RESPONSE OF *HELICOVERPA* SPP. (LEP. : NOCTUIDAE) AND THEIR NATURAL ENEMIES TO PETROLEUM SPRAY OIL IN COTTON IN AUSTRALIA

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Refined petroleum products have been used since last century for the control of phytophagous arthropod pests. The response of *Helicoverpa* spp. and its natural enemies to petroleum oil sprays on cotton was investigated under laboratory choice/no-choice and small plot field conditions at the Australian Cotton Research Institute at Narrabri in New South Wales. In oviposition choice and no-choice tests, petroleum oil sprays suppressed oviposition in *Helicoverpa punctigera* (Wallengren) but not *H. armigera* (Hubner)(Lepidoptera : Noctuidae). *H. punctigera* females laid about seven times as many eggs on the control (water sprayed) cotton plants as on either petroleum oil spray alone or oil mixed with Kelgum. However *H. armigera* females laid the same number of eggs on both treated and control plants. In field trials, the number of eggs per metre per sample date found on the plots treated with petroleum oil spray was 3.83 compared with 6.29 and 7.82 eggs respectively on plots treated with conventional insecticide sprays and the unsprayed plots. The number of larvae found on plots treated with petroleum oil sprays was 2.9 times higher than the conventional insecticide sprayed plot, however, this was 1.6 times fewer than the unsprayed plot. The cotton yields from plots treated with petroleum oil sprays was 3.70 bales/ha compared with 7.32 and 2.69 bales respectively from the conventional insecticide treated and the unsprayed plots. Petroleum oil sprays had little or no effect on predatory beetles, bugs, lacewings and spiders.

KEY-WORDS: *Helicoverpa armigera, Helicoverpa punctigera*, integrated pest management (IPM), petroleum spray oil, kelgum, surfactant.

Cotton crops in Australia are attacked by a wide range of insect pests, the key ones being the larvae of *Helicoverpa punctigera* (Wallengren) and *H. armigera* (Hubner) (Lepidoptera : Noctuidae). Although no regular studies have assessed the yield losses caused by insects in commercial cotton crops, early studies with unsprayed cotton indicated insects caused about 50 - 90% yield reductions (Hearn *et al.* 1981). Recently Fitt *et al.* (1992) have given values in the

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range of 10 - 30% although in some years this loss may be higher. McGahan *et al.* (1991) estimated the average annual loss due to *Helicoverpa* spp. alone in Queensland cotton at 7.7%, despite expenditure of A$7.5 million for control. Extrapolating such estimates over the entire Australian crop suggests losses of A$60-70 million in 1990-1991, despite the expenditure of almost A$90 million on control (Fitt 1994).

To sustain production, the cotton industry currently relies heavily on pesticides for the control of these major pests. Over-reliance on insecticides, associated problems of insecticide resistance especially in *H. armigera,* disruption of natural enemies and environmental consequences have cast doubt on the long term viability of the cotton industry using a traditional insecticide approach. A control programme that has minimal effect on natural enemies and the environment with negligible chances of inducing resistance would be a desirable alternative. Petroleum oil sprays have been used extensively on a wide variety of crop pests (Lee *et al.* 1991; Beattie 1991; Johnson 1985; Riehl 1981; Simanton and Trammel 1966) and are now an essential component of many integrated pest management (IPM) programmes for scale insects and mites (Beattie 1991). They are also used as surfactants with the bacterial insecticide, *Bacillus thuringiensis* for the control of *Helicoverpa* spp. on cotton. However, no research has been conducted on cotton to determine the effect of petroleum oil sprays *per se* on *Helicoverpa* spp. and their natural enemies.

In this study, we examined the effects of petroleum oil spray and a mixture of petroleum oil and Kelgum sprays on *Helicoverpa* spp. oviposition in choice and no-choice tests in a mesh house and in small plot field trials. In addition the effect of petroleum oil spray on *Helicoverpa* spp. and predatory insect populations and cotton yield was studied in a commercial cotton crop.

MATERIALS AND METHODS

CHEMICALS

The treatments evaluated were petroleum spray oil (Caltex Lovis, a C_{21} narrow-range oil with a 50% distillation temperature of 361°C at 101.33 kpa), Kelgum (Kelco & Co., San Diego, CA) and a mixture of Lovis petroleum oil and Kelgum

SOURCES OF PLANT AND INSECT MATERIALS

Unless otherwise stated, all experiments were conducted in a Sarlon mesh house (4 m x 10 m) during summer 1992/93 and 1993/94 at the Australian Cotton Research Institute at Narrabri in New South Wales, Australia.

The experimental plants used in all studies were potted cotton plants (Sicala VI), 0.5m high. The plants were grown from seeds in pots in the same mesh house where experiments were carried ont. *Helicoverpa* spp. moths used in all the mesh house experiments were from colonies established by the Institute's Insecticide Resistance Management Group. All experimental data were subjected to analysis of variance (Graphpad Version 2.03 Instat Software Inc. San Diego, California) and least significant difference (lsd) used to separate the means (Zar 1984).

OVIPOSITIONAL PREFERENCE OF *HELICOVERPA* SPP. TO PETROLEUM OIL SPRAY

Experiments were conducted in January 1993 when cotton plants were 4 weeks old. A randomised complete block design was used for each experiment with three treatments and a control. There were 5 replicates of each treatment, with each replicate consisting of 8 plants.

The treatments were 0.5% (vol/vol) Lovis petroleum spray oil, 0.01% (wt/vol) Kelgum, a mixture of 0.5% Lovis petroleum oil and 0.01% Kelgum and water (control). Separate experiments were conducted for *H. armigera* and *H. punctigera*.

Under free-choice conditions, the plants were treated run off (approximately 100 ml of test solution) using a knapsack sprayer. Following treatment 110 pairs of *H. armigera* or 100 pairs of *H. punctigera* were introduced into the mesh house. The numbers of eggs laid on the plants were counted daily until all adults died thus giving the total number of eggs laid per plant per treatment.

Under no-choice conditions plants from each treatment were enclosed in separate cages within the mesh house and eight pairs (*H. armigera*) or five pairs (*H. punctigera*) adults were released into each cage. Numbers of eggs per plant per treatment were recorded daily.

FIELD STUDIES ON *HELICOVERPA* SPP. AND THEIR NATURAL ENEMIES

Experiments were conducted in a commercial irrigated cotton field at Norwood (29° 28'S, 149° 50'E) near Moree, NSW. The treatments were (1) 0.5% petroleum oil (Lovis) spray, (2) control (untreated) and (3) plot treated with conventional insecticide sprays (treated control) viz Endosulfan (organochlorine), *Bacillus thuringiensis*, Thiodicarb (carbamate), Profenofos (organophosphate), Esfenvalerate (pyrethroid) and Chlorfluazuron (chitin inhibitor) (treated control). One ha plots were arranged in a randomized complete block design with 4 replicates per treatment.

Foliar applications of each treatment were applied on October 27, 1992 and thereafter at 14 d intervals using a ground rig until the end of February, 1993 when spraying ceased. On each occasion 142 litre/ha of petroleum oil spray was applied. Eight applications of this treatment were made during the season. The control (untreated) was left unsprayed and the treated control received 10 applications of synthetic insecticides during the season.

Pre-treatment counts of insects were made 24 h before treatment application and then every 7 days until the end of the experiment (13 weeks).Visual counts of *Helicoverpa* spp eggs and larvae on plants were made on one metre row of cotton plants in each replicate i.e. 4 metres per treatment. Cumulative total number of eggs and larvae from each treatment and control were computed and expressed as cumulative numbers per metre.

Cotton in each treated plot and unsprayed contol plots was harvested at the end of the season and the average yield (bales per acre) were compared.

Predators of *Helicoverpa* spp., were sampled weekly with sweep nets and identified and counted in the laboratory. On each sampling occasion, one sweep per plant for 50 plants in each treated plot was made on the outer top foliage of each plant following completion of visual assessments of prey numbers. Predators were separated into predatory beetles, bugs, lacewings and spiders and data expressed as cumulative predator numbers per sweep.

RESULTS

OVIPOSITIONAL PREFERENCE OF *HELICOVERPA* SPP. TO PETROLEUM OIL

In choice tests, the treatments did not suppress oviposition by *H. armigera* (Table 1). *H. punctigera* females laid significantly fewer ($P<0.05$) eggs on plants treated with petroleum oil and petroleum oil-Kelgum mixture than on the unsprayed (control) and Kelgum sprayed plants (Table 1). Under no-choice tests, *H. punctigera* again laid significantly ($P<0.05$) more eggs on the control and Kelgum sprayed plants compared with the petroleum oil and petroleum oil-Kelgum mixture sprayed plants (Table 2). *H. armigera* however, laid the same number of eggs on both treated and control plants.

FIELD STUDIES ON *HELICOVERPA* SPP. AND THEIR NATURAL ENEMIES

Approximately equal numbers of eggs were found on all treatments until the seventh sampling date (28 January). Thereafter, significantly fewer ($P< 0.05$) eggs were found on plants sprayed with petroleum oil than on unsprayed and insecticide treated plants (Fig. 1a). The number of eggs per metre per sample date found on plots treated with petroleum oil was 3.83 compared with 7.82 and 6.29 eggs respectively found on the conventional insecticide sprayed and the unsprayed plots respectively. The lower number of eggs may result from either adult repellency or fewer adults present in the treated plots.

Significant differences ($P<0.05$) in numbers of larvae were also found between treatments with the conventional insecticide sprayed plots recording the least numbers of larvae, followed by the plot sprayed with petroleum oil (Fig 1b). The highest numbers of larvae were found on the unsprayed control plot. At the end of study 4.4 and 1.6 times fewer larvae had been recorded on the conventional insecticide and petroleum oil sprayed plots respectively compared with the unsprayed control plot (Fig. 1b).

Significantly higher ($P<0.01$) cotton yields (7.32 bales/ha) were harvested from plots which received conventional insecticide sprays than from petroleum oil sprayed plots (3.70 bales/ha). The latter yield was significantly higher ($P<0.01$) than that from the unsprayed control plot (2.69 bales/ha). No phytotoxicity was detected on any of the plots.

Natural enemies of Helicoverpa spp.

Predators of *Helicoverpa* spp., identified from the plots, are given in Table 3. The highest numbers of predatory beetles and bugs per plot were recorded on the unsprayed, followed by petroleum oil and the synthetic insecticide treated plots (Figs 2). Predatory lacewings per plot were significantly higher ($P<0.05$) on the petroleum oil treatment followed by the unsprayed control with the insecticide treatment recording the least numbers (Fig. 3a). Similar numbers of spiders were recorded in the petroleum oil and the unsprayed control plots and these were significantly higher ($P<0.001$) than in the insecticide treated plot (Fig. 3b).

DISCUSSION

The reduced oviposition recorded in these experiments suggests that oil acted as a repellent discouraging egg deposition (Davidson *et al.* 1991; Larew and Locke 1990; Larew 1989). Laboratory tests conducted by Ochou (1985) and Hesler (1986) showed that mineral oils produced significant mortality of eggs and larvae of tobacco budworm, *Heliothis virescens* (F). In orchards, oils have been used as dormant sprays to control scale insects, mites, insect eggs and hibernating caterpillars, and as summer sprays to control aphids, mealybugs, mites, thrips, psyllids and whiteflies (Metcalf *et al.* 1962; Chapman 1967). In Australia, petroleum oils have been used in citrus to control a range of scales and mites and form a major component of an integrated pest management programmes (Beattie 1990; Beattie 1991).

While the field results indicated that petroleum oil apparently affected oviposition, the suppression effects were not as pronounced as in the mesh house experiments. This may be due to the fact that the oil has an effect only on *H. punctigera* and not *H. armigera* and under field conditions treated plants were exposed to both species for oviposition. Also it may be due to the failure of timing oil sprays to the development of new leaves which were of good quality, attractive and highly acceptable as suitable oviposition sites by *Helicoverpa* spp. The ovipositional suppressant effect therefore could have been partially offset by increased *H.*

armigera oviposition, the eggs of which could not be separated during the period of study from those of *H. punctigera* and also plant suitability. The high numbers of eggs recorded on all treated plots in February - March was the result of heavy *H. armigera* infestations. The answer to why the oil was effective on *H. punctigera* but not *H. armigera* might possibly be found if petroleum oil sprays with different mean molecular weights were tested. It may be possible that *H. armigera* oviposition can be suppressed by using oils with lower or higher mean molecular weights than Lovis petroleum oil used in these assays.

In spite of the non-appreciable effect on *H. armigera,* the yield from the oil sprayed plot was 1.4 times higher than the unsprayed control plot. Petroleum oils could be used most effectively before January when populations are predominantly *H. punctigera.*

Predatory beetles and bugs were suppressed by the petroleum oil spray but lacewings and spiders were not. Although predatory beetles and bugs may have come into direct contact with the oil spray, there was no evidence of dead beetles and bugs in oil sprayed plots as was found in the insecticide treated plots. The short-term residual activity of petroleum oil sprays does not severely affect populations of beneficial insects which reinvade plots after spray, although most predators and parasites are killed on contact when sprayed directly (Davidson *et al.* 1991). Therefore the impact of oil sprays on beneficial insect species may vary depending on the mobility of a species and its ability to reinvade sprayed areas from other locations. Spiders, which are less mobile compared with the predatory insects, were not affected by the spray probably because spiders on field cotton plants usually prefer the undersurface of leaves and also could descend the cotton plants into crevices in the soil. This behaviour usually helped them to avoid direct spray contact.

It should be noted that the differences observed in our mesh house oviposition choice and no-choice tests and small field plots may not be evident in a large scale commercial cotton situation under high *H. armigera* infestations. A large scale commercial cotton field presents even very mobile pests like *Helicoverpa* spp. with essentially no choice of oviposition site. Thus, the potential effectiveness of petroleum oil sprays in laboratory and field trials for *H. armigera* remains to be demonstrated. The successive applications (8 times) required for partial reduction of *Helicoverpa* population and its associated lower cotton yields makes the product too expensive for the farmer to use. However, petroleum oil may enhance potency of insect control agents improving thereby the control of *Helicoverpa* species.

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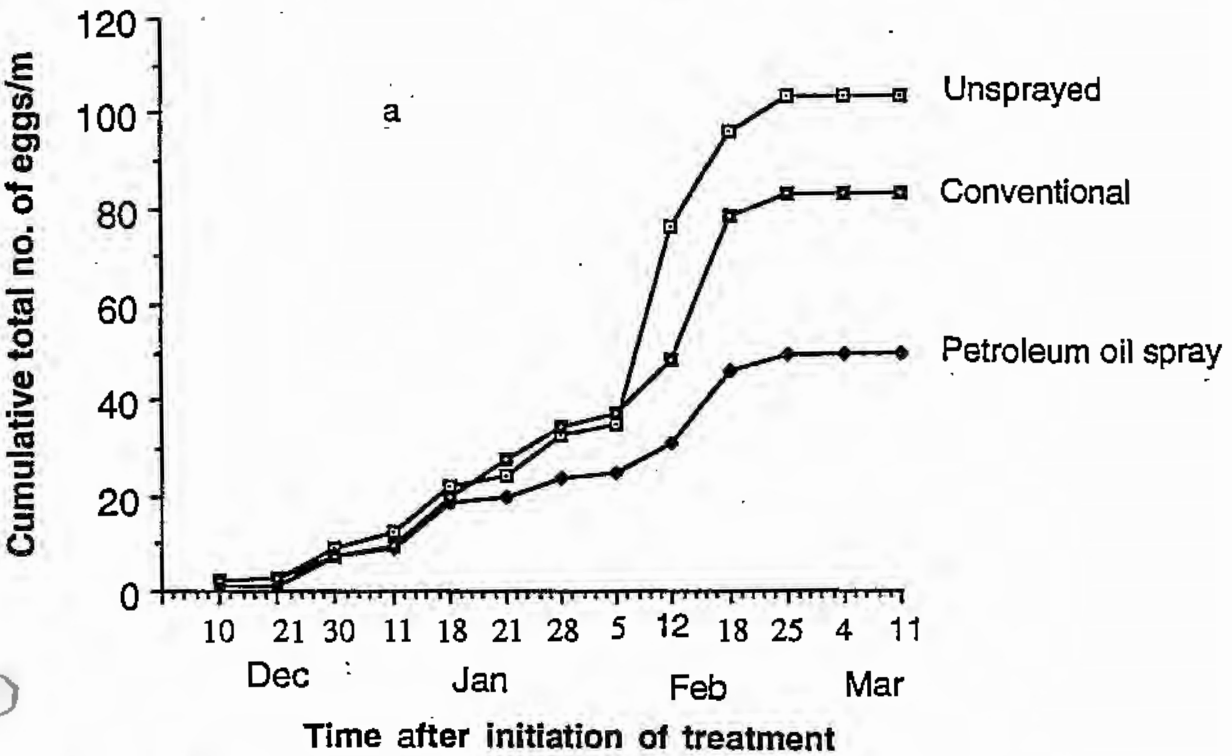
Fig. 1. Response of *Helicoverpa* spp. (a) eggs and (b) larvae to petroleum oil and conventional sprays in commercial cotton at Norwood near Moree, 1992-93.


Cumulative total no. of eggs/m
120
100
80
60
40
20
0
a
Unsprayed
Conventional
Petroleum oil spray
10
21
30
11
18
21
28
5
12
18
25
4
11
Dec
Jan
Feb
Mar
Time after initiation of treatment

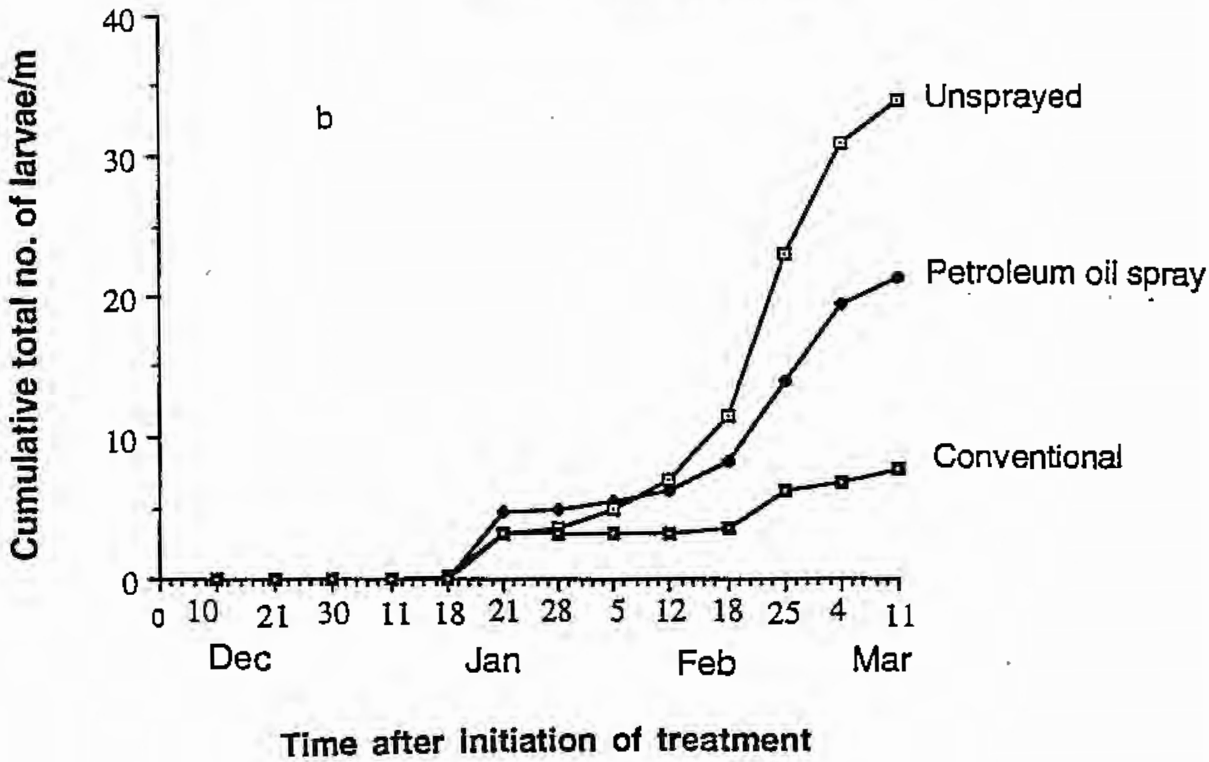

Cumulative total no. of larvae/m
40
30
20
10
0
b
Unsprayed
Petroleum oil spray
Conventional
0
10
21
30
11
18
21
28
5
12
18
25
4
11
Dec
Jan
Feb
Mar
Time after initiation of treatment

Fig. 2. Effect of petroleum oil sprays on the abundance of (a) predatory beetles and (b) bugs in commercial cotton at Norwood, 1992 - 93.

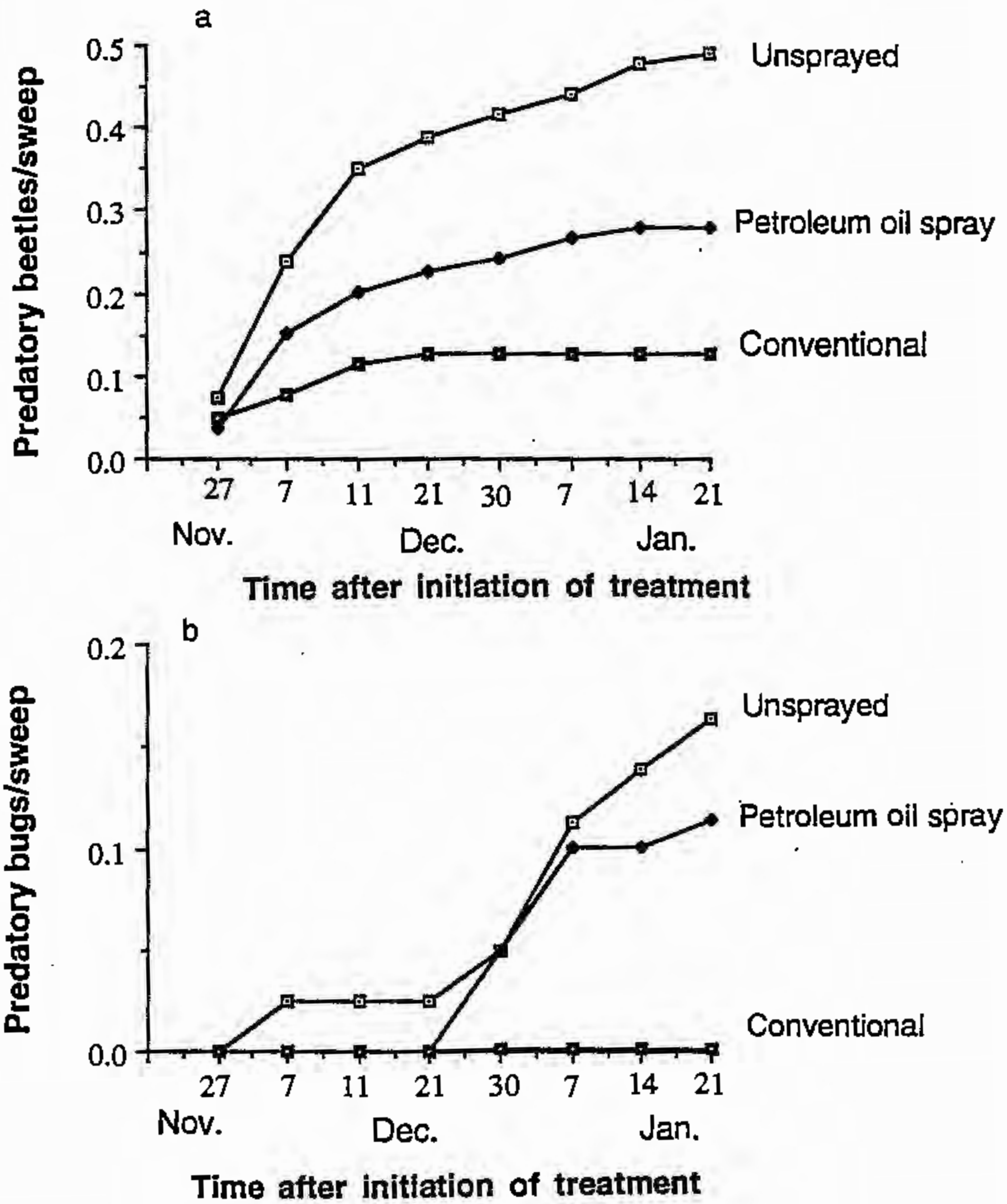

a
Predatory beetles/sweep
0.5
0.4
0.3
0.2
0.1
0.0
Unsprayed
Petroleum oil spray
Conventional
27 7 11 21 30 7 14 21
Nov.
Dec.
Jan.
Time after initiation of treatment
b
Predatory bugs/sweep
0.2
0.1
0.0
Unsprayed
Petroleum oil spray
Conventional
27 7 11 21 30 7 14 21
Nov.
Dec.
Jan.
Time after initiation of treatment

Fig. 3. Effect of petroleum oil sprays on numbers of (a) predatory lacewings and (b) spiders in commercial cotton at Norwood, 1992 - 93.

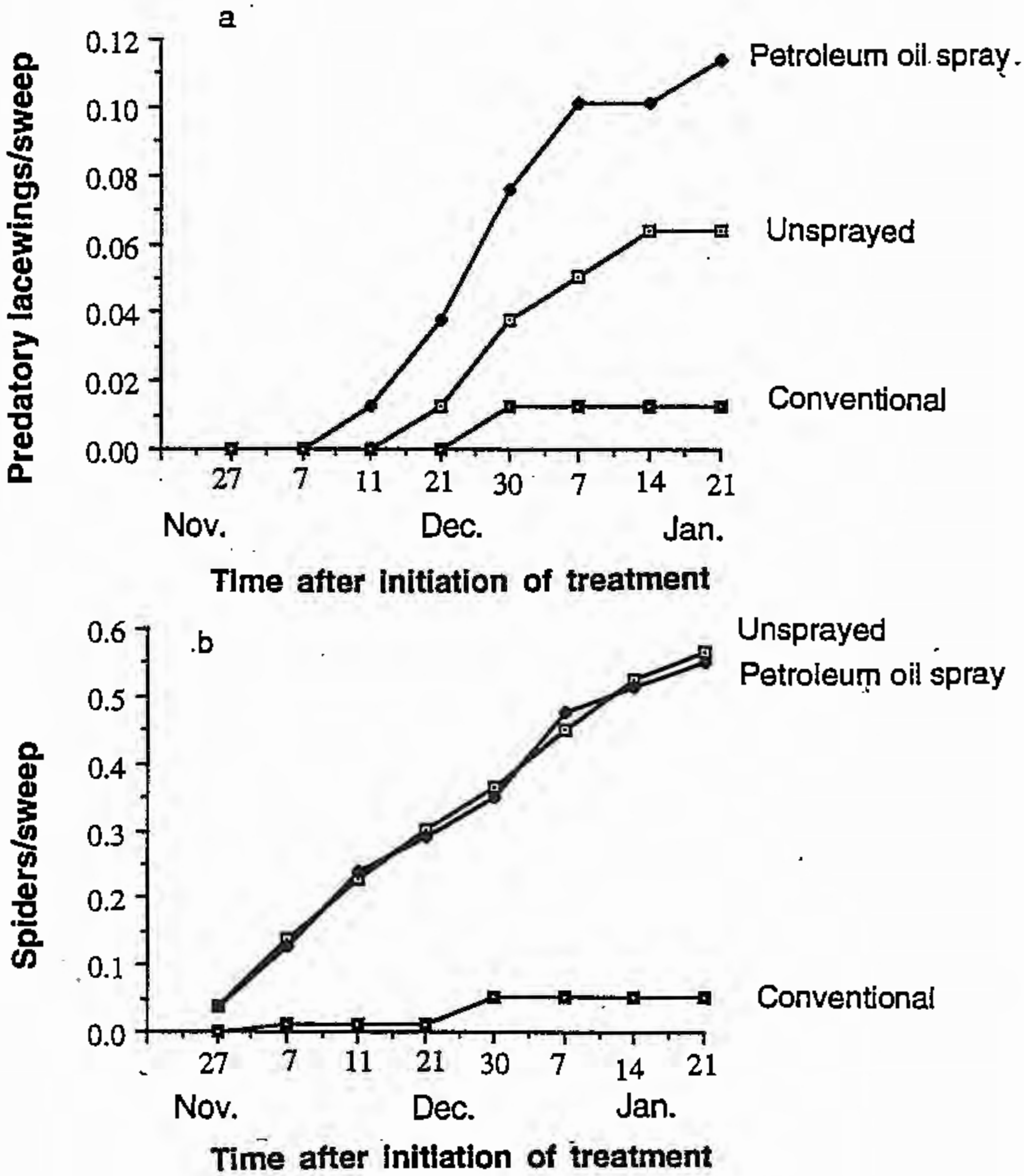

a
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Predatory lacewings/sweep
Petroleum oil spray
Unsprayed
Conventional
27
7
11
21
30
7
14
21
Nov.
Dec.
Jan.
Time after initiation of treatment
b
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Spiders/sweep
Unsprayed
Petroleum oil spray
Conventional
27
7
11
21
30
7
14
21
Nov.
Dec.
Jan.
Time after initiation of treatment

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Table 1

Free choice tests for ovipositional preferences of Helicoverpa amigera *(n = 110 pairs) and* Helicoverpa punctigera *(n = 100 pairs) to cotton plants (n = 40 plants per treatment) sprayed with petroleum oil and Kelgum in a mesh house at Narrabri, 1992 - 93.*

Treatments	*Helicoverpa armigera* Eggs/plant	*Helicoverpa punctigera* Eggs/plant
Petroleum oil	21.93 ± 2.15 a	3.13 ± 0.77 a
Kelgum	27.03 ± 2.03 a	18.36 ± 1.71 b
0.01% Kelgum + 0.5% petroleum oil	25.20 ± 2.11 a	3.06 ± 1.04 a
Control (water)	28.50 ± 2.78 a	23.17 ± 2.76 b

Means within a column followed by the same letter not significantly different ($P > 0.05$) (Least significant difference).

Table 2

No choice test for oviposition of Helicoverpa armigera *(n = 8 pairs) and* Helicoverpa punctigera *(n = 5 pairs) on cotton plants (n = 40 plants/treatment) sprayed with petroleum oil and Kelgum in a mesh house at Narrabri, 1992 - 93.*

Treatments	*Helicoverpa armigera* Eggs/plant	*Helicoverpa punctigera* Eggs/plant
Petroleum oil	6.82 ± 1.59 a	2.54 ± 0.47 a
Kelgum	7.58 ± 1.04 a	5.36 ± 1.52 b
0.01% Kelgum +0.5% petroleum oil	5.33 ± 1.15 a	1.99 ± 0.10 a
Control (water)	7.61 ± 1.23 a	5.45 ± 1.21 b

Means within column followed by the same letter not significantly different (P > 0.05) (Least significant difference).

Table 3

Major predators identified from study plots within commercial cotton at Norwood near Moree, 1992 - 93.

Order	Family	Species
Coleoptera	Coccinellidae	*Harmonia arcuata* (Fabricius)
		Diomus notescens (Blackburn)
		Coccinella repanda (Thunberg)
	Melyridae	*Dicranolauis bellulus* (Guerin)
Hemiptera	Nabidae	*Nabis capsiformis* (Germar)
	Lygaeidae	*Geocoris lubra* (Kirkaldy)
	Pentatomidae	*Cermatulus nasalis* (Westwood)
Neuroptera	Chrysopidae	*Chrysopa* spp.
	Hemerobiidae	*Micromus tasmaniae* (Walker)
Araneidae	Lycosidae	*Lycosa* spp.
	Oxyopidae	*Oxyopes* spp
	Salticidae	*Salticidae* spp.
	Araneidae	*Araneus* spp.