Field Evaluation of *Steinernema carpocapsae* (Weiser) (Rhabditida: Steinernematidae) and Selected Pesticides and Enhancers for Control of *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae)

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ABSTRACT The efficacies of sprays containing the entomopathogenic nematode *Steinernema carpocapsae* and selected pesticides and enhancers for control of citrus leafminer, *Phyllocnistis citrella*, were evaluated in two experiments. The first compared three rates of nematode infective juveniles plus a nonionic surfactant with three rates of petroleum spray oil, three rates of fenoxycarb, and single rates of methidathion and permethrin. The second compared three rates of infective juveniles plus nonionic surfactant with the same three rates of infective juveniles plus a polysaccharide and petroleum spray oil mixture, three rates of fenoxycarb plus petroleum spray oil, and single rates of methidathion and fenoxycarb. Larval mortalities caused by methidathion, permethrin, the highest rate of the nematode, and the two higher rates of fenoxycarb in the first experiment were all significantly higher than the control, with permethrin the most effective treatment. The effect of oil on mortality was ambiguous, and the percentage of mined leaves in all sprayed treatments did not differ significantly from the control. In the second experiment larval mortalities were only significantly higher than in the control in the fenoxycarb and methidathion treatments. However, with the exception of the nematode/surfactant and methidathion treatments, the number of mines per leaf in all sprayed treatments was significantly lower than in the control. Similar differences were recorded for percentage of mined leaves. In the nematode/polysaccharide/oil treatments these effects were not related to nematode concentration indicating a controlling effect of the polysaccharide/oil mixture warranting further investigation. We believe these effects on infestation levels were more important than any effect on larval mortality.

Introduction

Citrus leafminer, *Phyllocnistis citrella* Stainton, is a major pest of citrus trees. The larvae mine immature foliage using their blade-like, finely toothed mouthparts to destroy epidermal cells. Extensive mining by one or more larvae on a leaf can lead to reduced photosynthesis, severe leaf distortion and premature leaf-drop (Pruthi and Mani 1945). The damage caused may result in reduced growth rates and yields (Zhang *et al.* 1994). Recent observations in Australia suggest that infestations may induce unseasonal flowering and adversely affect normal production (pers. comm. with L. Sims, Simarloo (Australia) Pty Ltd; L. Revelant and K. Bevington, NSW Agriculture). Mature trees are less susceptible than immature trees because they produce foliage less frequently and less extensively. Causal links with the spread and severity of citrus canker, *Xanthomonas campestris* var *citri* (Hasse) Dowson (Sohi and Sandhu 1968, Sinha *et al.* 1972), and infestations by other pests (e.g. mealybugs: Shewale *et al.* 1981) have been reported.

Historically, citrus leafminer has been a serious pest in its native subtropical and tropical Asia (CAB International Institute of Entomology 1986; Ebeling 1959). In Australasia it has been recorded in American Samoa, Australia, Federated States of Micronesia, Fiji, Irian Jaya, Mariana Islands, New Caledonia, Niue, Papua New Guinea, Solomon Islands, Tonga, Wallis and Futuna, and Western Samoa (CAB International Institute of Entomology 1986; D. F. Waterhouse, CSIRO Division of Entomology, pers. comm.). It was first recorded in Australia in 1912 (Hill 1918; Mertin 1952), but was of limited importance for the next 60 years. However, in the last 25 years, it has become a significant pest following sporadic but dramatic extensions to its distribution (Beattie 1989; Beattie and Smith 1993; Sabine 1971; Tough 1975). By 1993 it had infested 97% of commercial citrus orchards in the eastern and southern states (Beattie and Smith 1993), and by April 1995 100% of the Australian industry was affected after outbreaks in southwestern Western Australia (W. Woods, Department of Agriculture Western Australia, pers. comm.). Similar explosive expansions in its distribution occurred in Africa in the 1970s (Guérout 1974), and since 1993 it has become permanently established in South Africa, North America (Alabama, Florida, Louisiana, and Texas), and most countries in Central America, the Caribbean and the Mediterranean (Heppner 1993; Knapp *et al.* 1995: pers. comm. with J. C. Allen, University of Florida, USA; M. Marsà, Institut de Recerca i Technologia Agroalimentàries, Spain; G. M. Orphanides, Agricultural Research Institute, Cyprus; D. Smith Queensland Department of Primary Industries; A. B. Ware, Outspan Citrus Centre, South Africa; D. F. Waterhouse, CSIRO Division of Entomology).

Effective control of leafminer is difficult because larvae are protected by their mines and pupae by their pupal chambers. Since 1960 commercial control has generally relied on the use of organophosphate, carbamate or pyrethroid

sprays (Heppner 1993; Zhang *et al.* 1994); control methods not compatible with sustainable integrated pest management (IPM) programs (Beattie *et al.* 1991; Helle and Sabelis 1985; Rosen 1990; Viggiani 1984; Zhang *et al.* 1994) but recommended in the absence of suitable alternatives. Multiple sprays are required to protect new leaves on growing flushes because their residual activity can be shorter than the susceptible growth phase, and residues are diluted as young leaves present at spraying grow and new leaves are produced. In the tropics, leaves are produced almost continuously (Bhumannavar and Singh 1983; Wilson 1991) and sprays are often applied fortnightly.

Sprays of entomopathogenic nematodes have been used to control bark and foliar pests instead of broad spectrum pesticides (Butani 1979; Deseö and Miller 1985; Gaugler 1981; Harris *et al.* 1990). This led one of us (V. Somsook) to dip leaves infested by citrus leafminer larvae in solutions containing up to 10×10^6 *Steinernema* (= *Neoaplectana*) *carpocapsae* (Weiser) juvenile infectives/L of water and subsequently observe >80% mortality of parasitised larvae.

Here we report the outcome of two experiments which examined the efficacy of *S. carpocapsae* for control of leafminer in a citrus nursery. The first compared sprays containing either *S. carpocapsae* and a surfactant, with petroleum spray oil, fenoxycarb, fenoxycarb plus petroleum spray oil, permethrin or methidathion. Oil was included to determine its effect on egg and larval mortality as research workers at the Biological and Chemical Research Institute (BCRI) were already investigating the use of oils to control other citrus pests. Fenoxycarb was evaluated as another alternative to broad-spectrum pesticides. Permethrin and methidathion were current NSW Agriculture & Fisheries' recommendations for the control of leafminer in commercial nurseries and orchards, respectively (Beattie 1989). The second experiment compared sprays containing either *S. carpocapsae* plus surfactant, with the nematode plus petroleum spray oil and polysaccharides, methidathion, fenoxycarb, or fenoxycarb plus petroleum spray oil. The oil and polysaccharides were used to slow the evaporation of spray droplets and to enhance nematode movement into larval mines.

Materials and methods

Both experiments were conducted in a commercial nursery at Kenthurst, on the outskirts of Sydney, New South Wales. Separate lots of 384 potted, 1-1.5 m tall Eureka lemon *Citrus limon* (L.) Burm. f. trees with 0.5 m high canopies were arranged in four, single-tree width rows of 96 trees for each experiment. Details of the sprays applied are given in Table 1. The petroleum spray oil was Caltex Lovis, a C21 narrow-range oil (50% distillation temperature of 361 °C at 101.33 kPa) formulated with two nonionic surfactants (1% v/v). The polysaccharide was a food-grade blend of xanthan and locust bean gums (Kelgum). The nonionic surfactant used in the nematode sprays was Triton CS-7.

Each experiment was a randomised complete block design with 12 treatments replicated four times, and eight trees per replicate (= plots). The position of plots along rows was used as a

Table 1. Sprays applied to potted lemon trees for control of citrus leafminer.

Experiment	Year	Treatment	Formulation in 1L water	Figure code
1	1991	1	unsprayed control	control
		2	5×10^6 *S. carpocapsae* infectives plus 0.1 mL nonionic surfactant	low nem
		3	10×10^6 *S. carpocapsae* infectives plus 0.1 mL nonionic surfactant	mid nem
		4	30×10^6 *S. carpocapsae* infectives plus 0.1 mL nonionic surfactant	high nem
		5	5 mL petroleum spray oil	low oil
		6	10 mL petroleum spray oil	mid oil
		7	20 mL petroleum spray oil	high oil
		8	0.3 g 250 g/kg fenoxycarb	low feno
		9	0.5 g 250 g/kg fenoxycarb	mid feno
		10	1 g 250 g/kg fenoxycarb	high feno
		11	0.1 mL 400 g/L permethrin	perm
		12	1.25 mL 400 g/L methidathion	meth
2	1992	1	unsprayed control	control
		2	5×10^6 *S. carpocapsae* infectives, 5 mL petroleum spray oil plus 0.1 g Kelgum	low cok
		3	10×10^6 *S. carpocapsae* infectives, 5 mL petroleum spray oil plus 0.1 g Kelgum	mid cok
		4	30×10^6 *S. carpocapsae* infectives, 5 mL petroleum spray oil plus 0.1 g Kelgum	high cok
		5	5×10^6 *S. carpocapsae* infectives plus 0.1 mL nonionic surfactant	low ct
		6	10×10^6 *S. carpocapsae* infectives plus 0.1 mL nonionic surfactant	mid ct
		7	30×10^6 *S. carpocapsae* infectives plus 0.1 mL nonionic surfactant	high ct
		8	1 g 250 g/kg fenoxycarb plus 0.5 mL petroleum spray oil	low f/o
		9	1.5 g 250 g/kg fenoxycarb plus 0.5 mL petroleum spray oil	mid f/o
		10	2 g 250 g/kg fenoxycarb plus 0.5 mL petroleum spray oil	high f/o
		11	2 g 250 g/kg fenoxycarb	feno
		12	1.25 mL 400 g/L methidathion	meth

covariate. Rows were about 2.5 m apart and 1 m separated each 2 m-long plot within rows. Trees were pruned and fertilised several weeks before each experiment to encourage new growth.

Chapin 2179, 9 L compressed air sprayers equipped with Rega 031 fan-nozzles (internal orifice diameter = 1.37 mm) were used to apply 250 mL of spray per plot on each occasion sprays were applied. Different spray units were used for each treatment type. Sprays were applied in two separate 10 second passes along each side of a plot. The nozzle was held about 0.5 m from the trees and positioned so that the spray fan was vertical. One pass was made with the nozzle angled up at 45° from horizontal, the second with the nozzle angled down at 45° from horizontal. The procedure was equivalent to applying about 125 mL/m²/side/plot. All sprays were applied at dusk to minimise detrimental effects of ultraviolet radiation and sunlight on the nematodes (Gaugler and Boush 1978). The spray units were shaken gently during spray application to ensure mixing of the water with the chemicals and nematodes, and to provide some aeration of the nematodes. A portable plastic screen was used to prevent spray drift.

Experiment 1. Sprays were applied on 4, 11 and 18 April 1991. A shipment of sachets containing known numbers of *S. carpocapsae* infective juveniles in 1 cm³ foam was imported overnight from Thailand in an insulated container with an ice pack. At BCRI sachets were stored in a refrigerator for up to 5 weeks at 10 °C. Nematode sprays were prepared 24 h before application by progressively rinsing infective juveniles from appropriate quantities of foam, gradually making the volumes up to 1 L with water and adding the surfactant. Each 1 L mixture was stored at 10 °C in a 2 L plastic bottle with a loosely fitted cap (to allow some aeration) until the bottles were taken to the nursery. At the nursery, bottles were kept cool until the sprays were applied. All leaves on these flushes, including the smallest ones visible within buds and those on the tips of more developed flushes, were examined. *In situ* counts of the number of leaves per flush with mines containing live larvae, eclosed mines (classed as live), dead larvae and non-eclosed mines with no larvae were made on 24 April using 8× prism loupes. Three randomly selected susceptible flushes were examined per tree. Any acute phytotoxicity (discolouration and burns) caused by the sprays was assessed visually throughout the experiment.

Experiment 2. The sprays were applied on 10, 15, 24, and 30 April, and 11 May. Known numbers of infective juveniles of the A24 strain of *S. carpocapsae* were supplied regularly in milled attapulgite by the CSIRO Division of Entomology, Canberra, and stored at 10 °C. About 24 h before spraying weighed portions of attapulgite containing the required number of infective juveniles were wrapped separately in clean tissue and stored at 10 °C. Immediately before application sprays were prepared by gently mixing the weighed portions with small amounts of water or water plus polysaccharide, then filtering the mixture through a 425 µm test sieve and making the volumes up to 1 L before adding the surfactant or oil. Flushes were randomly selected and cut from the trees on 27 and 28 May and stored at 4 °C for up to 17 d before examination. The level of leafminer infestation was so high that counts of live, dead and eclosed mines, leaves with live, dead or no mines, mines with larvae parasitised by the endemic ectoparasitoid *Semielacher petiolatus* (Girault) (Hymenoptera: Eulophidae), and visual assessments of acute phytotoxicity, had to be made in the laboratory using a stereomicroscope. The number of larvae parasitised was based on the presence of immature stages of the ectoparasitoid on dying hosts. Mines containing live parasitoids were classed as "live". Flushes were categorised into six age groups ranging from 2-week-old immature flushes to mature flushes more than 5-weeks old based primarily on leaf colour (young purple, purple, purple/green, young green, green, old green). Only leaves ≥10 mm long were examined because observations in the first experiment indicated that eggs were rarely laid on younger leaves. Also, the number of leaves counted per flush did not include undeveloped leaves ≤2 mm long.

Statistical analyses. Because eggs were rarely laid on leaves ≤10 mm in length the emphasis of the analysis was changed to determine the effectiveness of sprays in controlling infestation by leafminer on flushes that began growing at the start of each experiment rather than including all flushes sampled regardless of age. For Experiment 2 in which flushes were aged, this simply involved culling the data for old green flushes (which began growing prior to 10 April) and, young/purple and purple flushes (whose growth spurt began after 30 April). Culling of data for flushes in Experiment 1, however, was not possible because no measure of flush age was recorded. For this reason the number of leaves on a flush was used to estimate if it was probably too young. We randomly selected 30 flushes with no leaves greater than 10 mm long and 30 flushes with at least one leaf longer than 10 mm from potted lemon trees and made histograms of both samples. The histograms suggested that flushes with 6 or fewer leaves were too young so only flushes with more than 6 leaves were included in the analysis of Experiment 1. There was no objective way of excluding old green flushes that began growing prior to 4 April, but few were present because of the pruning carried out before the experiment. A consequence of this culling of data in both

experiments was that the number of trees varied between plots as, in some cases, individual trees had all their sampled flushes excluded and this meant that the experimental designs were unbalanced.

In Experiment 1 we examined the effect of treatments on the proportion of mines that were dead on a flush (number of dead mines divided by the number of live and dead mines) and the proportion of infested leaves on a flush (number of leaves with live and dead mines divided by the total number of leaves). For each tree in a plot the average value for each dependent variable was used rather than the individual flush data: "tree" was therefore the sample unit not "flush". Data were arcsine square-root transformed to stabilise variances and to better approximate normal distributions. The proportion of infested leaves on a flush was analysed by ANCOVA with position of plot along a row as the covariate. Because some plots had no mines on any flush, calculation of the proportion of mines on a flush that were dead resulted in the ANCOVA having eight empty cells. To overcome this problem (see Norusis 1993), the analysis was performed with block number also treated as a covariate. Variances were homogeneous for the proportion of leaves infested (Cochran's C: $C_{4,46} = 0.06$, ns) but not for the proportion of dead mines ($C_{10,12} = 0.21$, $p<0.05$). Data remained skewed to the right despite the transformation. The assumption of homogeneity of regression slopes was met for the proportion of leaves infested ($F_{14,266} = 1.24$, ns) and for the proportion of dead mines ($F_{22,98} = 0.81$, ns).

For dependent variables in which ANCOVA revealed a significant difference between treatments, a series of nonorthogonal *a priori* contrasts were performed. We used t-tests to compare each spray treatment to the control and polynomial contrasts to look for linear and nonlinear components within the levels of the nematode, oil and fenoxycarb treatment groups. For each of these polynomial contrasts the control was used as the "zero concentration" giving four levels and three polynomial component effects for each treatment group. We used the Dunn-Sidák method (Sokal and Rohlf 1981) to calculate the comparisonwise error rates for nonorthogonal contrasts. Our results are presented using both the pairwise (α) and comparisonwise (α') significance levels. We considered differences at comparisonwise error levels as "significant" while those at pairwise error levels as trends.

Dependent variables in Experiment 2 were the proportion of mines on a flush that were dead (square root transformed), the proportion of leaves on a flush that were infested (cube root transformed) and the proportion of larvae parasitised by *S. petiolatus* (reciprocal transformed). As for Experiment 1, "tree" was used as the sample unit. Statistical analysis was as for Experiment 1. All variances were homogeneous (proportion dead: $C_{4,46} = 0.07$, ns; proportion infested: $C_{4,46} = 0.08$, ns; proportion parasitised: $C_{4,46} = 0.09$, ns). Data again remained non-normal (right-skewed) despite the transformations applied. The homogeneity of regression slopes assumption was met for the proportion of dead mines ($F_{14,205} = 0.93$, ns) and for the proportion of mines parasitised ($F_{14,205} = 0.76$, ns) but not for the proportion of leaves infested ($F_{14,205} = 2.28$, $p<0.01$, ns). In this latter case, slopes within blocks ($F_{3,205} = 1.73$, ns) and treatments ($F_{11,205} = 1.68$, ns) were homogeneous.

For both experiments results are presented as back-transformed unweighted means adjusted for covariate and block effects. Adjustment was made for the covariate (see Norusis 1993) regardless of whether or not its effect was significant. Averaging all samples within a treatment regardless of variations in sample sizes between replicates gives a biased estimate of the mean. An unbiased estimate is obtained by averaging data within each replicate then averaging these values across all replicates. For those treatment groups with significant polynomial trends, r^2-values were calculated based on regressions fitted to the adjusted, unweighted treatment means.

All analyses were performed using the SPSS for Windows Version 6.0 statistics package (SPSS Inc 1993).

Results

Experiment 1. *Larval mortality* (Fig. 1a): Significant differences occurred between treatments ($F_{11,117} = 8.58$, $p<0.01$). Compared to the unsprayed control, mortality was significantly higher in five treatments and tended towards significance in two others. Permethrin was the most effective treatment resulting in 100% mortality. The nematodes only caused significant mortality at the higher dose, but a linear trend was evident with increasing concentration ($t = 6.80$, $p<0.001$, $r^2 = 0.92$). Fenoxycarb caused significant mortality at all concentrations and a linear trend was apparent with increasing concentration ($t = 3.09$, $p<0.01$, $r^2 = 0.95$). Oil tended to be significant at the middle concentration (1%) and there was a significant but weak linear increase in mortality ($t = 7.88$, $p<0.001$, $r^2 = 0.07$) with increasing oil concentration.

Per cent infested (mined) leaves (Fig. 1b): There were no significant differences ($F_{11,32} = 1.01$, ns).

Acute phytotoxicity: No symptoms were observed.

Experiment 2. *Larval mortality* (Fig. 2a): Significant differences occurred between treatments ($F_{11,32} = 5.88$, $p<0.001$). Compared to the unsprayed control, mortality was significantly different in two treatments and tended towards significance in four others. Methidathion was the most effective treatment

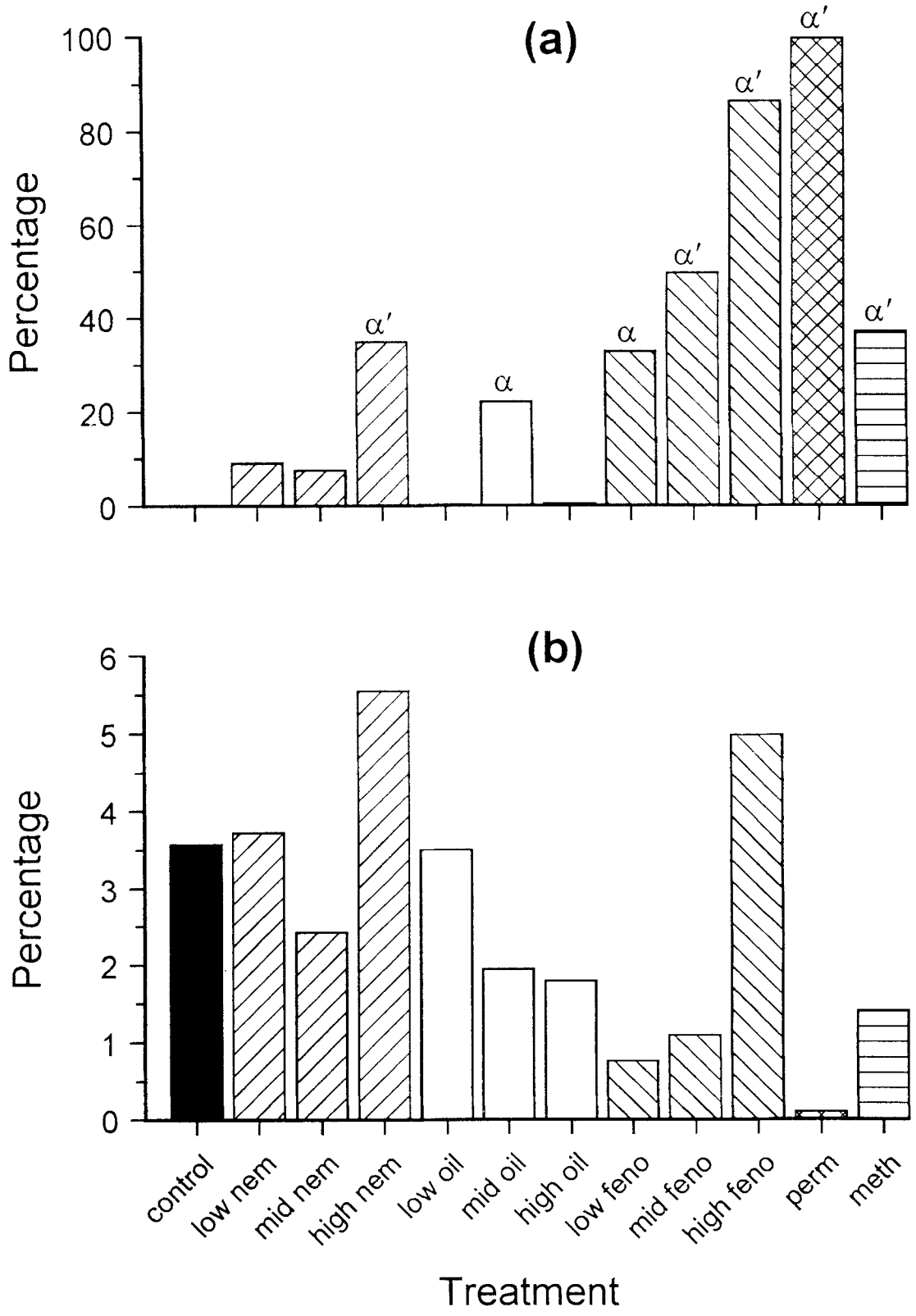

Fig. 1. Effect of Experiment 1 treatments on the average percentage of dead mines on flushes (a) and the average percentage of leaves on flushes that were infested (b); see Table 1 for codes; α = significant only at pairwise error rate, α′ = significant at pairwise and companionwise error rate.

resulting in 59% mortality. Significant linear increases in mortality were apparent with increasing concentrations of nematodes in the nematode plus oil and polysaccharide treatments ($t = 6.33$, $p<0.001$, $r^2 = 0.89$) and the nematode plus surfactant treatments ($t = 5.23$, $p<0.001$, $r^2 = 0.87$). The addition of oil to fenoxycarb appeared to reduce its effectiveness. There was a very weak linear trend for the fenoxycarb plus oil treatments ($t = 4.66$, $p<0.001$, $r^2 = 0.05$).

Per cent infested (mined) leaves (Fig. 2b): Significant differences occurred between treatments ($F_{11,32} = 12.57$, $p<0.001$). Infestations were significantly fewer than the unsprayed control in seven treatments: the nematode, oil plus polysaccharide treatments and all fenoxycarb treatments. There was a significant linear decrease in infestations with increasing concentration of nematodes in the nematode plus surfactant treatments ($t = 7.35$, $p = <0.001$, $r^2 = 0.37$).

Number of mines per leaf (Fig. 2c): The number of mines per leaf differed significantly between treatments ($F_{11,32} = 12.61$, $p<0.001$). The number of mines were significantly fewer than the unsprayed control in seven treatments: the nematode, oil plus polysaccharide treatments and

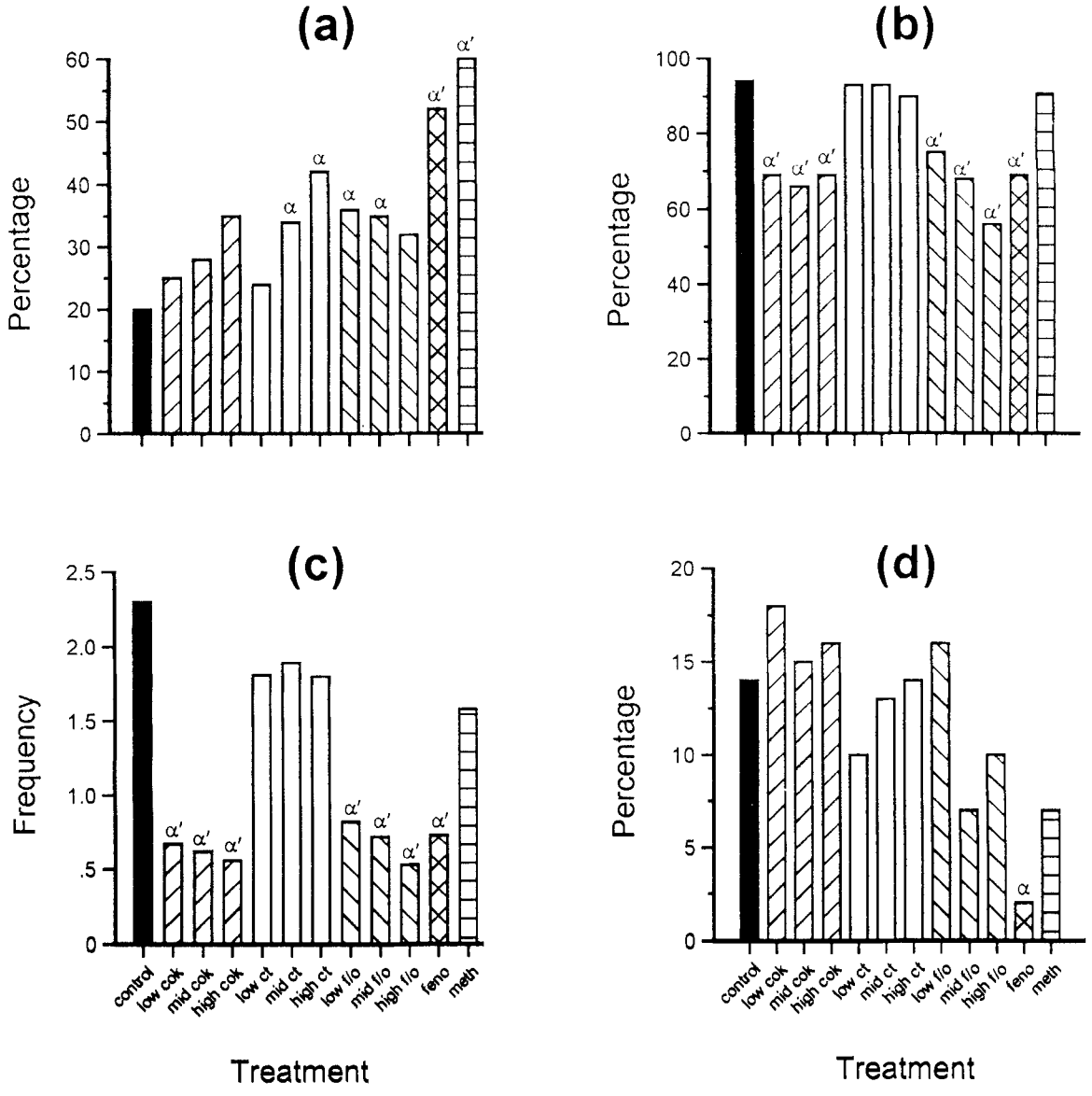

Fig. 2. Effect of Experiment 2 treatments on the average percentage of dead mines on flushes (a), the average percentage of leaves on flushes that were infested (b), the average number of mines per leaf on flushes (c) and on the percentage of mines parasitised (d); see Table 1 for codes.

all fenoxycarb treatments. These differences were substantial, representing a 69% reduction in the number of mines. The effect of the nematode, oil plus polysaccharide treatments, moreover, was independent of the concentration of nematodes in the sprays. There was a weak linear trend in the nematode and surfactant treatment ($t = 7.35$, $p < 0.001$, $r^2 = 0.036$).

Per cent parasitism (Fig. 2d): There was no significant differences between treatments. The sex ratio of *S. petiolatus* was 1:1 based on 59 male and 58 female pupae or adults observed.

Acute phytotoxicity: Yellow spotting of young purple leaves was apparent in the fenoxycarb plus oil treatments but disappeared as the leaves matured. No symptoms were observed in the other treatments.

Discussion

The results for permethrin (Fig. 1a) and methidathion (Figs 1 and 2) were expected and consistent with previous research on pyrethroids and organophosphates (Awate *et al.* 1976; Beattie and Loebel 1983; Bhumannavar 1987; Batra and Sandhu 1986; Radke and Kandalkar 1988). The results for fenoxycarb (Figs 1 and 2) indicate that it can be used as an effective alternative to broad-spectrum pesticides in commercial orchards but rates required might not be commercially acceptable. In Australia costs could exceed $400/ha for a 3,000 L/ha spray applied to mature 4 m-high trees planted at 450-500 trees/ha; some 4-5 times higher than methidathion. The results for *S. carpocapsae* show that it will control leafminer, but its use (based on current costs) is not commercially acceptable at the concentrations tested (R. Bedding, CSIRO Division of Entomology, pers. comm.). Better aeration of the nematodes before and during spraying may have enhanced their effectiveness, but this was not possible under field conditions.

The effect of the polysaccharide/oil mixture on the number of mines per leaf (Fig. 2c) was entirely unexpected given the results obtained for oil in Experiment 1 (Figs 1a,b). We assume it repelled adult females and reduced oviposition. The mixture was chosen independently of previous research on the use of anti-desiccants (Shapiro *et al.* 1985) after laboratory tests indicated that the evaporation rate of droplets containing the mixture was significantly slower than droplets of water, or water and surfactant (Somsook and Beattie unpublished data). However, the mixture did not improve the efficacy of the nematode treatments in Experiment 2 (Fig. 2a). While some petroleum spray oils are toxic to *S. carpocapsae* (Shapiro *et al.* 1985), we found no evidence to suggest that Lovis was detrimental to nematodes (e.g. Fig. 2c).

The results (Fig. 2c) clearly indicate that one or both components of the polysaccharide/oil mixture were as effective or more effective than methidathion and fenoxycarb treatments but, whether the oil or the polysaccharide caused the effect was not resolved in these experiments. Crude oil and kerosene emulsions with or without tobacco decoctions or nicotine sulphate were recommended for control of leafminer in Asia before 1950 (Dammerman 1929; Fletcher 1917, 1919; Hutson 1933; Hutson and Pinto 1934; Srivastra 1957), but it is clear, however, that kerosene was effective without nicotine (Anon. 1937; Hutson 1933). The distillation properties of the crudes and kerosenes used is not known. However, their distillation properties may have varied considerably and the kerosenes may have been different to contemporary ones. There are no references to the use of saturated white oils, including contemporary narrow-range petroleum spray oils. Based on knowledge about the use of oils for the control of citrus pests other than leafminer, the kerosenes and the crudes were probably quite phytotoxic (Ebeling 1950; Riehl 1969). Dammerman (1929) suggested larval mortality and oviposition deterrence as two possible modes of action of oils.

Despite the references to crude oil and kerosene, the possibility of an effect related to Kelgum cannot be dismissed. Xanthan gum is a product of the fermentation of glucose by *X. campestris* pv. *campestris* (Pammel) Dowson. Dead mines are often associated with canker in Asia, leading us to consider that adult moths might avoid wounds due to the presence of gums. However, the locust bean gum in Kelgum is produced from ground kernel endosperms of pods of the carob or locust bean tree, *Ceratonia siliqua* L. Unfortunately, very little is also known about the behaviour of leafminer, particularly of the criteria used by adult females to differentiate immature from older leaves, although leaf polysaccharides could be involved.

Whatever the cause of the effect of the polysaccharide/oil mixture the implications could be far reaching. Petroleum spray oils are compatible with IPM programs (Beattie 1990; Riehl 1969) and there is no reason to assume that Kelgum would be disruptive. The cost of the chemicals would be less than a quarter of that of methidathion.

Acknowledgments

We gratefully acknowledge the Horticultural Research and Development Corporation and the N.S.W. Horticultural Stock and Nurseries Act Ministerial Advisory Committee for financial support in 1991 (HRDC Project CT031), A. T. Eyles and Sons for nursery trees and facilities, Caltex Oil (Australia) Pty Ltd for Lovis, and Dr R. Bedding for Kelgum and *S. carpocapsae* infective juveniles in 1992. We thank Mary Ann Terras, Melanie Scanes and Ross Parkes for their assistance.

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(Accepted 26 June 1995)