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Hidrayani [a], Purnomo [b], Aunu Rauf [b], Peter M. Ridland [c] & Ary A. Hoffmann [d]

[a] Fakultas Pertanian, Universitas Andalas, Padang, West Sumatra, Indonesia

[b] Department of Plant Pests and Diseases, Faculty of Agriculture, Bogor Agricultural University (IPB), Kampus Darmaga, Bogor, Indonesia

[c] Department of Primary Industries (PIRVic), Ferntree Gully Business Centre, Victoria, Australia

[d] Centre for Environmental Stress and Adaptation Research, Department of Zoology, University of Melbourne, Victoria, Australia

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Pesticide applications on Java potato fields are ineffective in controlling leafminers, and have antagonistic effects on natural enemies of leafminers

HIDRAYANI[1], PURNOMO[2], AUNU RAUF[2], PETER M. RIDLAND[3], & ARY A. HOFFMANN[4]

[1]*Fakultas Pertanian, Universitas Andalas, Padang, West Sumatra, Indonesia,* [2]*Department of Plant Pests and Diseases, Faculty of Agriculture, Bogor Agricultural University (IPB), Kampus Darmaga, Bogor, Indonesia,* [3]*Department of Primary Industries (PIRVic), Ferntree Gully Business Centre, Victoria, Australia, and* [4]*Centre for Environmental Stress and Adaptation Research, Department of Zoology, University of Melbourne, Victoria, Australia*

Abstract

In Indonesia a range of insecticides is routinely applied to control agromyzid leafminers. Insecticide applications can reduce parasitism by indigenous parasitoid wasps and also decrease numbers of the predatory muscid fly, *Coenosia humilis*, and these effects reduce control of leafminers. In replicated field trials, repeated applications of Profenofos were ineffective in controlling *L. huidobrensis* numbers on potatoes. Applications of Profenofos and Carbosulfan decreased rates of parasitism by *Hemiptarsenus varicornis* and *Opius chromatomyiae*, and reduced numbers of *C. humilis*. These detrimental effects of the pesticides observed may have contributed to the increased damage and decreased yield in the pesticide-treated fields. An alternative control strategy involving the applications of Abamectin led to a reduction in leafminers without harmful effects on parasitoids and predators. Abamectin applications provide one potential component of an effective *Liriomyza* control strategy for Indonesian potato farmers.

Keywords: *Leafminer, Abamectin, parasitoid, predator,* Liriomyza huidobrensis*, Agromyzidae, Indonesia, Profenofos, Carbosulfan*

1. Introduction

Chemicals are often applied indiscriminately against a pest without regard to their effectiveness against the target, and without monitoring potential harmful side-effects on non-target organisms. Applications of pesticides as a response to perceived pest problems can have substantial economic and environmental costs that are rarely considered (Pimentel et al. 1992).

The leafminers *Liriomyza huidobrensis* Blanchard and *L. sativae* Blanchard (Diptera: Agromyzidae) are responsible for major yield losses in Indonesia and around the world (Parrella 1987). *L. huidobrensis* is particularly damaging to potatoes (*Solanum tuberosum*). In response to these losses, a range of chemicals is being applied by Indonesian farmers (Rauf et al. 2000); it includes broad-spectrum pyrethroids and organophosphates, nereistoxins and, to a lesser extent, translaminar compounds such as Cyromazine and Abamectin. Many of these chemicals have been shown in other countries to be ineffective against *Liriomyza* spp., mainly because of the evolution of resistance (Vandeveire 1991; Weintraub and Horowitz 1998).

Recent Indonesian surveys indicate a diverse fauna of parasitoids and some predators attacking *L. huidobrensis* and *L. sativae*. The most important of the local parasitoids in Indonesia include *Hemiptarsenus varicornis* Girault, *Asecodes delucchii* Boucek, *Neochrysocharis formosa* Westwood (Hymenoptera: Eulophidae) *Opius chromatomyiae* Belokobylskij and Wharton (Hymenoptera: Braconidae) and, in some areas, *Gronotoma micromorpha* (Perkins) (Hymenoptera: Eucoilidae) (Rauf et al. 2000; Belokobylskij et al. 2004). A predatory fly, *Coenosia humilis* Meigen (Diptera: Muscidae), is also common in fields (Rauf et al. 2000) and is known to be effective against *L. huidobrensis* in some situations (Harwanto et al. 2004).

Laboratory tests on Indonesian leafminers indicate that Abamectin and Cyromazine can be effective in controlling leafminers (Prijono et al. 2004). These chemicals also had few detrimental effects on the common parasitoids found in Indonesia, including *H. varicornis*, *O. chromatomyiae* and *G. micromorpha*. In contrast, the commonly used nereistoxin, Dimehypo, was partially effective against leafminers but detrimental to beneficials (Prijono et al. 2004). Trials in many parts of the world have established the

Correspondence: Ary Hoffmann, Department of Zoology, University of Melbourne, Victoria 3010, Australia. Fax: +61 3 83447089. E-mail: ary@unimelb.edu.au

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negative impact of broad-spectrum pyrethroids, carbamates, organophosphates and other chemicals against leafminer parasitoids (Trumble and Toscano 1983; Saito et al. 1992).

Here, we examine the impact of commonly used chemical treatments on leafminers and beneficials in farmer fields in Java, to assess the effectiveness of the treatments in controlling leafminers, and to examine potential detrimental effects of the widely used chemicals on parasitoids and predators. We also consider the field effectiveness of Abamectin, which represents a potential alternative control option against leafminers.

2. Methods

Three field experimental trials were undertaken in Java during the 1999 – 2001 growing seasons to evaluate the impact of insecticide applications on leafminers and their natural enemies. The first trial involved applications of the organophospate Profenofos to control leafminer populations. In the second trial, the effects of the carbamate Carbosulfan, applied as part of normal farmer practice was evaluated. In the third trial, the impact of Abamectin on leafminer control and on beneficials was evaluated.

In all trials, potatoes (cv. Granola) were grown according to local practices. This involved a raised bed, planting distances of 70 × 30 cm, chicken manure applied at 20 t/ha, ammonium sulphate applied at 650 kg/ha, TSP (granular triple superphosphate) applied at 650 kg/ha, and KCl applied at 125 kg/ha. Weeding was carried out twice: 4 and 9 weeks after planting (w.a.p.).

2.1. Trial 1: Profenofos (Cipanas, Cianjur)

The effect of Profenofos was studied in experimental plots in the subdistrict of Cipanas, Cianjur (West Java) from July until October 1999. Potatoes were planted in five 40 × 65 m plots. Two plots were treated with insecticides, while three others were designated as controls. The formulation used was Profenofos 500 g/l (Curacron 500 EC) with a dosage of 1 – 1.61 per ha applied with a knapsack sprayer. The insecticide was applied twice a week from 5 to 11 w.a.p. All plots were also sprayed with Mefenoxam 4% and Mancozeb 64% (Ridomilgold MZ 4/64 WP) at 8 and 9 w.a.p. to control late blight, *Phytophthora infestans*.

Adult *L. huidobrensis* population densities were estimated from fly numbers captured on yellow sticky traps. Once a week, two yellow cylinder sticky traps (9 × 12 cm), attached to bamboo stakes, were positioned 30 cm above the ground in each plot for 1 week, starting at 5 w.a.p. Traps were replaced weekly and the number of flies counted.

The levels of parasitism in larval populations of leafminers were assessed by direct sampling of larvae. Every week, 30 leaves containing leafminer larvae (second or third instar) were randomly collected from each plot and placed in an ice box. In the laboratory, each leaf was confined in a separate transparent plastic cup (diameter 6 cm, height 5 cm) with paper towel to absorb excess leaf moisture and thereby prevent fungal growth. Cups with leaves were covered with plastic film and held at room temperature for 3 – 4 weeks. The numbers of emerging *L. huidobrensis* adults and parasitoids were recorded. The level of parasitism was estimated as the number of parasitoids divided by total number of flies and parasitoids that emerged.

Crop damage was measured weekly beginning 7 w.a.p. From each plot, 32 potato plants were randomly selected. Every plant was scored on a validated damage scale as follows (Raman et al. 1994): 0 = no leaf damage; 1 = leaf damage restricted to basal half of plant (1 – 25% damage); 2 = leaf damage restricted to middle and basal half of plant (26 – 50% damage); 3 = entire plant damaged except terminal leaves (51 – 75% damage); 4 = most of the plant damaged (76 – 100% damage).

Potatoes were harvested on 5 October 1999, and tubers from each plant sample were weighed to assess yield effects.

2.2. Trial 2: Farmer Carbosulfan applications (Pangalengan, Bandung)

This study was conducted in Pangalengan, Bandung (West Java) from June to August 2001. Two plots (20 × 100 m each), separated by 100 m, were planted with potatoes. No insecticides were used on these plots, but several fungicides were applied twice a week to control leaf blight. Fungicides used were Mancozeb 80% (Vondozeb 80 WP), Simoksanil 8.36% and Mancozeb 64.64% (Curzate 8/64 WP), Propamocarb hydrochloride 722 g/l (Previcur-N), and Maneb 80% (Pilaram 80WP). These chemicals were applied in rotation. For comparison, two potato plots of the same size, but treated by a farmer were also studied. The farmer applied the same regime of fungicides as in the treatment plots, and also applied the insecticide Carbosulfan 200 g/l (Marshal 200 EC) weekly to control insect pests.

In each plot, 24 sampling units (each unit consisted of three adjacent plants) were selected for monitoring. Once a week, the numbers of *L. huidobrensis* and *C. humilis* flies in the canopy of the three selected plants were counted in the morning. Leaves infested with leafminers were also collected regularly as described above and monitored in the same way for emergence of parasitoids. To estimate level of crop damage, 16 potato plants were randomly selected in each field, and scored for damage using the same scale as in Trial 1.

2.3. Trial 3: Abamectin (Pangalengan, Bandung)

This study was conducted in Pangalengan, Bandung (West Java) during August–December 2000. Twenty plots, each measuring 4×5 m and separated by 1 m, were prepared and managed according to the standard cultural practices described above. The same fungicides used in Trial 2 were applied twice a week to control late blight.

There were five treatments involving different applications of Abamectin (Agrimec 18 EC) which has a translaminar mode of action: no insecticide; two applications at 7 and 9 weeks (after planting), three applications at 5, 7, and 9 weeks; four applications at 7, 8, 9, and 10 weeks; and six applications at 5, 6, 7, 8, 9, and 10 weeks. Abamectin was applied at a rate of 0.5 ml/l with a dosage of 500 l/ha.

Crop damage was monitored at 5, 7, and 9 w.a.p. Five plants were randomly selected, and the number of leaves with mines as well as the number of leaf mines per plant were counted. In addition, from 5 to 10 w.a.p., 10 plants for each plot were randomly selected to assess crop damage as outlined for Trial 1. Twenty leaves containing leafminer larvae (second or third instar) were also randomly selected from each plot, brought back to the laboratory, and processed for parasitoid emergence as in Trial 1.

Potatoes were harvested at 13 w.a.p. From each plot, 10 plants were randomly selected and then harvested. Tubers were weighed to assess yield.

2.4. Analyses

To examine the effects of insecticide treatments on leafminer numbers, parasitism rates, and damage levels, mean values were computed for each replicate plot and one-way ANOVAs were undertaken. In addition, repeated measures ANOVAs were undertaken to consider the temporal component because these variables were repeatedly measured in the same plots. Both linear and quadratic components of repeat measures were assessed. To ensure that data were normally distributed, count data were transformed to natural logs and parasitism proportions were transformed to arcsin values prior to analysis.

3. Results

3.1. Trial 1: Profenofos (Cipanas, Cianjur)

In this trial, there were significant effects of the chemical treatments on damage and parasitism, and a marginally non-significant effect on numbers of *L. huidobrensis* (Table I). The farmer chemical treatments reduced parasitism in the two treated fields compared to the three control fields, whereas damage levels and *L. huidobrensis* numbers were relatively higher in the unsprayed treatments (Figure 1). Chemical treatments were therefore ineffective in controlling the leafminers, but may have harmed or repelled the parasitoids. Repeated measures ANOVAs indicate a linear increase in damage levels with time, whereas there were quadratic components for leafminer numbers and parasitoid effects (Table II). Leafminer numbers increased initially to peak at 9 weeks after planting, whereas the percentage parasitism peaked earlier to a maximum of 60% in one of the control plots (Figure 1). Chemical treatments were therefore antagonistic to parasitism but less effective in controlling leafminers, presumably due to the detrimental effects of the treatments on parasitoids and other beneficials.

3.2. Trial 2: Farmer Carbosulfan applications (Pangalengan, Bandung)

The farmer treatments influenced damage, leafminer numbers and the percent parasitism, but did not significantly influence predator numbers (Table I).

Table I. ANOVAs comparing insecticide treatments for average scores in farmer field trials for *L. huidobrensis* numbers (ln transformed), damage scores, parasitism (angular transformed proportions), and parasitoid/predator numbers (ln transformed).

Variable	Mean square for effect (df)	Mean square for error (df)	*F*	*P*
Trial Experiment 1				
L. huidobrensis	2.552 (1)	0.382 (3)	6.681	0.081
Damage score	2.576 (1)	0.114 (3)	22.654	0.018
Parasitism ($\times 10^2$)	0.432 (1)	0.024 (3)	17.740	0.024
Trial Experiment 2				
Pangalengan (potato)				
L. huidobrensis	5.191 (1)	0.182 (2)	28.594	0.033
Damage score	3.712 (1)	0.067 (2)	55.535	0.018
Parasitism ($\times 10^2$)	16.613 (1)	0.700 (2)	23.612	0.040
Predatory flies	16.127 (1)	2.020 (2)	7.983	0.106
Trial Experiment 3				
Damage (score)	2.412 (4)	0.258 (15)	9.344	0.001
Parasitism ($\times 10^2$)	0.650 (4)	1.216 (15)	0.535	0.711
H. varicornis	0.394 (4)	1.211 (15)	0.326	0.856
Opius chromatomyiae	1.017 (4)	2.027 (15)	0.502	0.735

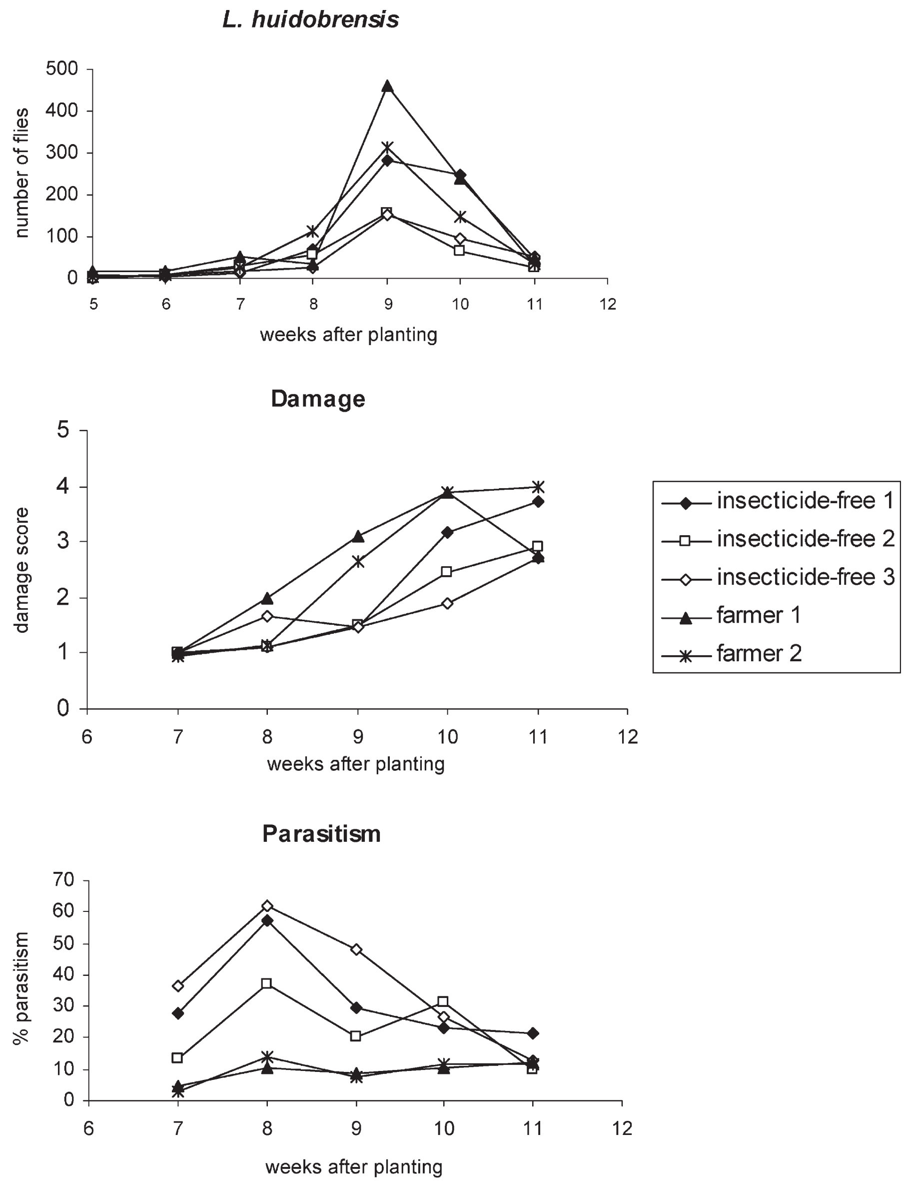

Figure 1. Changes in number of *L. huidobrensis* leafminers, damage score and parasitism rate after planting of potatoes in replicate insecticide-free and Profenofos-treated plots at Cipanas (Trial 1).

Table II. Mean squares and significance of linear and quadratic terms in repeated measures ANOVA for scores in farmer field trials for *L. huidobrensis* numbers, damage scores, parasitism (arcsin-transformed proportions), and parasitoid/predator numbers (ln transformed).

	Time (df = 1)		Insecticide × time (df = 1/1/4[1])		Error (df = 3/2/15[2])	
Variable	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic
Trial 1						
L. huidobrensis	32.850***	14.513**	0.389	0.002	0.139	0.326
Damage score	18.985**	0.094	0.323	1.361	0.455	0.219
Parasitism ($\times 10^2$)	0.612	7.472*	8.645	2.444	0.961	0.349
Trial 2						
L. huidobrensis	13.079*	1.851	6.692*	2.963*	0.146	0.123
Damage score	23.232**	1.400**	0.076	0.580**	0.068	0.001
Parasitism ($\times 10^2$)	26.095*	6.702*	2.119	7.978*	0.461	0.225
Predatory flies	0.056	2.790*	0.882	4.113*	0.154	0.064
Trial 3						
Damage score	57.984***	0.083	1.781***	0.073	0.099	0.107
Parasitism ($\times 10^2$)	208.368***	165.111***	0.878	2.113	2.192	2.726

[1]df for this term is 1, 1, and 4 for Trials 1, 2, and 3, respectively. [2]df for this term is 3, 2, and 15 for Trials 1, 2, and 3, respectively. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

L. huidobrensis numbers and damage were higher in the farmer-treated fields, while the percent parasitism was relatively lower in these fields (Figure 2). Predator numbers also appeared to be adversely influenced by the insecticide treatments. In the repeated measures ANOVAs, there were significant linear trends for all variables except the predators (Table II), reflecting a gradual increase in damage and parasitism but a more abrupt increase in leafminer numbers (Figure 2). Percentage parasitism peaked at a similar level as in the first trial.

3.3. Trial 3: Abamectin (Pangalengan, Bandung)

Whereas damage levels differed significantly between the control and Abamectin treatments, there were no significant differences in numbers of parasitoids captured or in parasitism levels (Table I). Abamectin

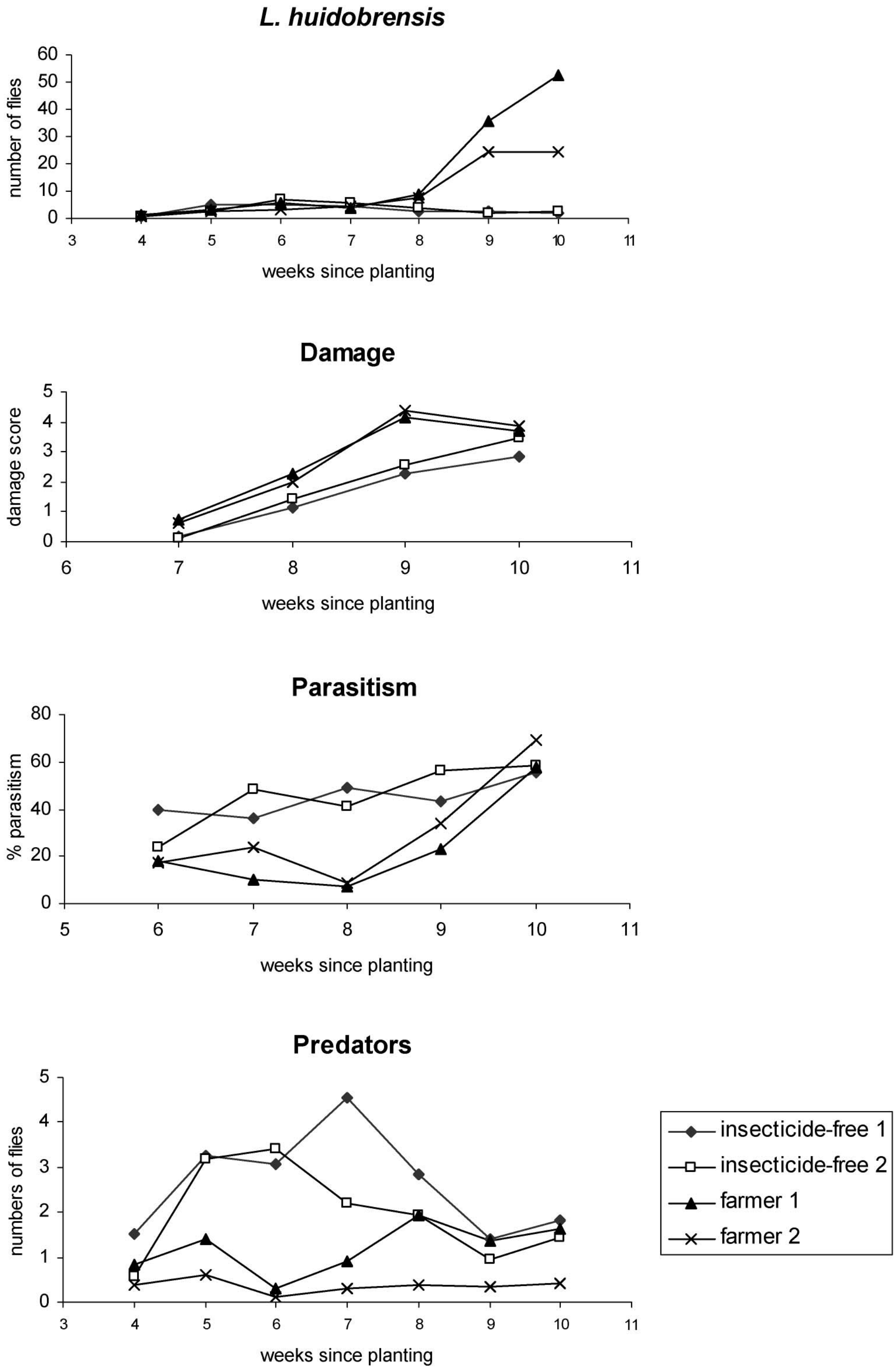

Figure 2. Changes in number of *L. huidobrensis* leafminers, damage score, parasitism rate and predators after planting of potatoes in replicate insecticide-free and farmer-treated plots at Pangalengan (Trial 2).

treatments therefore did not influence beneficials as measured by these methods. Damage levels increased linearly over time, while parasitism levels increased early and were then maintained at around 40%. This was associated with a significant linear component in the repeated measures ANOVA for damage, and a non-linear as well as linear component for parasitism (Table II). There was no difference in damage levels between the 4 × and 6 × treatments. However, with fewer treatments, damage levels increased as treatment numbers decreased (Figure 3).

4. Discussion

The results show that chemical applications against leafminers involving Profenofos and Carbosulfan were ineffective in controlling these target pests. Moreover, applications of both these pesticides had deleterious effects on the beneficials, reducing parasitism. Thus while these chemicals are widely applied by farmers, their effects appear to be negative rather than positive. As the same fungicide treatments were used in the sprayed and control plots, the effects can be attributed to the insecticides *per se*. Pesticides including pyrethroids and organophosphates are considered ineffective against *L. huidobrensis* because of resistance (Macdonald 1991; Weintraub and Horowitz 1995). As Indonesian populations of *L. huidobrensis* are likely to have been derived from invasions of resistant European populations, these are also likely to be resistant.

In contrast, the Abamectin treatments were successful in reducing damage without deleterious effects on the parasitoids. Abamectin as well as the insect growth regulator Cyromazine have provided effective control of *L. huidobrensis* in several countries (Vandeveire 1991; Hammad et al. 2000; Weintraub 2001). Abamectin may be harmful to beneficials including parasitoids (Consoli et al. 1998; Darvas and Andersen 1999; Shipp et al. 2000). In laboratory studies, it was shown to kill Indonesian parasitoids but only at rates above those applied in the field (Prijono et al. 2004). Adult parasitoids were more tolerant of Abamectin than the target leafminer *L. huidobrensis*, and this chemical was far less toxic than other compounds used by Indonesian farmers (Prijono et al. 2004).

Unfortunately Abamectin treatments are relatively expensive when compared to applications of other compounds used more widely by farmers. However, the Abamectin trial shows that numerous applications of this chemical are unnecessary to obtain sufficient control. A few applications, to coincide with the presence of larvae at 40 days after planting, may suffice, given that damage levels were similar regardless of whether sprays were applied prior to this time. The importance of well-timed sprays is also evident in the results of Weintraub (2001), who

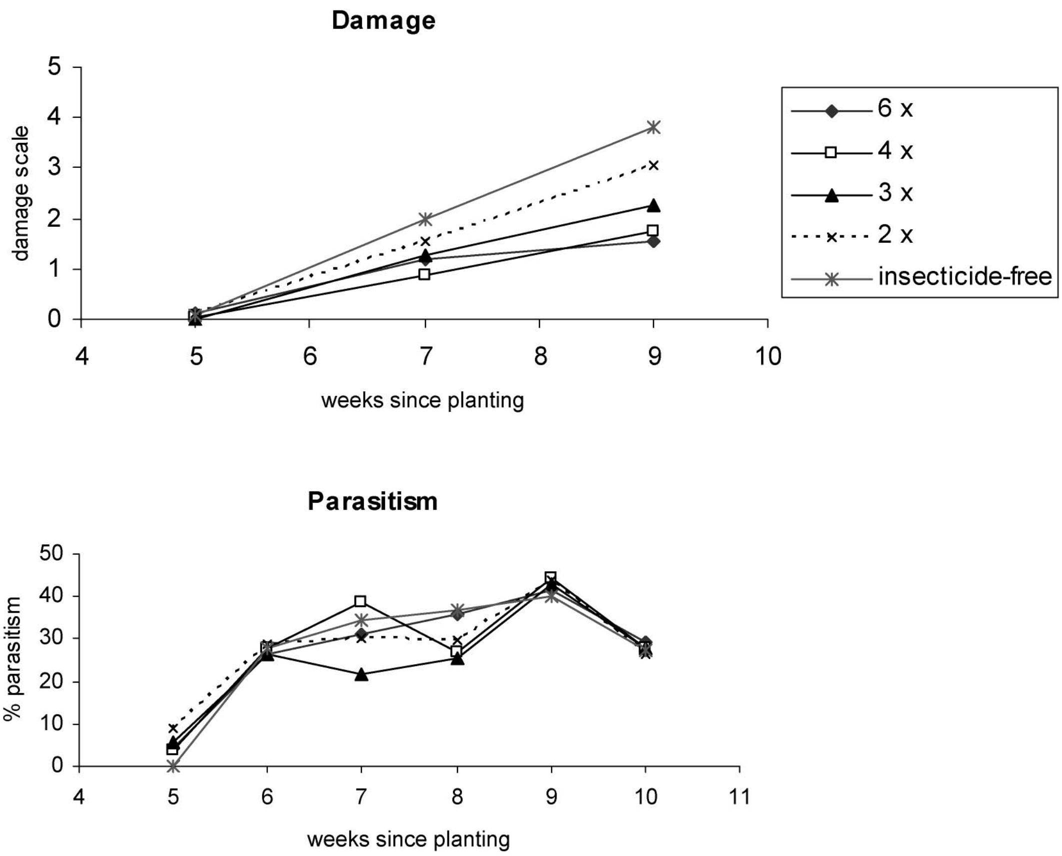

Figure 3. Changes in damage score and parasitism rate after planting of potatoes in insecticide-free and Abamectin-treated plots at Pangalengan (Trial 3).

showed that one such application of Abamectin or Cyromazine provided sufficient control of *L. huidobrensis* in potatoes. In those trials, Cyromazine was more effective than Abamectin at reducing numbers of leafminer adults, but parasitoid populations in the Cyromazine plots took longer to recover than in the Abamectin plots. These results were attributed to the much longer residual activity of Cyromazine when compared with Abamectin. Further trials could address the timing of Abamectin applications more thoroughly, to develop recommendations for further reducing spray applications.

The next challenge is to communicate these results to farmers, and to effect a change in farming practices. The results outlined here and elsewhere (Macdonald 1991; Darvas and Andersen 1999) indicate that pyrethroids, organophosphates and other compounds are likely to be ineffective and may be costly to farmers, particularly as they reduce the activity of beneficials. They may even be contributing to outbreaks of leafminers, as documented for other insecticides such as Methomyl (Oatman 1976). Further trials could be undertaken with other chemicals likely to be effective against *L. huidobrensis* but potentially have a limited impact on beneficials, e.g., Cyromazine and Spinosad, although the latter has reduced translaminar effects and needs be applied carefully, since resistance to Spinosad has already been documented in *L. trifolii* (Ferguson 2004).

As new spray practices are adopted, it should become possible to incorporate the conservation of indigenous parasitoids into control programmes. A complex of resident parasitoids has now been identified, and this complex can be responsible for very high levels of parasitism of leafminers. In addition, one predator has been identified (Rauf et al. 2000) and there are likely to be other generalist predators that may benefit from a reduction of broad-spectrum pesticide applications.

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