Petroleum spray oils-Lubricating the path to IPM: Part 1. Use of Petroleum spray oil as insecticide to control *Helicoverpa* spp. on commercial cotton fields

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Introduction

Petroleum spray oils (PSOs) have been used for many decades to control a wide range of crop pests (Beattie et al 1995) and are known to have little impact on natural enemies of crop pests (Mensah *et al.* 1995). They form an essential part of many integrated pest management (IPM) programs (Beattie and Smith 1997). Despite these benefits, the use of PSOs in the Australian cotton industry has been limited due to a perceived risk of PSO-induced phytotoxicity. In addition, since PSOs do not have quick knockdown effect like synthetic insecticides, growers do not consider PSOs as appropriate products to use against major cotton pests such as *Helicoverpa* spp. when their economic threshold is reached.

However, historical research has shown that the risk of PSO-induced phytotoxicity can be minimised when a number of key base oil properties are considered in good practice PSO formulation. According to Johnson (1994) the use of a high quality base oil of no less than 91% unsulfonatable residues will ensure that few unsaturated compounds remain in the base oil to cause phytotoxicity. Subsequently, research on citrus and a range of other horticultural crops has led to the development of new PSO formulations, some containing UV light absorbers to eliminate photo-oxidation to further reduce the risk of phytotoxicity.

Furthermore, there has been increasing evidence that PSOs similar to summer spray are appropriate for use in cotton to reduce numbers of *Helicoverpa* spp. eggs and to suffocate larvae (Mensah *et al.* 1995; Liu and Stansly 1995). The insecticidal efficacy of PSOs is related to their viscosities (Johnson, 1994; Beattie et al 1995; Rae et al 1997 and Lui et al 2001). As a result there is a need to undertake studies using high viscosity oils for the management of *Helicoverpa* spp. on commercial cotton crops.

The aim of this study was to determine the efficacy of high viscosity PSO and other crop oils as a stand-alone insecticidal product for activity against *Helicoverpa* spp. on cotton.

2.0 Materials and methods

Two separate experiments were conducted over three cotton seasons in commercial cotton fields and on outdoor-potted cotton plants. The oils used in these studies were Canopy®, (Caltex Australia), Summer spray oil, (Caltex Australia), Synertrol® an emulsified canola oil extracted from Canola and Tea tree oil, an emulsified essential oil extracted from Tea trees

2.1 The efficacy of Canopy oil and other crop oils against Helicoverpa spp. in cotton fields at the Australian Cotton Research Institute in Narrabri.

The experiment was conducted in a 3 hectare irrigated cotton field at the Australian Cotton Research Institute in Narrabri in New South Wales. The cotton variety used for the experiment was Sicala V2. The field was sown on the 13 October 1999 at a rate of 10 plants per metre with row spacing of 1 m. The Canopy oil was evaluated at 2, 3 and 5% v/v and the other crop oils at 2% v/v. The treatments evaluated were: (1) 2% v/v Canopy oil (2) 3% v/v Canopy oil, (3) 5% v/v Canopy oil (4) 2% v/v Tea tree oil, (5) 2% v/v Canola oil, (6) 2% v/v Summer oil and (7) unsprayed (control). Plots were arranged in a complete randomised block design with four replicates of each treatment. Each plot measured 8m (rows) wide x 100 m long. There was a buffer of five metres or rows between each plot.

Foliar applications of the treatments were applied to the cotton plants from a groundrig using 100-150 L/ha. Treatments were applied on 5 December 1999, 12 December 1999, 3 January 2000 and 15 January 2000. The decision to apply these treatments was based on a predator-to-*Helicoverpa* spp. (pest) ratio of 0.5 (Mensah 2002). Visual counts of *Helicoverpa* spp. on cotton plants in each treatment were made weekly in four randomly selected 1 m lengths of row of each treatment replicate, *i.e.* a total of 4 m per treatment. Counts were separated into *Helicoverpa* spp. eggs, very small and small larvae (VS+S) and medium and large larvae (M+L). Data were expressed as numbers per metre per sample date for each treatment.

2.2 The efficacy of different concentrations of Canopy oil against Helicoverpa spp. larvae.

The experiment was conducted on a 72 ha irrigated commercial cotton (Sicala V 2 variety) field at Auscott in Narrabri in New South Wales during the 2000-2001 cotton season. Three (3) concentrations of Canopy oil were evaluated against *Helicoverpa* spp. The treatments were: (1) 1% v/v (2) 2% v/v (3) 5% v/v and (4) conventional insecticide treated plots.

Plots were arranged in a randomised complete block design with four replicates, each treatment replicate measuring 48 metres (rows) by 700 metres long. No conventional insecticides were applied between or before PSO applications. Sprays were applied with a ground rig using 100 - 120 L/ha of water during the early - mid season (5^{th} October 2000 until 15^{th} January 2001). In all, 7 applications were made on the PSO treated plots, and 4 on the synthetic insecticide-treated plots (Table 1).

Table 1. Treatments applied to cotton crops in the study sites at Auscott in Narrabri in NSW from October to mid January 2001.

Treatments	Product/Chemical applied	Dates applied
1% v/v Canopy oil	0.8L/ha Canopy 1.0L/ha Canopy 1.2L/ha Canopy	19/10, 2/11, 16/11, 30/11/2000 14/12/2000, 2/1/2001 15/1/2001
2% v/v Canopy oil	1.6L/ha Canopy 2.0L/ha Canopy 2.4L/ha Canopy	19/10, 2/11, 16/11, 30/11/2000 14/12/2000, 2/1/2001 15/1/2001
5% v/v Canopy oil	4.0L/ha Canopy 5.0L/ha Canopy 6.0L/ha Canopy	19/10, 2/11, 16/11, 30/11/2000 14/12/2000, 2/1/2001 15/1/2001
Conventional insecticides	0.9L/ha Costar (NPV) 0.2L/ha Tracer 0.2L/ha Tracer + 0.3L/ha Abamectin 2.1L/ha Endosan + 2.0L/ha Amitraz	7/12/2000 15/12/2000 29/12/2000 11/1/2001

Visual counts of *Helicoverpa* spp. stages on whole cotton plants were made in four selected 1 m lengths of row of each treatment replicate, *i.e.* 4 m per treatment. Counts were separated into *Helicoverpa* spp. eggs, V+S larvae (1^{st}-3^{rd} instar stage) and M+L larvae (4^{th}-6^{th} instar stage). Data were expressed as numbers per sampling date per treatment. When *Helicoverpa* control with PSO ceased to be adequate (late January 2001) conventional insecticides were used in its place and the study ceased.

2.3 Analysis of data

Data was analysed using repeated measures ANOVA (Graphpad Instat Software, Inc. Version 2.03, San Diego, CA, USA). Tukey-Kramer Multiple Comparison tests were used to separate the means. Arithmetic rather than transformed means are given in the results. Significance was determined at the 95% confidence level ($P<0.05$).

3.0 Results

3.1 The efficacy of Canopy oil and other crop oils against Helicoverpa spp. in cotton fields at the Australian Cotton Research Institute in Narrabri.

All Canopy oil treatments showed significant ovipositional deterrence ($P<0.05$) compared to the control but without significant rate effect (Figure 1). All Canopy oil treated plots contained significantly fewer eggs than the plots treated with the other oils($P<0.0001$). Tea-tree oil and Canola oil treatments did not have significant effect compared to the control however the Summer oil did provide measurable effect.

All Canopy oil treatments gave significant control ($P<0.0001$) of very small and small larvae (VS+S) but once again without a rate effect (Figure 1). No other treatment provided significant control of VS+S larvae. Similar results were obtained for the control of M+L larvae.

3.2 The efficacy of different concentrations of Canopy oil against Helicoverpa spp. larvae.

The effect of 1%, 2% and 5% v/v Canopy oil application rates on *Helicoverpa* spp. populations was evaluated (Table 2). All rates of Canopy oil showed a significant reduction ($P<0.05$) in egg numbers 3 DAT compared to the conventional insecticides. No significant effects on VS+S larvae were detectable however the 1% rate was significantly less effective ($P<0.05$) than the 2 and 5% v/v rates against the M+L larvae.

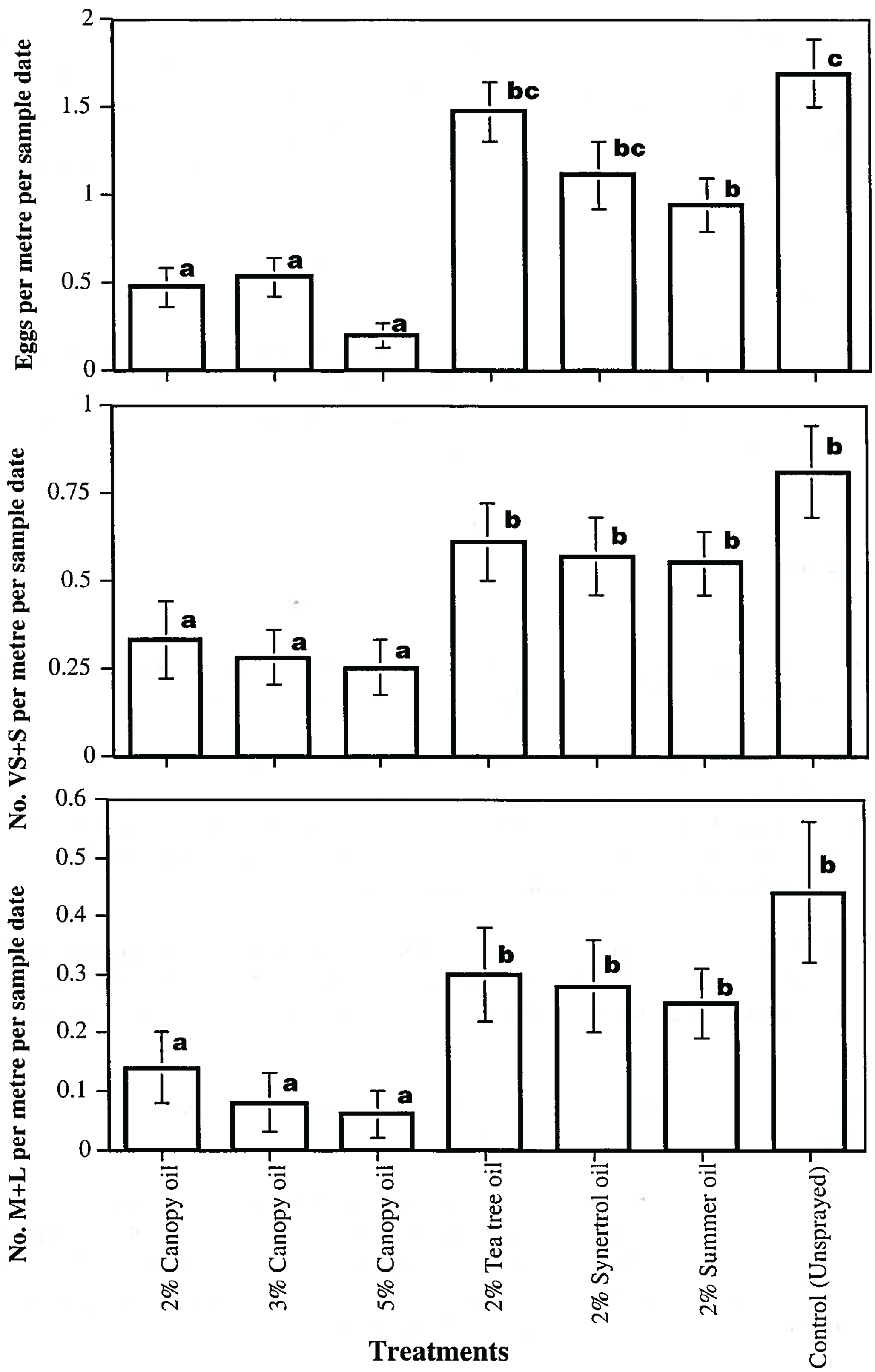

Figure 1. Mean number *of Helicoverpa* spp. eggs, VS+S and M+L larvae per metre per sample date recorded on plots treated four times from October 1999 to January 2000 with different concentrations of spray oils in commercial cotton fields at the Australian Cotton Research Institute near Narrabri. (Means followed the same letters are not significantly different ($P > 0.05$) (LSD).

Table 2. The effect of different PSO rates on the average number of *Helicoverpa* spp. per metre at Auscott, Narrabri, 2000-2001.

Sample date	Treatment	Eggs/m		VS+S/m		M+L/m	
		mean	SE	mean	SE	mean	SE
Pre-treatment	1% Canopy®	2.86 a	0.83	1.18 a	0.22	0.33 a	0
	2% Canopy®	2.46 a	0.61	1.11 a	0.27	0.14 a	0
	5% Canopy®	2.43 a	0.65	1.18 a	0.19	0.07 a	0.07
	Conventional	2.25 a	0.58	1.33 a	0.36	0.08 a	0
3DAT	1% Canopy®	1.69 a	0.33	1.09 a	0.22	0.31 b	0.03
	2% Canopy®	1.69 a	0.43	0.88 a	0.15	0 a	0
	5% Canopy®	1.63 a	0.42	0.91 a	0.18	0 a	0
	Conventional	2.25 b	0.67	0.69 a	0.19	0 a	0
7DAT	1% Canopy®	1.81 a	0.49	0.53 a	0.19	0.34 b	0.09
	2% Canopy®	1.75 a	0.63	0.38 a	0.24	0.06 a	0.04
	5% Canopy®	1.50 a	0.61	0.41 a	0.18	0 a	0
	Conventional	1.38 a	0.46	0.75 a	0.44	0.06 a	0.06

Means within columns followed the same letters are not significantly different ($P > 0.05$) (LSD).

Discussion

This study showed that Canopy oil (PSO) could deter oviposition when applied at a rate of at least 2% v/v. Neither the tea tree oil nor canola oil was effective in this aspect. The Summer oil deterred oviposition better than the tea tree and canola oils but was not as effective as the Canopy oil. The PSO was also efficacious against *Helicoverpa* spp. larvae and more so than the other oils tested. There was no significant rate effect, between 2 and 5% v/v, from the PSO on either ovipositional deterrence or larval efficacy although plots treated with the 5% rate generally had fewer eggs and larvae than those treated with the lower rates. The 2%v/v rate showed efficacy against *Helicoverpa* eggs and larvae for up to 7 days after treatment. In the other experiments, the 1% rate was not as effective as the 2% v/v rate. The optimum rate of application of the PSO is therefore 2% v/v. Overall, the efficacy of the PSO was highest against very small and small larvae. Thus, in general, the application of PSO should coincide with periods when the *Helicoverpa* spp. larval population is predominantly at the first and second instar stage.

It is apparent that the PSOs are inherently more effective than the plant oils and that higher molecular weight PSOs are more efficacious against *Helicoverpa* spp than lower molecular weight PSOs. This is consistent with the accepted maxim that petroleum oil efficacy is related to the average molecular weight of the oil. Liu *et. al.* (2001) and Rae *et. al.* (1997) reported that the insecticidal efficacy of PSOs is proportional to their median normal equivalent carbon number. This effect is most likely due to the increased persistence of the heavier oils on the leaf surface.

PSOs leave some residues on the leaf surface and the data showed that these residues are not toxic to adult moths but can discourage them from laying eggs on the cotton plant. Studies by Mensah *et al* (2004) showed that the oviposition deterrence activity of PSOs could last for 4-5 days and the mechanism involved in the oviposition deterrent activity of PSOs is through the suppression of volatile compounds normally released by cotton plants (see part 2 of this paper in the procceedings). These volatile compounds in part, provide a means of identification for the ovipositing female moth and if their distribution to the atmosphere is affected then the moth's recognition of the cotton plant is affected.

The mode-of-action of PSOs appears to be multifaceted. Along with direct ovipositional deterrence aspect comes some direct toxicity to the eggs that are laid, resulting in a reduction of the number of viable larvae that hatch. Furthermore, a proportion of the generation that survives to the larval stage will then suffer some direct feeding toxicity, whilst a proportion of those early instar stages of larvae that were present at the time of spraying will succumb to direct contact from the oil. However, because only a moderate percentage of the entire population will be affected by any of these modes-of-action, the survival rate from high pest pressures can be too high for PSOs to be used as the only means of control under those circumstances. In addition, PSOs in general do not appear to reduce pest numbers as quickly as synthetic insecticides so PSO sprays may need to be applied before a recommended *Helicoverpa* spp. larval threshold (2 larvae per metre (CottonLogic 1999) is reached. The presence or absence of a significant predator population is also likely to impact on the performance of the PSO in cotton pest management systems. As a result the predator/pest ratio concept (Mensah 2002) could be a useful decision making tool for the application of PSOs for the control of *Helicoverpa* spp. in cotton.

In the mid to late season (mid January onwards), application of PSO will provid some control of the high pressure *Helicoverpa* spp. population present however, the control will not be enough to reduce *Helicoverpa* spp. numbers below the recommended economic threshold of 2 larvae per metre. Effective performance of the PSO appeared very much dependent on the leaf coverage achieved from the application. High volume sprays are required to achieve the necessary coverage and adequate coverage can really only be achieved in the early cotton season. During the mid to late season, PSOs may have to be used in a mixture with other pesticides to effectively control *Helicoverpa* spp.

In conclusion, the results of this study showed that PSOs are efficacious as an ovipositional deterrent and as a *Helicoverpa spp.* larvicide and could therefore be a useful tool to complement IPM programs in cotton.

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