	0.5 (0.19)*
		coulter	0.4 (0.14)	0.6 (0.20)	0.5 (0.17)*
carbofuran	2	surface	–	0.9 (0.27)	–
		coulter	–	1.0 (0.31)	–
	4	surface	0.9 (0.29)	1.8 (0.45)	1.3 (0.37)
		coulter	0.7 (0.23)	1.2 (0.34)	0.9 (0.29)
control			0.9 (0.27)	2.5 (0.55)	1.6 (0.41)
se of mean [2]			(0.094)	(0.102)	(0.068)
P [2]			0.256 ns	0.145 ns	0.030

– treatment not applied
Means followed by * significantly lower than untreated control by lsd test (P = 0.05)
[1] Target rate; calculated rates using coulters given in text
[2] By analysis of variance of data transformed as log (x+1); ns, P > 0.05

Comparison of application methods: aldicarb and carbofuran

When surface and coulter application were compared in two trials using aldicarb and carbofuran, a significant treatment effect was observed only when trial results were combined (Table 3). Carbofuran at 4 kg a.i. ha^{-1} was ineffective by either application method. Aldicarb at 4 kg a.i. ha^{-1} significantly reduced larval numbers by both methods. Aldicarb at 2 kg a.i. ha^{-1} was only effective by coulter application. A coulter tube blocked during application of the high rate of carbofuran in Trial 7 and the calculated rate of application was below the target rate.

Comparison of other compounds

Following surface application of a range of insecticides in two trials, there was no significant difference in the number of larvae between treatments in either trial or in the combined results (Table 4).

Discussion

Larvae of *I. rubriceps* are concentrated along the planting rows in canefields (Robertson 1984, Samson and McLennan 1992), so insecticides should be most effective when placed along the rows as done in our trials. Most larvae are found within 15 cm of the surface (Samson and McLennan 1992). Obtaining an adequate horizontal distribution of insecticide at sufficient depth is one difficulty with control of *I. rubriceps* in ratoon crops.

In laboratory bioassays, both carbofuran and aldicarb had high activity against *I. rubriceps* (Samson 1992). They were slightly more active than ethoprophos, which in turn was markedly better than fenamiphos. All four chemicals have appreciable water solubility (320 mg L^{-1}) and all except ethoprophos are systemic (Worthing and Hance 1991). Thus, they may all have the mobility in soil or plant that is probably needed to reach larvae in ratoon sugarcane crops. Carbofuran achieved registration for control of *I. rubriceps* in seedling maize crops in New Zealand (Robertson 1979).

In several of our field trials, carbofuran and aldicarb were more effective than ethoprophos and fenamiphos. Performance of the high rate of fenamiphos was compromised in trials using coulters because of application problems, but it performed poorly in other trials using surface application. In New Zealand, effective rates of fenamiphos against *I. rubriceps* in pasture were about double those of carbofuran (Robertson 1979).

Aldicarb seemed superior to carbofuran in our trials. This conflicts with trial results against *I. rubriceps* in pasture in New Zealand (Dixon 1976). Aldicarb is much more water-soluble than carbofuran (6000 and 320 mg L^{-1} respectively) (Worthing and Hance 1991). In our trials, this greater solubility may have allowed more of the insecticide to move in the soil to where larvae were feeding, either by mass transport in water or by diffusion.

There was no clear difference between the effectiveness of surface and coulter applications in Trials 1 to 5. Coulter application of several compounds was effective in Trials 4 and 5. Surface application of aldicarb was effective in Trial 3, but not in Trials 1 or 2. Coulter application of aldicarb was more effective than surface application in Trials 6 and 7 when both methods were used simultaneously.

Application of a range of insecticides to ratoons in Trials 8 and 9 gave poor control of *I. rubriceps* larvae. The alternative insecticides included two systemic organophosphorus compounds, a pyrethroid (bifenthrin), and a highly soluble systemic carbamate (oxamyl). None of these was successful. Aldicarb, which had reduced larval numbers in previous trials, also failed in Trials 8 and 9. Treatments were applied late (November) when larvae tend to move deeper because of high soil temperatures (Samson and McLennan 1992). However, aldicarb did reduce larval numbers by surface application in December in a previous trial (Trial 3).

Our results indicate that insecticide treatment in ratoons can reduce larval numbers of *I. rubriceps*. However, we could not achieve consistent results, even with aldicarb which we judged as the best of the insecticides tested. Greater consistency might be obtained with greater knowledge of insecticide movement in the soil and the effect of irrigation. The best result we achieved with a high application rate of aldicarb was a reduction in larval numbers of about 80%, similar to the level of insecticidal control achieved in pasture in New Zealand (Robertson 1979). Annual insecticide applications may be needed to maintain low population levels, and this would be expensive (>$200 ha^{-1} $year^{-1}$).

We conclude that insecticidal treatment of infested ratoons is unlikely to provide effective control of *I. rubriceps* using existing application techniques. An alternative strategy of applying insecticides at planting is now being evaluated.

References

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Table 4. Number of living larvae of *Inopus rubriceps* per 4-core soil sample, following surface application of insecticides on 1/11/91 in Trial 8 and 27/11/91 in Trial 9. Back-transformed means are given with means of transformed data in parenthesis.

Insecticide	Trial 8 (6/1/92)	Trial 9 (30/1/92)	Combined
aldicarb G	5.3 (0.80)	10.0 (1.04)	7.3 (0.92)
carbofuran G	5.5 (0.81)	6.6 (0.88)	6.1 (0.85)
carbofuran SC	2.7 (0.57)	7.1 (0.91)	4.5 (0.74)
terbufos G	3.4 (0.64)	11.3 (1.09)	6.2 (0.86)
oxamyl EC	6.8 (0.89)	9.7 (1.03)	8.1 (0.96)
isofenphos EC	5.3 (0.80)	9.2 (1.01)	6.9 (0.90)
bifenthrin EC	4.1 (0.71)	8.3 (0.97)	5.9 (0.84)
control	6.9 (0.90)	17.2 (1.26)	11.0 (1.08)
se of mean[1]	(0.101)	(0.119)	(0.078)
P[1]	0.357 ns	0.537 ns	0.192 ns

All insecticides applied at 4 kg a.i. ha^{-1} except bifenthrin (0.4 kg a.i. ha^{-1})

[1] By analysis of variance of data transformed as log (x+1); ns, P > 0.05