Journal of Agricultural Science, Cambridge (2000), **134**, 413–420. *Printed in the United Kingdom*

Efficacy of Chinaberry tree (Meliaceae) aqueous extracts and certain insecticides against the pea leafminer (Diptera: Agromyzidae)

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(*Revised MS received 11 January 2000*)

SUMMARY

Aqueous extracts of fruits and leaves of the Chinaberry tree, *Melia azedarach* L. were tested for their efficacy versus other biotic and synthetic insecticides against the pea leafminer, *Liriomyza huidobrensis* (Blanchard). The study included field experiments on naturally infested swiss chard, *Beta vulgaris* var. *Cicla* L., and greenhouse experiments on artificially infested cucumber, *Cucumis sativus* L. that were conducted in 1995–96. The other treatments included azadirachtin (0·25%), ultrafine mineral oil, abamectin, cyromazine, imidacloprid, pyrazophos and control. Results of field experiments indicated that *Melia* fruit extract and the other insecticides significantly lowered the number of larvae per swiss chard plant as compared to the control, at 5 days sampling after second spray or 15 days after first spray, when two consecutive sprays were performed. However, at 10 days after second spray, the fruit extract did not differ significantly from the control, but it was comparable in its effect to the insecticides, except abamectin and cyromazine. In greenhouse experiments, the pea leafminer larvae were found at higher densities on cucumber leaves located at the lower plant part (10–60 cm) compared to other leaf positions. The *Melia* fruit extract and the other pesticides significantly decreased the number of live larvae per cucumber leaf compared to the control, 10 days after each spray. The fruit extract, abamectin, cyromazine, imidacloprid and pyrazophos lowered the leafminer population significantly compared to the control, throughout the period of the experiments. However, the fruit extract was significantly less effective than these insecticides at the final count, 20 days after second spray. Abamectin and cyromazine consistently showed a significant decrease in number of larvae, in both field and greenhouse experiments. At certain periods of the experiments, *Melia* extracts were comparable in their efficacy to the tested commercial biorational and synthetic pesticides. Thus, they have a good potential to be used in the management of the pea leafminer. This is the first report for use of *M. azedarach* against *L. huidobrensis*.

INTRODUCTION

The pea leafminer, *Liriomyza huidobrensis* (Blanchard) has been lately identified as a new species in Lebanon and most probably was introduced on imported material (Abou-Fakhr Hammad & Nemer 2000) The leafminer outbreak occurred in Lebanon in 1990 and was first noticed by local farmers on *Gerbera jamesonii* (J. D. Hook, personal communication). Other crops such as cucumber, *Cucumis sativus* L., and bean, *Phaseolus vulgaris* L., were also attacked, and especially swiss chard, *Beta vulgaris* var. *Cicla* L., whose marketing has become impossible. Although other dipterous leafminers were previously identified in Lebanon, none caused economic damage (Talhouk 1969). The invasion of *L. huidobrensis* was not an isolated incident but was related to its invasion in other countries like Syria and Israel (Weintraub & Horowitz 1995). *L. huidobrensis*, which until recently had a relatively limited distribution, can now be considered cosmopolitan, and is a major pest on numerous ornamental and vegetable crops almost everywhere it occurs (Parrella 1987; Shepard *et al.* 1998).

The control of *L. huidobrensis* by chemicals remains a great challenge due to its resistance to insecticides (Parrella & Keil 1985; Macdonald 1991). Implementing biological control for this pest where it is not indigenous is also difficult (Harris *et al.* 1990; Jayaraj

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& Rabindra 1992). The Chinaberry tree, *Melia azedarach* L., is a biopesticidal tree originating in India, and is found in Lebanon and other Mediterranean regions. It contains several limonoids, a class of chemicals that act as feeding deterrents and growth regulators in insects (Lee *et al*. 1991). A limited number of studies dealt with use of organic solvent extracts of *M*. *azedarach* against different pests (Schmidt *et al*. 1997; Valladares *et al*. 1997). Several studies investigated the effect of aqueous neem extracts against *Liriomyza trifolii* (Burgess) (Webb *et al*. 1983; Stein & Parrella 1985; Larew 1987; Meisner *et al*. 1987). The main objective of the present research was to study the insecticidal efficacy of aqueous extracts of *M*. *azedarach* in comparison with other commercial biorational and synthetic pesticides against the pea leafminer. These extracts could provide a relatively inexpensive and readily available insecticide to combat the pest resistance to insecticides.

MATERIALS AND METHODS

Field experiments

The experiments were conducted in three different locations: location 1 at the greenhouse area (sea level), Faculty of Agricultural and Food Sciences (FAFS), American University of Beirut (AUB), location 2 in Choueifat at an elevation of 150 m, and location 3 in Wadi Chahrour at an elevation of 300 m. The experiments were conducted from September until November 1995. Another modified field experiment was repeated at location 1 from September until November 1996.

Plant material and chemicals

Seeds of the local swiss chard variety 'Baladi' were planted in the two seasons: September–November 1995 and 1996. Two-week-old seedlings were transplanted to the field where they were naturally infested by the leafminer. Treatments included the following insecticides: abamectin (Dynamec®), Sunspray® ultrafine oil, azadirachtin 0·25% (Margosan-O®), imidacloprid (Confidor®), and cyromazine (Trigard®) that were tested against the leafminer at their recommended rates (Table 1).

Table 1. *Insecticides tested during this study with their corresponding rate of application*

Treatment	Rate (ml/l)
Abamectin	0·50
Oil	4·00
Azadirachtin	3·10
Imidacloprid	0·75
Cyromazine	0·25*

* 0·25 g/l.

Preparation of M. azedarach *extracts*

In the autumn of 1995, 200 g of fresh mature fruits or leaves were collected from Wadi Chahrour and were ground in a blender with distilled water at 1:3·5 (w/v). The ground extracts were soaked for 24 h, filtered through cheesecloth, and applied directly on field swiss chard. In the autumn of 1996, 200 g of fresh mature fruits or leaves were ground in a blender at 1:5 (w/v), soaked for 24 h and filtered by vacuum through filter paper (Whatman no. 41). The first concentration of 0·28 g-eq/ml was chosen, based on our preliminary trials. The change in the used concentrations was due to the necessity of using a lot of water because the active ingredients of neem, a related meliaceous tree, are known to be of very low solubility in water (National Research Council 1992).

Experimental set-up

In each field of the selected locations, a plot of 40 m² was divided into 24 subplots, each subplot of one m² area. Twenty-eight swiss chard plants were transplanted into each one m² and planted in four rows at a distance of 15 cm within row and 30 cm between rows. Eight treatments including the control, distilled water, were applied at the rate of about 283 ml/m² as a full cover spray by a 5 litre sprayer Deltaspray® (Angiolo and Armandu Deltaglia S.P.A., Italy). Each treatment was replicated three times, each subplot being one replicate. The experiment was laid out as a completely randomized design with multiple observations. In the autumn of 1995, plants in all locations were treated once at the larval stage. In the autumn of 1996, plants were sprayed twice at an interval of 10 days. The first spray was at the puncture stage, i.e. punctures performed by the female leafminer for egg laying or for feeding on plant sap (McKinlay *et al*. 1992). The second spray was at the larval stage.

Data collection

Each plot was observed several times: initially just before treatment, followed by observations at 7 and 14 days after single treatment in 1995, and at 10 days after first treatment and at 5 and 10 days after second treatment in 1996. Counts were limited to the same 10 plants in the middle of each subplot to avoid border effects. The data were collected by direct count of mines on the upper leaf surface with the help of a magnifying lens. Total number of mines was reported per swiss chard plant.

Statistical analysis

The statistical package MSTAT (MSTAT-C 1991) was used for data analysis in all experiments of the study. Data collected from each location were analysed separately to eliminate variability among locations. Bartlett's (1937) test for homogeneity of variance (Gomez & Gomez 1984) was performed on

variances of data collected at each observation date in each location. The data were transformed into log $(x+1)$, x being the total number of mines per plant, to stabilize variances (Sokal & Rohlf 1987). ANOVA was applied to data collected after first spray, at the puncture stage, in autumn 1996. Covariance analysis was applied to the collected data after the single spray (autumn 1995) and after the second spray (autumn 1996); initial counts of mines served as the covariate. All means were separated by Fisher's (1949) least significant difference (LSD) test, if significant *F* values were obtained.

Greenhouse experiments

The experiments were conducted at the FAFS Greenhouse area, AUB, from March until July 1996.

Insects, plant material and chemicals

A leafminer colony was maintained in a glasshouse compartment at 28 ± 3 °C, 70 ± 20% RH and a photoperiod of 14:10 (L:D) h on swiss chard and bean. Seeds of the greenhouse cucumber, *Cucumis sativus* L., variety 'Fatima' (Local supplier: Amalia Ltd.; original source: AgrEvo, Holland) were planted in plastic pots. The seedlings were placed in insect-proof cages (30 by 20 cm diameter) until they reached the two-true leaf stage. Each plant was then exposed to two adult leafminers from the rearing colony for 2 h to ensure oviposition, before transplanting. The insecticides tested were the same as for the field experiments on swiss chard in addition to pyrazophos (Afugan® 30 EM) applied at the recommended rate of 30 ml/litre.

Extraction of M. azedarach

The extracts were prepared from 200 g frozen mature fruits or leaves, collected from Wadi Chahrour in October–December 1995, and stored at −20 °C. The above extraction procedure for plant extracts of the field swiss chard experiment (autumn 1996) was used. Fresh samples were not tested due to their shortage at that time, as leaf shedding takes place in the Mediterranean region during October and November.

Experimental set-up

The experiments were conducted in two greenhouses (16·3 m by 6·3 m) whose soil was steam sterilized, and organic manure Doubaline® ($N:P_2O_5:K_2O$; 2·5%:2·5%:2·5%) was added at the rate of 1 kg/m² and NPK (15:15:15) at the rate of 50 g/m². Each greenhouse was divided into 30 exclusion compartments by nets made of BIORETE 20/10 mesh of size 270×270 µm (local supplier: Robinson SARL; original source: ARRIGONI, Italy).

In one greenhouse, the population of the leafminer larvae was studied according to three leaf positions of a cucumber plant. In the other greenhouse, nine treatments including the control, distilled water, were applied at a rate of about 94 ml/m² as a full cover spray by a 5 litre sprayer. Treatments were applied twice at an interval of 20 days on the larval stage of the leafminer, starting at one month after planting. Each treatment was replicated three times with one compartment of six plants being considered as a replicate.

Sampling method

In the first greenhouse, each compartment was sampled four times. Sampling consisted of picking three leaves from each plant: one leaf from the upper part (> 100 cm), one from the middle (60–100 cm) and one from the lower (10–60 cm) part. In the other greenhouse, each compartment was sampled twice after each treatment. Samplings were at 10 and 20 days after each treatment. Sampling consisted of picking six leaves from the lower part of the plants in each compartment, as these leaves were exposed twice to the treatments. Samples were kept in the refrigerator at 10 °C until pest assessment. The number of live larvae in the collected leaves was checked under a binocular at 20× magnification.

Statistical analysis

The experiment was laid out as a completely randomized design with multiple observations (six plants per replicate). ANOVA-1 was performed for each of the leaf positions and treatment separately. Bartlett's (1937) test for homogeneity of variance (Gomez & Gomez 1984) was performed on variances collected at each sampling date. The data were transformed into square root $(x+1)$, x being the average number of live larvae per leaf, to stabilize variances (Sokal & Rohlf 1987). All means were separated by Fisher's (1949) LSD test, if significant *F* values were obtained (MSTAT-C 1991).

RESULTS AND DISCUSSION

Field experiments

In the autumn of 1995, data analysis indicated that homogeneity of variance was satisfied for data collected on all sampling dates in each of locations 1 and 2. However, location 3 had an infestation level close to zero, and no statistical analysis was performed.

At location 1, there was a significant difference ($P < 0{\cdot}05$) in the average number of mines per plant among treatments on the first and second sampling dates after treatment (Table 2*a*). *Melia* extracts and azadirachtin (0·25%) were not significantly different ($P > 0{\cdot}05$) in number of mines per plant from the control but exhibited comparable results to other treatments (except abamectin) at 7 and 14 days after spraying. The botanical extracts were comparable in their effect to oil, imidacloprid and cyromazine. The latter chemical was the only one comparable in its

https://doi.org/10.1017/S002185969900773X Published online by Cambridge University Press

Table 2. *Number of* Liriomyza huidobrensis *larvae infesting field swiss chard after treatment with* Melia azedarach *extracts and selected insecticides in autumn 1995*. (a) *at location 1, American University of Beirut, and* (b) *at location 2, Choueifat*

Treatment	Average number of mines/plant ± S.E.*		
	Initial count	7 DAT†	14 DAT†
(*a*)			
Melia leaf extract	1·78 ± 0·36	3·22 ± 0·41	4·61 ± 0·57
Melia fruit extract	3·21 ± 0·49	5·35 ± 0·66	7·16 ± 0·80
Azadirachtin (0·25%)	6·80 ± 1·65	9·74 ± 1·66	12·4 ± 1·93
Abamectin	4·22 ± 0·49	4·09 ± 0·51	4·47 ± 0·58
Oil	2·88 ± 0·56	4·42 ± 0·68	7·50 ± 1·10
Imidacloprid	5·55 ± 0·86	6·42 ± 0·82	7·64 ± 0·88
Cyromazine	3·98 ± 0·67	4·57 ± 0·76	5·43 ± 0·82
Control	3·76 ± 0·89	7·15 ± 0·91	9·73 ± 1·18
(*b*)			
Melia leaf extract	0·31 ± 0·12	1·83 ± 0·33	6·04 ± 0·91
Melia fruit extract	0·36 ± 0·16	2·28 ± 0·36	5·06 ± 0·65
Azadirachtin (0·25%)	1·35 ± 0·71	2·86 ± 0·70	6·79 ± 1·74
Abamectin	0·48 ± 0·20	1·60 ± 0·30	2·07 ± 0·37
Oil	0·23 ± 0·14	2·08 ± 0·42	6·05 ± 0·73
Imidacloprid	0·74 ± 0·32	3·07 ± 0·45	5·02 ± 0·60
Cyromazine	0·10 ± 0·05	1·33 ± 0·28	2·03 ± 0·29
Control	0·06 ± 0·04	3·81 ± 0·71	4·71 ± 0·74

* S.E. refers to standard error of the mean.
† Sampling at 7 or 14 days after treatment. Average number of mines was adjusted according to initial count (Covariance analysis); S.E. (D.F. = 215).

Table 3. *The number of* Liriomyza huidobrensis *larvae infesting field swiss chard after two consecutive treatments with* Melia azedarach *extracts and selected insecticides in autumn 1996, at location 1, American University of Beirut*

Treatment	Average number of mines/plant ± S.E.*		
	Initial count	5 DAT†	10 DAT†
Melia leaf extract	2·79 ± 0·79	4·17 ± 0·80	6·44 ± 0·92
Melia fruit extract	1·13 ± 0·26	1·83 ± 0·30	4·16 ± 0·53
Azadirachtin (0·25%)	2·66 ± 0·38	3·53 ± 0·41	5·43 ± 0·61
Abamectin	1·72 ± 0·34	2·00 ± 0·35	3·30 ± 0·57
Oil	1·35 ± 0·43	2·02 ± 0·50	3·80 ± 0·61
Imidacloprid	2·37 ± 0·41	3·30 ± 0·56	5·80 ± 0·92
Cyromazine	2·13 ± 0·45	2·63 ± 0·57	3·67 ± 0·67
Control	2·07 ± 0·30	4·97 ± 0·50	8·77 ± 0·84

* S.E. refers to standard error of the mean.
† Sampling at 5 or 10 days after the second treatment application. Average number of mines was adjusted according to initial count (Covariance analysis); S.E. (D.F. = 215).

effect to abamectin, which was capable of maintaining the leafminer population at a relatively stable level during the experiment.

At location 2, on the second sampling date, there were significant differences ($P < 0·01$) in number of mines per plant among treatments (Table 2*b*). *Melia* extracts were not significantly different ($P > 0·01$) in their effect from the control. Only abamectin and cyromazine were found to have a prolonged period of protection from further leafminer infestation, up to 14 days after spraying in both locations 1 and 2 (Table 2). The two translaminar insecticides, abamectin and cyromazine, were found to significantly reduce the population of *L. huidobrensis* on celery compared to treatments with non-translaminar insecticides (Weintraub & Horowitz 1998).

https://doi.org/10.1017/S002185969900773X Published online by Cambridge University Press

Furthermore, there were no significant differences ($P > 0{\cdot}05$) in the average number of mines per plant among treatments at location 2, on the first sampling date after spraying (Table 2*b*). This could be related to the washing effect of rain, 8 h after treatment. However, observations were considered because the leaves can readily absorb certain treatments after spraying, and consequently cause an effect on the leafminer. Weintraub & Horowitz (1997) found that the systemic effects of a neem-based insecticide from a soil drench caused adverse effect on pupation and adult eclosion of *L. huidobrensis*.

In the autumn of 1996, data analysis indicated that variances for the five sampling dates, in location 1, were homogeneous. There were no significant differences ($P > 0{\cdot}05$) in the number of mines per plant among treatments, 10 days after the first treatment application. Thus, none of the treatments hindered hatching of the insect eggs. However, there were significant differences ($P < 0{\cdot}05$) in number of mines per plant among treatments, 5 and 10 days after second treatment application (Table 3). Fruit extracts caused comparable effects on leafminer larvae as all other insecticides with respect to the control, 5 days after second spray or 15 days after first treatment. At 10 days after second treatment, the fruit extract did not differ significantly from the control. However, azadirachtin (0·25%), cyromazine, imidacloprid, oil and abamectin were comparable and significantly different from the control in their effect. The leaf extract was not significantly different from the control but was comparable to the fruit extract and other treatments, 10 days after second spray. This might indicate that the leaf extract needs a longer period of time to show its effect. In general, it seems that a change in the extraction procedure applied in the experiment of autumn 1996 has relatively enhanced the bioactivity of the extracts. The effect of the extracts used in 1995 was not comparable to that of abamectin, the selective insecticide for leafminers. However, the extracts used in 1996 were comparable to abamectin at different particular periods of the experiments. Thus, results of the field experiments indicated that treatment at the puncture stage is useless, and it would be better to start treatment at the larval stage, to lower leafminer populations.

Melia fruit extracts and cyromazine caused the formation of deformed larvae which were partially brown, rotting and oozing, whereas larvae treated with imidacloprid were dry, non-intact and dark in colour. This indicates that the fruit extract may have a growth-regulating activity similar to that of cyromazine, a triazine insect growth regulator selective to the genus *Liriomyza* (Anon. 1994). Slight phytotoxicity was observed with the leaf extract. Swiss chard plants treated with this extract developed necrotic brown lesions on their leaves two days after treatment. This problem was previously faced with the very first trials of neem seed extract but its phytotoxicity was reduced when Tween-20 was used as a spreader-sticker with the extract (Stein & Parrella 1985). Furthermore, imidacloprid at a rate of 0·15 g [A.I.]/l showed phytotoxicity symptoms on swiss chard leaves in all locations during this study. There are limited records of using imidacloprid against leafminers (Mullins 1992; Redak & Bethke 1996; Seal 1998), and it is usually recommended as a soil-applied insecticide.

Several studies have reported that abamectin was effective against the pea leafminer (Hurni 1992; Ochoa Chavarria & Carballo Vargas 1993; Staay 1992). Ochoa Chavarria & Carballo Vargas (1993) found that abamectin at 3 ml [A.I.]/l and cyromazine at 0·39 g [A.I.]/l were among the most highly toxic compounds to *L. huidobrensis* and least toxic to its parasitoid, *Diglyphus isaea* Walker. Moreover, these used doses were much higher than those tested in the present study. Cyromazine resistance has been reported in houseflies (Bloomcamp *et al.* 1987), and hence the potential for development of resistance to this chemical in the pea leafminer should be taken into consideration.

In the field experiments, the plant extracts had a similar effect against the leafminer as azadirachtin (0·25%). The latter was tested at the lowest recommended rate of 7·33 g [A.I.]/ha (Scotts-Sierra Crop Protection Company 1992), though the company recommends the application of azadirachtin at least twice in succession at 7 days interval at a rate of 26·5 g [A.I.]/ha. This explains the low effect of the insecticide in 1995, since it was applied once as compared to its higher effect in 1996, when it was applied twice. Similarly the botanical extracts have performed better and were comparable to the other insecticides when applied twice consecutively during the season.

Even though there were considerable effects of the treatments against the leafminer in 1995 and 1996 seasons, none of the tested chemicals succeeded in preventing the occurrence of new mines. In this study, each single application of abamectin and cyromazine at the larval stage resulted in a significantly lower number of newly formed mines, and provided a protection interval of 10–14 days for swiss chard. However, the application of the fruit extract, azadirachtin (0·25%), cyromazine, imidacloprid, oil and abamectin at the larval stage provided only 5 days of protection against the leafminer in the autumn of 1996. Furthermore, the latter five insecticides were found to extend their protection period to 10 days. However, the high cost for some of these pesticides as abamectin, cyromazine, and imidacloprid plays an important economic role in crop management and the use of plant extracts would be more economical. Botanicals are also important from ecotoxicological terms, as in general, only 20–50 g of the active

principle is sufficient to treat one hectare to achieve a satisfactory reduction in pest populations and the products decompose in about one week (Schmutterer 1995).

Greenhouse experiments

Leaf position effect

Data analysis, over multiple generations of *L. huidobrensis*, indicated that the number of larval mines in the upper part of the cucumber plant was equal to zero in all treatments. Thus, leaves in the lower and middle plant parts only were compared. A significant ($P < 0{\cdot}01$) leaf position effect was revealed on four sampling dates. Higher numbers of live larval mines per leaf were encountered in the lower stratum (0·64, 0·85, 0·45 and 0·61 larvae/leaf) as compared to the middle stratum (0·02, 0·31, 0·31 and 0·36 larvae/leaf) on the four sampling dates consecutively. Thus, the pea leafminer prefers leaves located at the lower part of a cucumber plant (10–60 cm) in greenhouses compared to the other leaf positions. Other studies have also found significantly greater larval densities of other *Liriomyza* sp. at the plant base as compared with the distal end of a plant (Hanna *et al*. 1987; Lynch & Johnson 1987).

Treatment effect in bioassays

There were significant differences ($P < 0{\cdot}05$) in the average number of live larvae per leaf among treatments on all sampling dates. The fruit extract, abamectin, cyromazine, imidacloprid and pyrazophos lowered the number of live larvae per leaf significantly as compared to the control, throughout the period of the experiments (Table 4). However, the fruit extract was significantly less effective than these mentioned pesticides at the final count, 20 days after second treatment application (Table 4*b*). The fruit extract behaved better than the azadirachtin (0·25%) by being capable of lowering the leafminer population significantly compared to the control at all sampling dates whereas the latter botanical lowered the population at two sampling dates only, 10 days after first treatment and 20 days after second treatment application. The leaf extract was found to keep number of live larvae per leaf at a significantly lower density than the control only at 20 days after second treatment application. This indicates that the leaf extract might need a longer period of time to reveal its effect. This observation was also noticed in the field experiments.

The use of exclusion compartments might have contributed to the zero level of infestation since the nets suppressed the invasion of adult leafminers from the surroundings. This set-up has further helped to optimize the efficacy of each treatment in controlling the leafminer under greenhouse conditions. For example, abamectin, cyromazine and imidacloprid were able to significantly lower the infestation to approximately zero. Pyrazophos has also drastically reduced the number of live larval mines and was comparable to other treatments, and was significantly different in its effect from the control on all sampling dates. Pyrazophos showed a high killing effect due to the rate used (0·98 g [A.I.]/l) in our experiment, which is 1·5-fold the recommended rate as a fungicide (personal communication). Veire & Bleyaert (1990) indicated that cyromazine and pyrazophos at 1·5 g [A.I.]/10 litre controlled *L. huidobrensis* larvae by 90% when applied twice at 10-day intervals on lettuce in greenhouses. The use of pyrazophos should be limited due to the great potential for development of resistance, as Macdonald (1991) found that *L. huidobrensis* was more tolerant to pyrazophos than the related *L. trifolii*.

There are no records on the use of *M. azedarach* for the control of *L. huidobrensis*. The field assays indicated no effect of the aqueous extracts against the leafminer larvae except when two consecutive treatment applications were performed, where the fruit extract provided a short-term insecticidal effect. The greenhouse assays indicated that the fruit and leaf extracts helped to suppress the leafminer populations

Table 4. *Number of* Liriomyza huidobrensis *larvae infesting greenhouse cucumber after treatment with* Melia azedarach *extracts and selected insecticides in spring 1996*. (a) *After first treatment application, and* (b) *after second treatment application*

Treatment	Average number of live larvae/leaf ± S.E. (135 D.F.)*	
	10 DAT†	20 DAT†
(*a*)		
Melia leaf extract	1·11 ± 0·30	1·17 ± 0·31
Melia fruit extract	0·91 ± 0·20	0·33 ± 0·18
Azadirachtin (0·25%)	0·67 ± 0·21	1·05 ± 0·12
Abamectin	0·00 ± 0·00	0·00 ± 0·00
Oil	0·89 ± 0·29	1·44 ± 0·30
Imidacloprid	0·77 ± 0·28	0·61 ± 0·14
Cyromazine	0·00 ± 0·00	0·44 ± 0·24
Pyrazophos	0·50 ± 0·12	0·83 ± 0·16
Control	1·67 ± 0·41	2·27 ± 0·42
(*b*)		
Melia leaf extract	1·77 ± 0·27	0·61 ± 0·16
Melia fruit extract	0·33 ± 0·11	0·94 ± 0·27
Azadirachtin (0·25%)		0·44 ± 0·18
Abamectin	0·00 ± 0·00	0·05 ± 0·05
Oil	0·39 ± 0·14	0·72 ± 0·26
Imidacloprid	0·00 ± 0·00	0·27 ± 0·10
Cyromazine	0·00 ± 0·00	0·00 ± 0·00
Pyrazophos	0·33 ± 0·19	0·38 ± 0·11
Control	1·22 ± 0·33	2·11 ± 0·26

* S.E. refers to standard error of the mean.
† Sampling at 10 or 20 days after treatment.

https://doi.org/10.1017/S002185969900773X Published online by Cambridge University Press

at the end of the experiment, after two consecutive treatment applications. Increasing the number of consecutive sprays, due to the known ultraviolet degradation of botanical extracts (National Research Council 1992), might enhance the activity of these extracts under field conditions. Thus, the aqueous extracts used in the present study have indicated a potential insecticidal activity against the larval stages of the leafminer. Their efficacy was relatively comparable to most of the tested commercial pesticides even though they were used as raw extracts with no additives. These extracts have been compared with other types of *M. azedarach* extracts for their insecticidal bioactivity with initiation of isolating and characterizing the bioactive agent(s). Further studies of the compatibility of the extracts with specific biocontrol agents are being conducted to help in limiting pesticide application against leafminer pests.

The authors wish to thank the Lebanese National Council for Scientific Research for funding this research. We thank Dr Riad Baalbaki (American University of Beirut, Faculty of Agricultural and Food Sciences) for his assistance in the statistical analysis. Special thanks to Scotts-Sierra Crop Protection Co., Marysville, OH, U.S.A. for providing Margosan-O® (0·25% azadirachtin) for this research. We thank the following local companies: Agripest S.A.L. (Bayer, DEGESCH), Comptoir Agricole Du Levant, Najjar Agricultural and Trading Co. and Amalia S.A.L. for supplying free samples of Confidor®, Trigard®, Sunspray® ultrafine oil and Afugan®, respectively. Special gratitude to anonymous growers for allowing us to conduct experiments in assigned field plots at their farms. We also thank Lucia Hanna and Marcelle Dagher for their assistance.

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