

Petroleum spray oils - Lubricating the path to IPM : Part 4. Use of Synthetic insecticides and Petroleum spray oil combinations for improved efficacy against *Helicoverpa* spp. and green mirids on cotton crops

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1.0 Introduction

Integrated pest management (IPM) is currently the most acceptable approach to pest control in the Australian Cotton Industry. The adoption of IPM in the cotton industry may be regarded as a continuous journey of discovery. Cotton growers are continuously learning about tools and strategies that can be used in IPM in order to minimise synthetic insecticide use. The introduction of Bollgard cotton crops will be a major boost and also a platform for IPM adoption in Bollgard cotton cropping systems. However, cotton growers will continue to grow conventional cotton crops alongside Bollgard crops as they learn more about the management of Bollgard crops for maximum yield and profitability. Subsequently, cotton growers will need new tools and strategies to manage pests on both Bollgard and conventional cotton crops with minimal synthetic insecticide intervention.

The path to reduced insecticide use in the cotton industry may depend on the rate, timing and method of insecticide application. Spray timings based on economic thresholds and pest pressure are already in use in the cotton industry. The method of application has been exclusively by foliar sprays which can disrupt beneficial insect activity, depending on the type of pesticide used (biological or synthetic). The rate of application is an area where detailed research has not been focussed but it is an area that is likely to lead to reduced insecticide use and improved profitability. It may be argued that reducing rates of insecticides may result in increased rates of development in pest resistance to these insecticides. However, if efficacy equal to the full label rate is gained from these insecticides at the reduced rates, then resistance development should not be an issue. Consequently, the growers and the environment will benefit immensely.

Generally, the concept and principles of IPM do not exclude the use of synthetic insecticides as a control measure *per se*, instead they aim to reduce sole dependence upon synthetic insecticides for pest control. This is because IPM is a containment strategy, not an eradication strategy. As a logical part of research into IPM strategies, the question should be asked: "Can other IPM tools such as petroleum spray oils (PSOs) be used as adjuvants of synthetic insecticides to reduce the rate of insecticide sprays without affecting insecticide efficacy and cotton yields?"

PSOs have been used as stand-alone insecticides, or adjuvants of other insecticides, in the control of many pests of agricultural crops in many parts of the world. Within the cotton industry, until recently, PSOs have been regarded only as ULV bulking agents and carriers,

rather than as adjuvants of the synthetic insecticides they carry. Recently, the insecticidal properties of PSOs themselves have been used to deter *Heliothis* egg lay, cause mortality in *Helicoverpa* spp. neonate larvae, and to improve the efficacy and persistence of biological insecticides against *Helicoverpa* spp. larvae (Mensah et al. 2004). They are also less toxic to predators (Mensah et al. 2001; Mensah et al, 1995) and parasitoids (*Trichogramma* spp.) (Parker et al., 2004; Al Dabel et al 2004).

The objectives of this study were to (1) determine whether PSOs enhance the performance of synthetic insecticides against cotton pests such as *Helicoverpa* spp. and green mirids; (2) determine the level of *Helicoverpa* and green mirid control achieved by PSO/reduced rate insecticide mixtures in comparison to full label rate insecticides applied alone; and (3) compare the yield and gross margins of cotton crops managed with and without PSOs in combination with either full or reduced label rates of insecticides.

2.0 Methodology

2.1 Plants and materials

The PSOs used for the studies were Canopy® (an emulsified *n*C27 PSO) supplied by Caltex Australia Pty Ltd. and Biopest oil (an emulsified *n*C24 PSO) supplied by Spray Adjuvants Company of Australia (SACOA) Pty Ltd. All trials were conducted in commercial irrigated cotton fields at Greenbah near Wee Waa and at the Australian Cotton Research Institute in Narrabri, in the 2003-04 cotton season.

2.2 The effect of PSO and synthetic insecticide combinations on the level of *Helicoverpa* spp. and green mirids in commercial cotton crops.

2.2.1 ACRI Trials 2003-04

The PSOs were evaluated at 1 and 2.0% v/v (Mensah *et al* 2001; Mensah *et al* 2004) in mixtures with half ($\frac{1}{2}$) or full label rate synthetic insecticides applied to cotton crops against *Helicoverpa* spp. and green mirids. The treatments evaluated were (1) 2% v/v Biopest + $\frac{1}{2}$ rate insecticides (2) 2% v/v Canopy + $\frac{1}{2}$ rate insecticides (3) 1% v/v Biopest + full rate insecticides (4) 1% v/v Canopy + full rate insecticides (5) full rate insecticide alone (control) and (6) $\frac{1}{2}$ rate insecticide alone. Plots were arranged in a randomised complete block design with four replicates. Each treatment replicate measured 2.5 ha. An 8 row buffer separated each treated and control plot. The buffer plots were treated with insecticides to avoid pest damage.

Foliar application of each treatment was made from 10 December 2003 until 4 February 2004 (Table 1). The decision to apply these treatments was based on a predator-to-*Helicoverpa* spp. (pest) ratio of 0.5 (Mensah 2002a; Mensah 2002b). The decision to spray against green mirids was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 green mirids per metre (CottonLogic 1999).

Table 1. *Insecticides applied as indicated to cotton crops within the study site at ACRI in Narrabri, New South Wales, 2003-04.*

Insecticide treatment	Insecticides were applied with:	Date applied
<i>Half label rate:</i> 0.125L/ha Confidor + 0.2%v/v Pulse penetrant	2% Canopy or 2% Biopest or no PSO	10/12/2003
0.425L/ha Affirm		16/12/2003
0.425L/ha Steward		22/12/2003
0.425L/ha Steward		22/01/2004
0.425L/ha Steward		04/02/2004
<i>Full label rate:</i> 0.25L/ha Confidor + 0.2%v/v Pulse penetrant	1% Canopy or 1% Biopest or no PSO	10/12/2003
0.7L/ha Affirm		16/12/2003
0.85L/ha Steward		22/12/2003
0.85L/ha Steward		22/01/2004
0.85L/ha Steward		04/02/2004

Visual counts of *Helicoverpa* spp. on cotton plants in each treatment were made at approximately weekly intervals in two randomly selected 1 metre lengths of row of each treatment replicate, *i.e.* a total of 8 metres were examined per treatment. Counts were separated into *Helicoverpa* spp. eggs, very small and small (VS+S) larvae and medium and large (M+L) larvae. Data were expressed as numbers per metre and numbers per metre per sample date for each treatment.

Green mirids were sampled weekly using a D-vac suction tube (Mensah 1997, Mensah and Khan, 1997; CottonLogic 1999). On each sampling occasion, a 10-metre long sample was taken from a single pass of the vacuum tube along the tops of the plants. After each sampling, the contents of the sampler were transferred to separate plastic bags, taken to the laboratory and counted. Data was expressed as number of green mirids per metre and numbers per metre per sampling date.

Cotton in each treated plot was harvested separately using a four-row picker at the end of the season and the average lint yields (bales/ha) were compared between treatments. The gross margin for each treatment was calculated from the lint yield taking into consideration total pesticide (including PSOs) spray costs (namely number of insecticide sprayed + cost of insecticides + insecticide application costs), since all the other farm management or agronomic inputs in each treatment were the same and applied by the ACRI Farm Manager.

2.2.2 Greenbah (Wee Waa) Trials 2003-04

The treatments evaluated were (1) 2% v/v Biopest + ½ rate insecticides (2) 2% v/v Canopy + ½ rate insecticides (3) 1% v/v Biopest + full rate insecticides (4) 1% v/v Canopy + full rate insecticides and (5) full rate insecticide alone (control). Plots were arranged in a randomised complete block design with four replicates. Each treatment replicate measured 5 ha. An 8 row buffer separated each treated and control plot. The buffer plots were treated with insecticides to avoid pest damage.

Foliar application of each treatment was made from 10 December 2003 until 20 February 2004 (Table 2). The decision to apply these treatments was based on a predator-to-*Helicoverpa* spp. (pest) ratio of 0.5. The decision to spray against green mirids was made based on the IPM Guidelines and CottonLogic recommended economic threshold of 0.5 mirids/metre.

Table 2. Insecticides applied as indicated to cotton crops within the study site at Greenbah near Wee Waa in New South Wales, 2003-04.

Insecticide treatment	Insecticides were applied with:	Date applied
<i>Half-label rate:</i> 1.05L/ha Endosulfan 0.35L/ha Affirm 0.425L/ha Steward 0.425L/ha Steward 1L/ha Predator 0.32L Steward + 0.8L Parathion-Methyl	2% Canopy or 2% Biopest or no PSO	10/12/03 18-12-03 30-12-03 19-01-04 7-02-04 20-02004
<i>Full label rate:</i> 2.1L/ha Endosulfan 0.7L/ha Affirm 0.85L/ha Steward 0.85L/ha Steward 2L/ha Predator 0.65L Steward + 1.6L Parathion-Methyl	1% Canopy or 1% Biopest or no PSO	10/12/03 18-12-03 30-12-03 19-01-04 7-02-04 20-02004

Helicoverpa spp. were counted using a similar method to experiment 2.2.1.

Green mirids were sampled weekly (except rainy days) using D-vac suction tube using a similar method to experiment 2.2.1.

Cotton from each treated plot was harvested separately and the average lint yield (bales/ha) compared between treatments. The gross margin for each treatment was calculated in a similar manner to experiment 2.2.1.

Analysis of the data

All experimental data were transformed by $(X + 0.5)$ and analysed using repeated measures ANOVA (Graphpad Instat and Prism Software, Inc. v. 2.03, San Diego, CA, USA). Treatment and sample dates were the independent variables. Tukey-Kramer Multiple comparisons tests were used to separate means. Arithmetic, rather than transformed means are given in the results.

3.0 Results

3.1 *The effect of PSO and synthetic insecticide combinations on the level of Helicoverpa spp and green mirids in commercial cotton crops.*

3.1.1 ACRI Trials 2003-04

Helicoverpa spp. egg and larvae data for this trial are given in Figure 1. The only treated plots that had significantly fewer *Helicoverpa* spp. eggs in them over the season than the full rate of insecticides applied alone (2.56 eggs/m/d) were the 2% v/v Canopy + ½ label rate (1.74) treated plots. All other plots treated with an oil/insecticide mixture had a statistically similar number of *Helicoverpa* spp. eggs: full label rate of insecticides alone (2.56), 2% v/v Biopest + ½ rate insecticides (2.18), 1% v/v Biopest + full label rate insecticides and 1% v/v Canopy + full label rate insecticides. Plots treated with ½ label rate insecticides alone recorded a significantly higher ($P < 0.001$) number of *Helicoverpa* eggs per metre per sample date (3.14).

Approximately equal numbers of very small and small (VS+S) larvae were found in all plots treated with insecticides mixed with a PSO (Figure 1). The number of VS+S larvae per metre per sample date recorded in plots treated with full label rate insecticides were not significantly different ($P>0.05$) from plots treated with $\frac{1}{2}$ label rate insecticides mixed with PSOs. In contrast, full label rate insecticides mixed with either 1% v/v Biopest or Canopy had significantly fewer ($P<0.01$) VS+S larvae than full label rate insecticides alone. Overall, approximately 1.59 and 2.02 times more VS+S larvae were recorded in plots treated with $\frac{1}{2}$ rate insecticide alone than in plots treated with $\frac{1}{2}$ rate insecticides mixed with 2% Biopest and 2% Canopy oil, respectively.

The number of medium and large (M+L) larvae recorded in plots treated with full label rate insecticides were the same as plots treated with full label rate insecticides mixed with 1% PSOs and $\frac{1}{2}$ label rate insecticides mixed with 2% PSOs (Figure 1). The number of M+L larvae per metre per sample date recorded in plots treated with $\frac{1}{2}$ label rate insecticide alone was significantly higher ($P<0.01$) than all the other treatments tested. Overall, approximately 1.8 and 2.4 times more M+L larvae were recorded in plots treated with $\frac{1}{2}$ rate insecticide alone than in plots treated with $\frac{1}{2}$ rate insecticides mixed with 2% Biopest and 2% Canopy oil respectively. Plots treated with the full label rate of insecticides had 2.1 and 1.7 times more M+L larvae than plots treated with the full label rate mixed with 1% Canopy or 1% Biopest oil, respectively.

Approximately equal numbers of green mirids (adults + nymphs) were found in plots treated with 2% Biopest + $\frac{1}{2}$ rate insecticides (0.15), 2% Canopy + $\frac{1}{2}$ rate insecticides (0.11), 1% Biopest + full rate insecticides (0.11), 1% Canopy + full rate insecticides (0.09) and full rate insecticides alone (0.15) (Figure 2). The number of green mirids per metre per sample date recorded in plots treated with $\frac{1}{2}$ rate insecticides alone (0.22) was significantly higher ($P<0.01$) than the other treatments (Figure 2).

3.1.2 Greenbah (Wee Waa) Trials 2003-04

The number of *Helicoverpa* spp. eggs per metre varied significantly ($P<0.05$) amongst treatments (Figure 3). Plots treated with 2% Canopy + $\frac{1}{2}$ rate insecticides and 1% Canopy + full rate insecticides had significantly fewer ($P<0.05$) *Helicoverpa* spp. eggs per metre per sample date than the full label rate insecticides alone but this was not significantly different from the Biopest/insecticide mixture treatments (Figure 3).

The number of very small and small (VS+S) per metre per sample date was significantly lower ($P<0.01$) in plots treated with 1% Biopest + insecticides (1.33) and 1% Canopy + insecticides (1.38) than 2% Biopest + insecticides (2.36) and full rate insecticides alone (2.14) treated plots (Figure 3).

No M+L larvae were recorded on plots treated with 1% PSOs + insecticides (Figure 3). In contrast, 0.10, 0.02 and 0.26 M+L larvae per metre per sample date were recorded in the 2% Biopest + insecticides, 2% Canopy + insecticides and full rates insecticides alone treated plots (Figure 3).

Generally, the number of green mirids recorded was low and was not significantly different ($P>0.05$) among treatments (Figure 4).

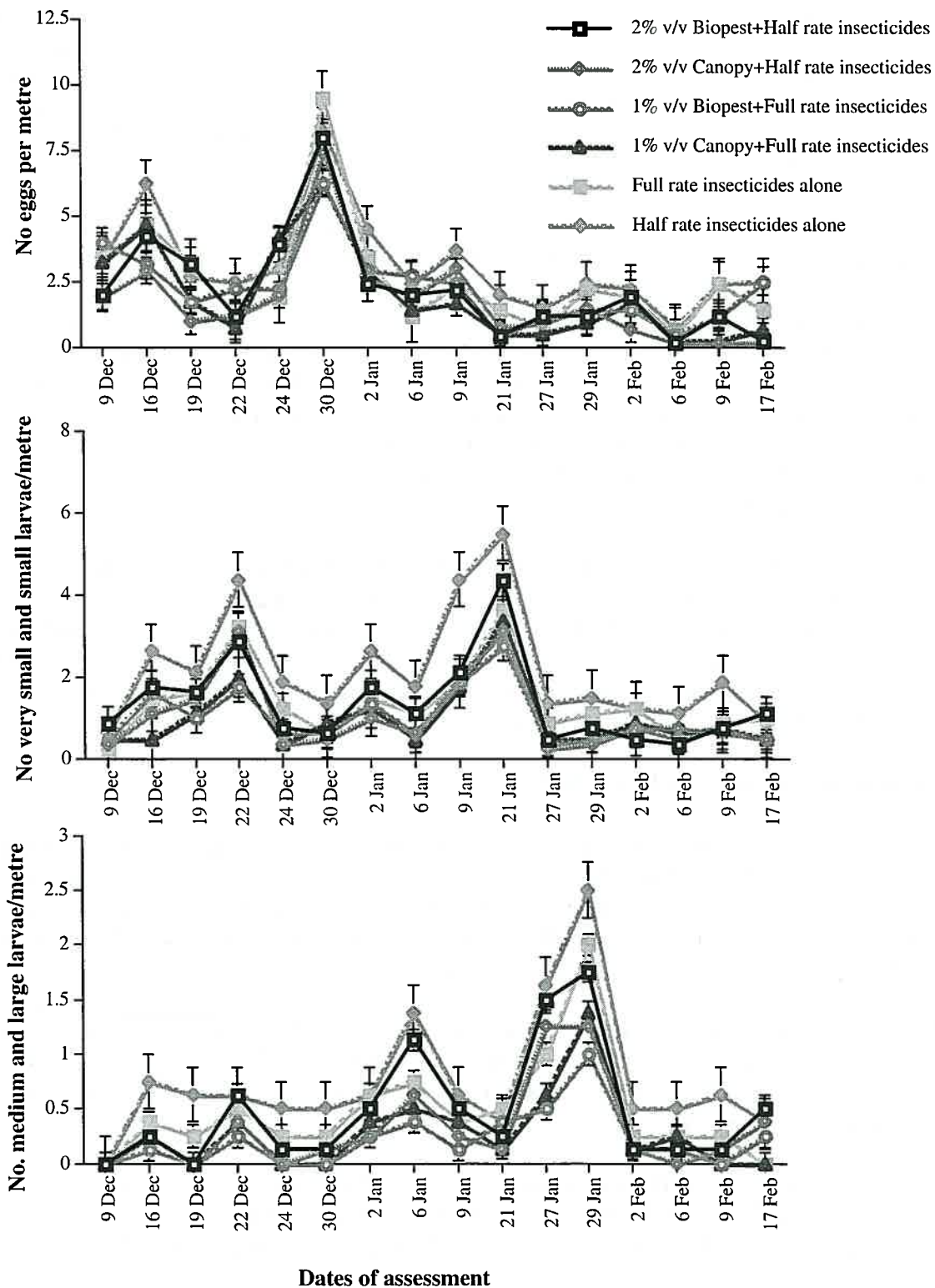


Figure 1. Number of *Helicoverpa* spp. eggs, very small and small larvae and medium and large larvae per metre in commercial cotton crops managed with full and half (1/2) label rates of synthetic insecticides in combinations with Biopest and Canopy PSOs, at ACRI in Narrabri, 2003-04.

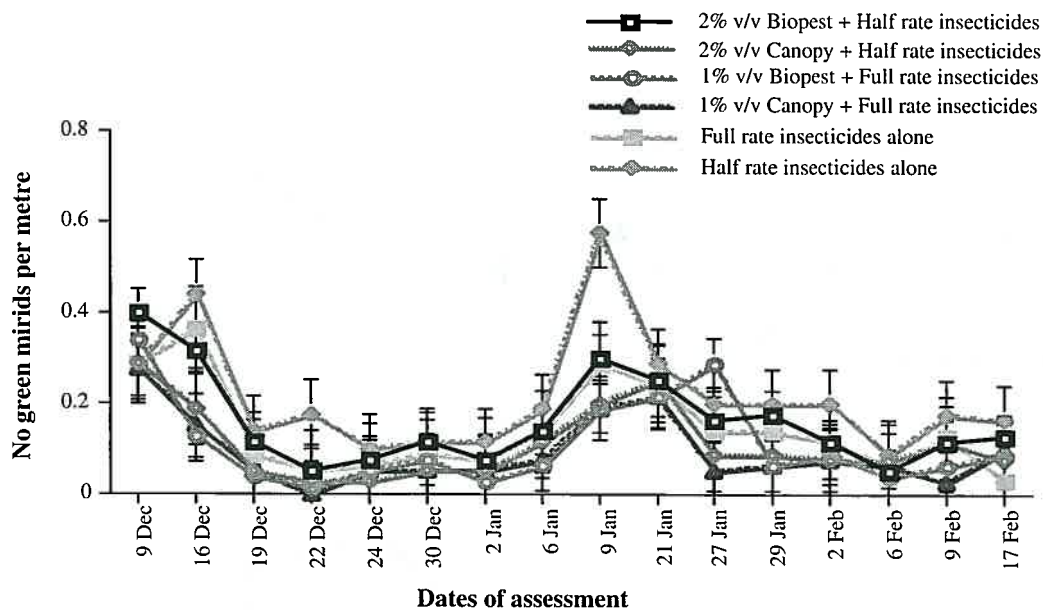


Figure 2. Number of green mirids per metre in commercial cotton crops managed with full and half ($\frac{1}{2}$) label rate insecticides in combinations with Biopest and Canopy PSOs at ACRI in Narrabri, NSW, 2003-04.

3.1.3 The effect of PSO and synthetic insecticide combinations on cotton yields and gross margins

Yield of cotton harvested from the plots treated with insecticide and PSO combinations at ACRI study site were not significantly different ($P > 0.05$) from the full label rate of insecticides alone but were significantly different ($P < 0.05$) from the $\frac{1}{2}$ label rates of insecticides alone (Table 3). The full label rate insecticides alone yielded 8.54 bales per hectare compared with 9.13 bales from 1% Biopest + full rate insecticides, 9.05 bales from 1% Canopy + full rate insecticides, 8.59 bales from 2% Canopy + $\frac{1}{2}$ rate insecticides, 8.05 bales from 2% Biopest + $\frac{1}{2}$ rate insecticides, and 7.79 bales from $\frac{1}{2}$ rate insecticide alone. The 2% Biopest + $\frac{1}{2}$ rate insecticides treatment was not significantly better than the $\frac{1}{2}$ rate of insecticide alone.

The total number of spray products (synthetic insecticides and PSOs) applied to the treatments at each study site is given in Tables 1 and 2. At the ACRI study site, 5 synthetic insecticides and PSOs were applied to the treatments (Table 1) and at Greenbah site 6 insecticides and PSOs were applied (Table 2). The average spray costs and the average gross margin per hectare for the ACRI study is given in Table 3.

The yield results from the Greenbah study site were not available prior to the deadline for submission of cotton conference manuscripts so was not included in this manuscript.

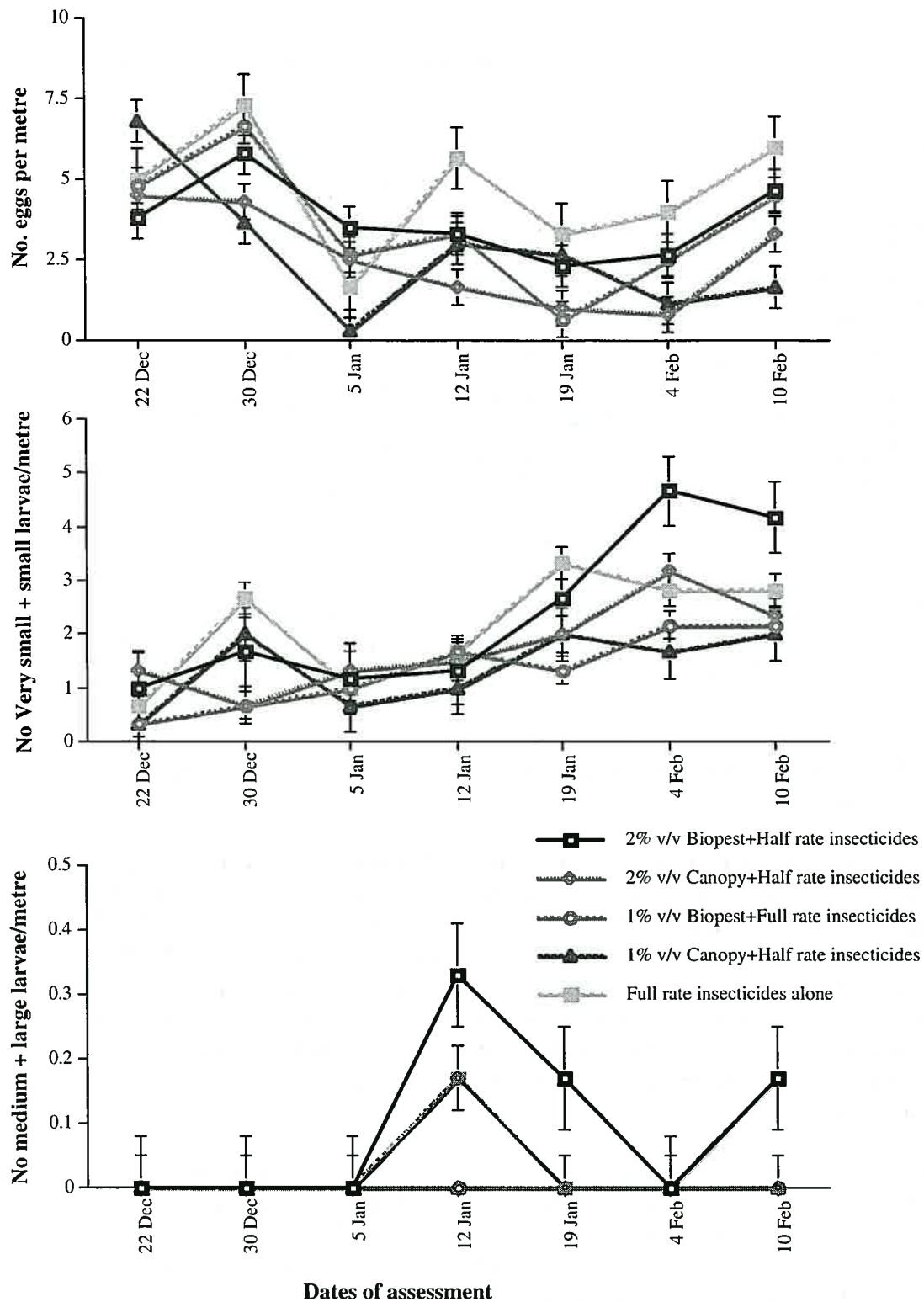


Figure 3. Number of *Helicoverpa* spp. eggs, very small and small larvae and medium and large larvae per metre in commercial cotton crops managed with full and half (1/2) label rates of synthetic insecticides in combinations with Biopest and Canopy PSOs at Greenbah, near Wee Waa, 2003-04.

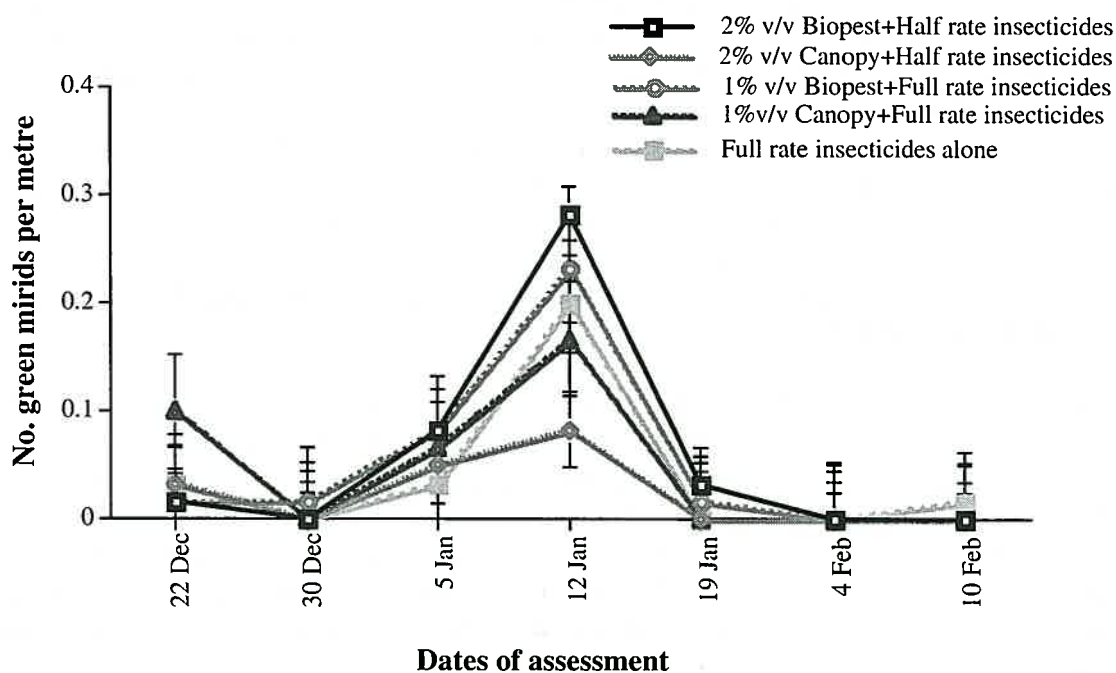


Figure 4. Number of green mirids per metre in commercial cotton crops managed with full and half ($\frac{1}{2}$) label rate insecticides in combinations with Biopest and Canopy PSOs at ACRI Greenbah, near Wee Waa, 2003-04.

Table 3. Yield economics of PSO and synthetic insecticide combination trials on commercial cotton crops at ACRI in Narrabri, 2003-04.

Treatments	Average Spray cost (\$/ha)	Average Yield/ha (bales/ha)	Estimated Gross margin (\$/ha)
2% Biopest + $\frac{1}{2}$ rate insecticides	187.86	8.05 ab	\$2,992
2% Canopy + $\frac{1}{2}$ rate insecticides	201.51	8.59 a	\$3,306
1% Biopest+ Full rate insecticides	292.54	9.13 a	\$3,552
1% Canopy+ Full rate insecticides	299.36	9.05 a	\$3,491
Full rate insecticides alone	280.81	8.54 a	\$3,202
$\frac{1}{2}$ rate insecticides alone	164.41	7.79 b	\$2,850

Means between treatments within columns followed by the same letter are not significantly different ($P > 0.05$) Tukey-Kramer Multiple comparison test.

Discussion

The results of these trials emphatically illustrate the importance of petroleum spray oils as adjuvants of synthetic insecticides in cotton pest control. PSOs by themselves can cause direct mortality to *Helicoverpa* spp. larvae particularly 1st -3rd instar stages (Mensah *et al.* 2001). The direct knockdown efficacy of PSOs arises from a suffocation mode-of-action (Beattie *et al.* 1995; Beattie and Smith 1997). This means that the oil has to come into direct contact with the insect to block its spiracles and cause mortality of the larva. Subsequently, addition of PSOs to either full or reduced rate insecticides may assist in increasing efficacy

against the pests. Another likely contributor to the enhanced efficacy of the synthetic insecticides when applied in combination with the PSOs could be the increased persistence of the insecticides. This effect may be dependent on the average molecular weight of the molecules within the base oils. The higher the molecular weight of the oil, the slower its likely rate of dissipation from the leaf surface. This is consistent with the observation that the 2% Canopy®/insecticide mixtures tended to show fewer pest and egg numbers per count than the Biopest®/insecticide mixtures at both ACRI and Greenbah. The median equivalent normal carbon number of Canopy® is 27 and that of Biopest is 24. The surfactant formulation of the PSO is also likely to affect the spray droplet retention, deposition, and spreading on the leaf surface.

This study found that the addition of 2% v/v of either Biopest or Canopy to ½ rate insecticides achieved better control of *Helicoverpa* spp and green mirids (particularly 2% Canopy) than ½ rate insecticides alone. In addition, cotton yields and gross margin achieved by adding 2% v/v Canopy to ½ rate insecticides were significantly better than the ½ rate insecticides alone (+\$456/ha). Although an increase in yield and gross margin was calculated for the mixture of Biopest at 2% v/v with ½ rate insecticides, this effect was not significant (+ \$142). This indicates that the success and effectiveness of PSOs added to reduced rate insecticides will vary and will depend on the PSO formulation.

Furthermore, when either 1% v/v Canopy or Biopest was added to the full rate of insecticides they increased the cotton yields by 0.51 and 0.59 bales per hectare, respectively. The gross margin was increased by \$289 for 1% v/v Canopy + full rate insecticides and \$350 for 1% v/v Biopest + full rate insecticides, but this difference was not significant. This indicated that PSO formulation differences may not be as important when a grower decides to use the full rate of insecticide in a mixture with a PSO. This study did not test the effect on efficacy and cotton yield of other oils with of different formulation and base oil origin. This will be further studied in subsequent trials.

In general, improved performance of synthetic insecticides mixed with PSOs has been attributed to a wide range of factors including those discussed above. Some of these factors have been outlined by Rae (2000) as oils (1) increasing canopy penetration and coverage of the plant surface, (2) enhancing the residual life of the insecticides by increasing rainfastness and (3) enhancing passage of active ingredients of the insecticide into the plant tissues resulting in a greater pick-up of the active ingredient by the target pest. The formulation of other additives in the PSOs (the presence of UV absorbers, surfactant type and concentration), may also affect the performance of insecticides and PSO combinations.

The practice of most cotton growers who have used PSOs in their spray programs recently, has been to use 2% v/v of PSO in every insecticide spray applied to conventional cotton crops. This approach will help to build up enough oil residues on the cotton leaf surface to suppress egg lay. In this study, egg lay and survival of *Helicoverpa* spp. larvae were significantly reduced when the insecticides were mixed with the PSOs. In conventional cotton, suppression of egg lay is important to reduce overall *Helicoverpa* larval numbers and subsequent insecticide use. However, in Bollgard cotton crops, where the priority is on sucking pests, the benefit of this approach has not been measured, and is therefore the subject of further research that will commence in the 2004/05 cotton season.

In conclusion this study showed clear synergies from the combined use of PSOs such as Canopy® and Biopest, and synthetic insecticides, in the control of *Helicoverpa* spp. and

green mirids in cotton. The main advantages of reduced rate insecticides/ PSO mixtures over full rate insecticides alone, are their reduced disruption to the natural enemies of pests and improved efficacy without sacrificing cotton yields and gross margin. Such an insecticide combination could therefore form a useful tool to complement existing IPM programs in cotton.

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