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FINAL REPORT

PROJECT NO. US-707-83

~~Basic Research toward~~ Management of
LIRIOMYZA TRIFOLII Leafminer in the
U.S. and Israel *Burgess*

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Management of Liriomyza trifolii Burgess Leafminer in the USA and Israel

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c. ABSTRACT

The leafminer Liromyza trifolii (Burgess) which is highly polyphagous has become a major pest of vegetables, flowers and ornamentals in the United States and Israel. Short day conditions were found to be more favorable to L. trifolii feeding, oviposition and progeny production.

Use of plant growth regulators (PGR's) resulted in reduced adult feeding, oviposition and subsequent development.

High nitrogen fertilization resulted in more mines and pupae, as adult flies preferred to feed and oviposit on leaves with high nitrogen content.

Bionomic studies of L. trifolii on gypsophila did not prove it a preferred host.

Use of yellow sticky traps for monitoring adult populations was found to be optimal with traps hung vertically 30 cm above top of the plants.

Female L. trifolii flies did not pass a 100 mesh/cm² net, which thus provided protection to preferable susceptible host plants.

Soil treatment with contact insecticides proved ineffective, while systemic insecticides affected the immature stages. Neem seed extracts did not affect adult flies, but were promising against the immature stage either as antifeedents or insect growth regulators (IGR's). Among IGR compound cyramazine was by far the most effective, both as a preinfestation and post infestation treatment. XRD-473

did show some promise against the immature stages. LD₅₀'s of the commonly used pyrethroid insecticide permethrin and the newly registered bifenthrin for L. trifolii populations from three widely scattered locations in the U.S. showed the population from Maryland was much more resistant than those from Florida and California. The flies were all more susceptible to bifenthrin. Adult flies can be anaesthetized using either low temperature or CO₂ with minimal mortality.

Irradiation of plants infested with various immature stages established the minimum dose rates required to cause immediate mortality, prevent pupation or emergence, when applied to the egg, larval and pupal stages.

d. Objectives of the Original Proposal

1. To reveal the life history of L. trifolii under different environmental conditions.

2. To develop reliable monitoring approaches for detecting early infestation and estimating population numbers in Israel.

3. To determine the range of cultivated crops and native plants in Israel and the United States that L. trifolii will attack and the nature of adaptation to specific host plants.

4. To determine the extent of indigenous natural enemy adaptation to L. trifolii as a host or prey in Israel and the United States.

5. To determine the response of L. trifolii population growth to the factors of crop culture, plant nutrition and management in the United States on cultivars of plants that vary in their susceptibility to attack.

e. Body of Report

Introduction

Liriomyza trifolii (Burgess) (Diptera:Agromyzidae) is a highly polyphagous leafminer which has become a major pest of vegetables, ornamentals and flowers in the United States and Israel. Outbreaks of L. trifolii often result in increases in production costs, decreases in yield and quality of produce and economic losses due to failure to meet standards for pest-free exports to foreign markets. Accidental introductions into previously unaffected areas and inadequate knowledge of the pest's biology and factors which influence its occurrence and abundance such as biotic factors, natural enemies and resistance to approved insecticides are the basis for this species' relatively recent rise to major pest status.

Leafminer populations in chrysanthemums and other crops occur to varying degrees in response to biotic factors of crop culture, plant nutrition and crop management in the United States. Such factors include plant nutrition, the cultivar grown and how it is grown (e.g. pot, cut, standard or pompom) and use of plant growth regulators and chemical insecticides. Understanding how these factors influence

populations may aid in developing new, more effective management strategies. Study and development of other, less conventional tactics plus the determination of the pest's biology may also lead to heightened leafminer control.

Fig 1. Cage used for mass rearing Liriomyza trifolii. Pupal trays on the left.

I BIOLOGICAL STUDIES ON LIRIOMYZA TRIFOLII

INTRODUCTION

Gypsophila was one of the first floral crops in Israel to be attacked by Liriomyza trifolii. Gypsophila is a major export item in Israel, and as early as December 1979 packed gypsophila cartoons were destroyed before shipping, due to heavy L. trifolii infestation. As high infestations were found in gypsophila and high adult populations were observed on the plants, growers have adopted a strict schedule of pesticide applications and sanitary regulations.

No reference could be found concerning oviposition or fecundity of L. trifolii on gypsophila, although it is often mentioned as a host.

Damage to gypsophila is caused by larvae mining the leaves, but even feeding punctures without mines cause damage. The present study includes feeding and oviposition behaviour and bionomics on gypsophila, compared to bean, a well known preferred host.

A. FEEDING AND OVIPOSITION BEHAVIOUR OF LIRIOMYZA TRIFOLII ON GYPSOPHILA AND ON BEAN LEAVES

As suitability of gypsophila as a host to L. trifolii was not studied before, this study was undertaken to establish the host plant relationship regarding feeding and oviposition behavior. These functions were studied on Gypsophila pacifica Kom. compared to a preferred host, bean, Phaseolus vulgaris (Bulganani variety). The dispersion of feeding and oviposition punctures on gypsophila leaves were studied in order to find the sites favoured by L. trifolii for these functions. The punctures that developed into mines served as an indication of the number of eggs. The numbers of punctures and percent of mines/punctures were compared on old and young gypsophila leaves and also on the

upper and lower leaf side, as preliminary observations indicated flies visiting both sides of the leaves equally.

MATERIALS AND METHODS

Gypsophila plants (10-20 leaves/plant) used were grown singly in pots (height 9 cm, diam 10 cm). Old plants were considered seedling over 3 months after transplanting from the rooting nursery, and young plants were seedlings after transplanting, as soon as growth was resumed. Bean seedling were grown 4-5/pot and were used at the stage of the first 2 true leaves. Flies were obtained from a laboratory mass culture. Ten female flies were confined with each of the hosts in a transparent cage consisting of a plastic tube (height 22 cm, diam. 10 cm) inverted over the pot and enclosing the plants. The upper end was covered with a fine mesh nylon net. This was replicated 5 times.

After the plants were exposed to infestation by 10 female flies for 20 hours, the flies were removed. The punctures counted under magnification and the potted plants kept at 25°C and a 16:8 L:D photoperiod.

For counting, the gypsophila leaves were divided into three counting sections: i) the distal third of the leaf, ii) the mid third and iii) the basal third of the leaf. All sections were of equal length, but due to the shape of the lamina not of equal area.

Bean leaves were divided by the central vein into two counting sections, and the number of punctures in each section recorded.

After first instar mines appeared and were counted the leaves were cut off and the leaf area measured using a Licor area meter (model 31).

Punctures that developed into mines were considered oviposition punctures, the rest only feeding punctures.

RESULTS

The number of L. trifolii punctures and mines and percent of mines/punctures found on gypsophila leaves are presented in Table 1, and those on bean leaves in Table 2. The absolute numbers of punctures on bean leaves were by far higher than the highest total on both sides of gypsophila leaves; so was the total number of mines/leaf (50 on bean, 25 on gypsophila).

On the upper side of the bean leaves punctures were more or less uniformly dispersed; the differences found occasionally between the two halves were inconsistent and were not considered.

With gypsophila leaves the upper side of the leaf was affected 2.1 more than the lower leaf side. The mean $\pm$ SD for all gypsophila leaves (old and young) was 26.11 ± 30.62 , for the upper side and for the lower leaf side it was 12.64 ± 29.71 . This was not significant by F-test ($p=0.052$).

The mean number of punctures and mines, and the mean rate (%) of mines/punctures on gypsophila and on bean leaves are shown in Table 3. The rate of oviposition/feeding punctures was 6.1 times higher on gypsophila than on bean, which is significant at 1% level by F-test ($p=0.009$), although the absolute number of punctures and mines were higher on beans as seen in Tables 1 and 2.

The number of punctures found on old and young gypsophila leaves is shown in Table 4. The total number of punctures on young leaves was on an average 3.4 times higher than on old leaves ($\frac{70.80}{20.94}$), significant at the 1% level by F-test ($p=0.008195$). On the other hand, the number mines/leaf was about equal on young and old leaves. The rate of mines/punctures was thus by 3.1 higher in old leaves, however, this was not significant by F-test.

The dispersion of punctures along the upper and lower sides of old and gypsophila leaves is presented in Table 5, and the mean density/cm² $\pm$ SE,

in Table 6. The highest number of punctures was found in the distal third on the upper leafside of young leaves, and the lowest on the mid section of the lower leafside of old leaves. With only one exception the basal section was free of punctures. As the range was very wide, as seen in Table 5, significance was not calculated.

CONCLUSIONS

The occurrence of punctures on the lower side of gypsophila leaves is probably due to the vertical position of these leaves allowing an equal light intensity on both sides of the leaf, as opposed to the almost horizontal position of the bean leaves which kept the lower side shaded.

Bean leaves displayed over twice the number of punctures/cm² leaf area than gypsophila. However, the rate of mines/punctures was found to be higher on gypsophila leaves than on beans, suggesting they are less suitable for adult feeding than for larval development.

Young gypsophila leaves displayed significantly more punctures than old ones, but the number of mines was about equal on old and young leaves.

B. BIONOMICS OF LIRIOMYZA TRIFOLII ON GYPSOPHILA COMPARED TO BEANS

1. Individual studies

Liriomyza trifolii bionomics were studied on various preferable hosts like beans and chrysanthemums (Charlton and Allen, 1981; Vrie, van de and Dinkse, 1981), on celery (Leibee, 1984) tomatoes (Schuster and Patel, 1985) and also on some weeds (Smith and Hardman 1986; Zoebisch et al, 1985). Gypsophila was not

MATERIALS AND METHODS

Hosts used were old and young gypsophila plants and bean seedlings. The old plants were about 3 month after transplanting and the young plants were seedling as soon as they resumed growth after being transplanted. The gypsophila plants (10-20 leaves) were grown singly in a pot (height 9 cm, diam 10 cm), beans - two seedlings with the first two true leaves/pot.

Oviposition took place in a greenhouse under natural morning daylight conditions of July-August and 30°-35°C. Host plants were introduced into wooden cages (35x25x35-25 cm) with a slanting glass top. Cages with the different hosts were set up daily in the greenhouse and female flies, obtained from a mass culture were introduced and allowed to oviposit for 1 hour, in order to standardize larval age.

As oviposition on the various host differed, the bean plants were exposed to 15-20 flies, young gypsophila to 20-25 flies, while with old gypsophila 70-90 flies were introduced.

After 1 hour exposure the flies were removed and the inoculated plants incubated at 20°, 25° or 30°C and a 12:12 L:D photoperiod, until all visible larvae had exited the leaves. The development times of egg and larval stages were determined by following the progress of individual leafminers in the leaves of potted plants.

Egg stage

When, according to preliminary observation, hatching was expected, the inoculated leaves were inspected constantly for the appearance of mines, which were immediately marked and recorded. The incubation period was calculated from oviposition to the appearance of each separate mine.

Larval stage

First instar larvae were marked and examined twice daily using an illuminated magnifier. The progress of each marked mine was followed and drawn twice daily. One day before expected bail out was a white plastic plate put around each infested bean plant to assure catching the exiting larvae near their host plant. Over the long gypsophila leaves long glass tubes were inverted individually, to achieve the same goal. Plants were checked regularly for exiting larvae which were removed and recorded.

Prepupa

To obtain prepupae heavily infested plants were taken out from a mass culture and every 15 minutes the exiting mature larvae were collected using a camel hair brush. These mature larvae were put into constant temperature chambers at 20°, 25° and 30°C and checked every 15 minutes for stiffening and contraction which marked the end of the prepupal stage.

Pupa

Mature larvae were collected when exiting the leaves, as with the prepupae and incubated in glass test-tubes at 17°, 20°, 25° and 30°C. When emergence was expected they were checked every hour to record emergence of each individual fly.

The data obtained for the development of each stage of L. trifolii were analysed by the General lineara Models Procedure and the Analysis of Variance Procedure of SAS and by Duncan's Multiple Range Test to separate and compare means. Development rate [reciprocal of duration (days)] was calculated at each temperature for each host and regression on temperature. Regression equation and

appoint the lower development temperature threshold, and the thermal unit values (day-degrees) were calculated.

RESULTS

Egg stage

The incubation periods of L. trifolii eggs at 3 temperatures on bean and on gypsophila leaves are presented in Table 7. There were not significant differences found between old and young gypsophila leaves, and neither were there significant differences between beans and gypsophila

Larval stage

The development period of L. trifolii larvae on the two hosts is presented in Table 7 and the linear regression equation, regression coefficient (r), development threshold and thermal units ($^{\circ}\text{C}$ day-degrees) in Table 8.

The larval period was significantly shorter on bean than on gypsophila leaves. Differences observed between larval duration on old and young gypsophila were not significant by T-test at neither temperature, so the data were combined and compared with results on beans. At all temperatures the larval period was significantly shorter on beans than on gypsophila as seen in Table 7.

Prepupa

The prepupal stage, from the time the larva left the leaf till stiffening and contracting set in, was very short and lasted 3.3 ± 0.3 hours at 20°C , while at 25° and 30°C it lasted 1.8 ± 0.1 and 2.2 ± 0.1 hours respectively. The observed difference between the last two figures was not significant.

Pupa

The duration of L. trifolii pupal stage at 4 temperatures is presented in Table 7, and the linear regression equation, regression coefficient (r), development threshold and thermal units in Table 8.

The development period decreased significantly as temperature increased from 17° to 30°C.

2. Observations on group oviposition and development

To compare normal development of L. trifolii on gypsophila and bean, a preferred host, without interruption, 50 female flies were allowed to oviposit on these two hosts in a non choice test, and in a choice test, replicated twice

i. Non choice test - in one oviposition cage 12 bean seedlings in 3 pots were introduced, and exposed to 50 female L. trifolii for 24 hours. In a separate cage 3 gypsophila plants, in 3 pots, were exposed to the same number of flies for the same period.

ii. Choice test - in an oviposition cage 8 bean seedlings, in 2 pots and 2 gypsophila plants in 2 pots were introduced. These were exposed to 50 ovipositing female flies for 24 hours.

After a 24 hour exposure to flies the plants were removed, and when mines of 1st instar larvae appeared they were counted, and their number was considered the number of eggs laid.

When all the larvae had exited the leaves they were collected from the leaves and from 30 cm diam polystyrene plates placed under the plants to collect the larvae that fell from the leaves.

The leaf area available to oviposition was then measured using a Licor area meter (Model 31).

RESULTS

The number of leaves of each host and the total leaf area available to ovipositing flies, % of infected leaves, the number of eggs laid, as deducted from the number of 1st instar mines and the development period from oviposition to pupation are presented in Table 9 for both the non choice and choice tests. It is quite obvious that almost all the leaves and the whole leaf area of the bean seedlings were heavily infested in both tests. The gypsophila leaves were not all infested, and in spite of the big leaf area available, only part of the leaves were infested and they supported a much lower population than the beans, and development was longer on gypsophila by about 40%.

DISCUSSION

Tests on the feeding and oviposition of L. trifolii on gypsophila and beans as displayed by small scale non-choice tests involving 10 female flies, and oviposition tests involving 50 flies in non-choice and choice tests have indicated that gypsophila is not a very suitable host for adult feeding and oviposition, as was the case with tomato (Parrella et al. 1983).

Development of the immature stages too, lasted longer on gypsophila by about 40%. Heavy damages encountered in gypsophila monocultures are probably due to lack of more suitable hosts.

C. RESPONSE OF L. TRIFOLII TO ENVIRONMENTAL FACTORS

1. Response to photoperiod

MATERIALS AND METHODS

Five cultivars of chrysanthemums varying in their resistance to L. trifolii were selected and grown as standards or sprays, depending on the cultivar.

Chrysanthemum cv. Iceberg was grown as the susceptible cultivar for both sprays and standards. Grown as sprays were the intermediate cv. Yellow Beauregard and the resistant cv. Starburst. The intermediate cv. Bright Golden Anne and the resistant cv. Yellow Knight were grown as standards. Plants were grown in pots in a greenhouse and were fertilized and watered as needed. Temperature and relative humidity were recorded using a hygrothermograph.

Plants were grown for 4 weeks under a long day (LD) photoperiod (16L:8D) provided by high pressure sodium lamps. Plants grown as sprays were pinched at 2 weeks to promote lateral growth. At 4 weeks plants were divided and half grown under a short day (SD) regime (8L:16D). A black curtain was drawn each day at 1700 h and opened at 800 h the following day to simulate the SD photoperiod. Plants were exposed 3 weeks under their respective photoperiods. At 7 weeks, 4 plants from SD- and LD-grown spray cultivars were randomly chosen and placed in a cage containing 100-200 adult L. trifolii for 24 h, a procedure repeated for the SD- and LD-grown cultivars.

Plants were placed in an isolated greenhouse and grown under natural daylength (ca. 10 h light). Stipples and first instar mines (< 1 cm long) were counted 3-4 d later. When larvae reached third instars, all leaves longer than 2.5 cm were excised, passed through an area meter (LICOR^R, Lincoln, NE) and placed in plastic trays for larval eclosion. Pupae were collected 5-7 d later into glass vials which were placed in a growth chamber at 26° C and 14L:10D photoperiod until adult eclosion. Number of pupae and reared adults were counted.

A similar study investigating the effects of photoperiod was conducted using cv. Iceberg grown as sprays and standards and resistant cvs. Bright Yellow Tuneful and Yellow Knight grown as sprays and standards, respectively. The procedures used were the same as in the previous study except 6 plants were exposed per treatment and all plants were pinched. A second group of plants were studied for effects of photoperiod without pinching.

Densities of stipples, first instar mines, pupae and adults were calculated on a 100 cm² leaf area basis for statistical comparisons. Mean densities were analyzed by analysis of variance (ANOVA) and separated by Student's t-test or Duncan's multiple range test.

RESULTS

Results indicate L. trifolii adults prefer to oviposit in and feed upon chrysanthemums grown under SD conditions. In the initial study, the intermediate cv. Beauregard and

resistant cv. Starburst grown as sprays exhibited significantly more damage and produced more leafminer progeny under SD conditions than under LD conditions (Table 1). Likewise, the standard-grown resistant cv. Knight and intermediate cv. Anne were more heavily infested than LD-grown cvs. Knight and Anne. SD-grown cv. Iceberg also sustained more damage than the LD-grown cv. Iceberg plants when grown as standards (Table 10).

There was no significant difference in leafminer densities between spray cultivars under a SD photoperiod (Table 11). Certain densities were significantly greater, however, for cv. Iceberg sprays than for cvs. Beauregard and Starburst sprays grown under LD conditions. Similarly, when standard cultivars were grown under SD conditions, no significant differences in stipple and mine densities occurred between any of the cultivars (Table 11). However, significantly more pupae and adults occurred on SD-grown cv. Iceberg than on SD-grown cvs. Knight and Anne. Damage and leafminer densities were significantly greater for cv. Iceberg grown under LD conditions than for LD-grown cvs. Knight and Anne.

Results of the second study supported the preceding findings as standard-grown cvs. Iceberg and Knight under LD conditions contained and produced significantly fewer mines and leafminer progeny (Table 12). Significantly less damage and leafminer pupae and adults also occurred on spray-grown cvs. Iceberg and Tuneful under a LD photoperiod. Effects of

pinching, however, were not significant for leafminer damage and occurrence for cultivar and photoperiod (Tables 13 and 14).

Previous studies indicated leafminers preferred chrysanthemums grown under SD conditions and the findings of these studies support this conclusion. Also, the susceptibility level of the resistant cvs. Starburst and Knight and intermediate cvs. Beauregard and Anne could be enhanced by growing under a SD photoperiod. Growing the cultivars as a spray or standard did not affect the preference of leafminers for SD-grown plants.

2. Response to a plant growth regulator

MATERIALS AND METHODS

Plant cultivation and adult leafminer exposure were identical to those described in the preceding study except for the following exceptions. Only spray cultivars were used because plant growth regulators (PGR's) are most frequently applied to this type of chrysanthemum. Cultivars Iceberg, Beauregard and Starburst were chosen as the susceptible, intermediate and resistant cultivars, respectively. Fifty plants were grown from cuttings under a LD photoperiod (16L:8D) for 2 weeks, pinched at 2 weeks of age and grown for an additional 2 weeks under a LD photoperiod. Plants were grown under a SD photoperiod (8L:16D) for 3 weeks. On week 6, one-half of the plants of each cultivar were sprayed with a plant growth regulator, B9 or daminozide, at 2500 ppm. The other half were sprayed

with water as a control. One week after treatment (week 7), 4 plants from each cultivar were exposed to leafminer adults for 24 h. Plants were grown under natural daylength (ca. 10 h light) in a greenhouse. Data were collected and statistically analyzed as described in the photoperiod study.

RESULTS

PGR-treated resistant cv. Starburst produced significantly less pupae and adults than the water-treated cv. Starburst (Table 15). Treated intermediate cv. Beauregard had significantly less damage and leafminer densities than the water-treated cv. Beauregard, while the susceptible cv. Iceberg treated with B9 had lower densities, though not significant, of mines, pupae and adults than the water-treated cv. Iceberg.

Treated and control resistant cv. Starburst produced significantly fewer pupae and adults than treated and control cv. Iceberg (Table 16). Treated and control cv. Beauregard had significantly lower densities of stipples, pupae and adults than treated and control cv. Iceberg. B9-treated cv. Beauregard also had significantly fewer mines than treated cv. Iceberg.

Application of a PGR, B9, reduced leafminer feeding, oviposition and subsequent development. B9, however, did not enhance the level of leafminer resistance in susceptible and resistant cultivars.

3. Response to nitrogen fertilization

MATERIALS AND METHODS

Plant cultivation was similar to those described in the photoperiod experiment except for the following procedures. The susceptible cv. Iceberg, intermediate cv. Yellow Beauregard and resistant cv. Bright Yellow Tuneful were grown as sprays and cv. Iceberg, intermediate cv. Bright Golden Anne and resistant cv. Yellow Knight were grown as standards. Fifty plants were grown from cuttings for 2 weeks under a LD (16L:8D). Spray cultivars were pinched at 2 weeks of age. Fertilization began on week 2 and continued on a weekly basis until week 6. Fertilizer solutions were applied as a liquid drench (150 ml/pot). The low nitrogen (N) fertilizer was 400 ppm N and consisted of a 20N:20P:20K fertilizer solution. The high N fertilizer was 800 ppm N and consisted of ammonium nitrate added to a 20N:20P:20K fertilizer solution. Levels of potassium, phosphorus, calcium and magnesium remain unchanged. Five plants per cultivar were used per treatment. All plants were grown under a LD photoperiod until 3 weeks old, then changed to a SD photoperiod (8L:16D) until 6 weeks old when they were exposed to adult L. trifolii. Data were collected and analyzed as described in the photoperiod study. Leaves from 3 plants of each cultivar per treatment were sampled for Kjeldahl and macro-nutrient analysis at the Dept. of Agronomy, Univ. of Maryland, College Park.

RESULTS

A Kjeldahl and micro-nutrient analysis of leaf tissues for fertilizer treated plants indicated nitrogen was the major nutrient altered in the fertilizers (Table 17).

Resistant cv. Tuneful grown as sprays had significantly higher densities of mines, pupae and adults when treated with a high N solution than when treated with a low N solution (Table 18). High N fertilization also resulted in significantly more mines and pupae for spray-grown cv. Beauregard. Cultivar Iceberg sprays exhibited no significant differences in leafminer attack and numbers for plants treated with high and low N fertilizers. Significantly higher leafminer densities occurred for all cultivars grown as standards when treated with a high N fertilizer (Table 18).

Cultivar Tuneful grown as sprays had significantly lower densities of stipples, mines, pupae and adults than spray-grown cv. Iceberg at the low N and significantly fewer stipples and mines at the high N level (Table 19). Cultivar Beauregard as sprays, however, was not significantly different from cv. Iceberg as sprays at any fertilizer level. Cultivars Knight and Anne grown as standards had significantly less stipples, mines, pupae and adults than standard-grown cv. Iceberg, regardless of fertilization level (Table 19).

In summary, adult L. trifolii preferred to feed and oviposit on plants fertilized with a higher N level (800 ppm

N) than with a lower level (400 ppm N). Nitrogen level did not appear to affect susceptibility of cultivars to attack.

Fig 2. *Gypsophila* leaves damaged by *Liriomyza trifolii*. Top, mines and a prepupa. Bottom, distribution of stipples on basal, mid and distal leaf area (left to right).

TABLE 1. NUMBER OF *LIRIOMYZA TRIFOLII* PUNCTURES AND MINES/LEAF AND % OF MINES/PUNCTURES ON OLD AND YOUNG GYPSOPHILA LEAVES.

Leaf age and number	Number punctures/leaf			Number punctures/cm ²		Number mines/leaf	% mines/ punctures
	Total	Upper	Lower	Upper side	Lower side		
Old	1	1	0	-	-	0	
	2	6	3	0.24	0.24	0	0
	3	12	11	2.18	0.20	2	16.7
	4	5	4	0.33	1.32	1	20.0
	5	13	13	0	2.60	0	
	6	1	1	0	0.13	0	
	7	8	8	0	1.07	0	
	8	13	13	1.42	0	6	46.2
	9	110	83	7.34	2.39	25	22.7
	10	13	6	0.57	0.66	0	
	11	18	18	1.60	0	18	100
	12	15	15	1.77	0	15	100
	13	7	7	0.72	0	5	71.4
	14	6	5	0.46	0.09	6	100
	15	7	7	1.43	0	2	28.6
	16	10	10	1.00	0	9	90.0
	17	30	30	4.99	0	1	0.00
	<u>18</u>	<u>102</u>	<u>68</u>	<u>6.92</u>	<u>3.46</u>	<u>1</u>	<u>1.0</u>
Total	377	278	99				
Young	1	210	60	11.83	29.59	8	3.8
	2	39	39	3.80	0	2	5.1
	3	100	47	7.85	8.85	7	7.0
	4	55	39	3.45	1.41	2	3.6
	5	25	25	2.74	0	10	40.0
	6	5	5	0.67	0	0	
	7	31	26	4.02	0.77	6	19.4
	8	29	9	1.29	2.87	4	13.8
	9	99	99	18.00	0	13	13.1
	<u>10</u>	<u>115</u>	<u>104</u>	<u>31.90</u>	<u>3.37</u>	<u>4</u>	<u>3.5</u>
Total	708	453	255				

TABLE 2. NUMBER OF LIRIOMYZA TRIFOLII PUNCTURES AND MINES AND % MINES/PUNCTURES ON BEAN LEAVES

	Number of punctures/leaf			Number punctures/ cm ²	Number mines/ leaf	% mines/ punctures
	Total	Left side	Right side			
1	234	175	55	11.03	4	1.71
2	78	10	68	5.07	0	0
3	133	84	49	5.29	2	1.50
4	343	148	195	12.15	5	1.46
5	111	70	41	13.47	1	0.90
6	427	236	191	22.93	7	1.64
7	260	185	75	15.14	16	6.15
8	289	129	160	12.79	7	2.42
9	102	52	50	5.30	7	6.86
10	446	271	175	18.60	27	6.05
11	193	71	122	13.76	8	4.15
12	347	140	207	21.80	9	2.59
13	169	72	97	5.16	11	6.51
14	111	21	90	3.38	19	17.12
15	458	33	425	14.17	14	3.06
16	631	423	208	20.19	26	7.29
17	1130	544	586	25.17	50	4.42
18	105	62	43	4.51	2	1.90
19	493	293	200	22.12	9	1.83
20	455	217	238	20.14	25	5.49
Total	6511	3236	3275			

TABLE 3. MEAN NUMBER OF PUNCTURES, MINES AND PERCENT OF MINES/PUNCTURES ON GYPSOPHILA AND BEAN LEAVES

Host	Number of leaves	Number of punctures		Number of mine/leaf $\pm$ SE	% mines/punctures $\pm$ SE
		per leaf $\pm$ SE	per/cm ² $\pm$ SE		
Gypsophila	28	38.75 $\pm$ 9.49	6.44 $\pm$ 1.99	5.25 $\pm$ 1.19	25.45 $\pm$ 6.61
Bean	20	325.75 $\pm$ 55.60	13.64 $\pm$ 1.59	13.45 $\pm$ 3.13	4.15 $\pm$ 0.85

TABLE 4. MEAN NUMBER OF PUNCTURES, MINES AND PERCENT OF MINES/PUNCTURES ON OLD AND YOUNG GYPSOPHILA PLANTS

Age of gypsophila	Number of leaves	Number/leaf $\pm$ SE of		% mines/punctures $\pm$ SE
		punctures	mines	
Old	18	20.94 $\pm$ 7.47	5.11 $\pm$ 1.74	33.51 $\pm$ 9.66
Young	10	70.80 $\pm$ 19.45	5.60 $\pm$ 1.27	10.93 $\pm$ 3.47

TABLE 5. DISPERSION OF PUNCTURES ON OLD AND YOUNG GYPSOPHILA LEAVES i - DISTAL THIRD OF LEAF, ii - MID THIRD, iii - BASAL THRID OF LEAF

Age of leaves	Leaf side	Section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Old	Upper	i	1	3	9	1	13	0	0	13	7	10	30	68	44	6	18	15	7	5
		ii	0	0	2	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0
		iii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lower	i	0	3	1	4	0	1	8	0	0	0	0	34	27	2	0	0	0	0
		ii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		iii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Young	Upper	i	55	39	38	24	9	97	66	39	25	5								
		ii	5	0	9	2	0	2	32	0	0	0								
		iii	0	0	0	0	0	0	6	0	0	0								
	Lower	i	94	0	11	5	17	0	11	16	0	0								
		ii	56	0	42	0	3	0	0	0	0	0								
		iii	0	0	0	0	0	0	0	0	0	0								

TABLE 6. DENSITY OF PUNCTURES ON OLD AND YOUNG GYPSOPHILA LEAVES. i-DISTAL THIRD OF LEAF, ii-MID-THRID, iii-basal third

Age of gypsophila	Number of leaves	Leaf section	Number of punctures/cm ² $\pm$ SE	
			Upper leaf side	Lower leaf side
Old	18	i	13.89 $\pm$ 4.13	4.50 $\pm$ 2.30
		ii	2.28 $\pm$ 2.17	0.28*
		iii	0	0
Young	10	i	39.70 $\pm$ 8.71	15.40 $\pm$ 9.00
		ii	5.00 $\pm$ 3.14	10.10 $\pm$ 6.58
		iii	0.60*	0

*Once only

TABLE 7. DEVELOPMENT PERIOD OF LIRIOMYZA TRIFOLII EGGS, LARVE AND PUPAE

Tempera- ture °C	Host	Development Period (days $\pm$ SE)				
		Number	Eggs	Larvae	Number	Pupae
17					22	19.97 $\pm$ 0.21
20	Bean	99	3.88 $\pm$ 0.06	5.47 $\pm$ 0.08	120	14.75 $\pm$ 0.06
	Gypsophila	59	4.40 $\pm$ 0.21	6.93 $\pm$ 0.20		
25	Bean	25	3.65 $\pm$ 0.11	3.65 $\pm$ 0.11	17	10.41 $\pm$ 0.13
	Gypsophila	38	3.55 $\pm$ 0.17	4.37 $\pm$ 0.11		
30	Bean	75	2.65 $\pm$ 0.06	2.38 $\pm$ 0.06	13	7.81 $\pm$ 0.07
	Gypsophila	55	2.50 $\pm$ 0.11	3.65 $\pm$ 0.08		

TABLE 8. LINEAR REGRESSION EQUATION, r VALUES AND THERMAL CONSTANTS FOR DEVELOPMENT RATES OF LIRIOMYZA TRIFOLII LARVAE ON BEAN AND ON GYPSOPHILA

Stage	Host	Regression equation	r	Threshold °C	Thermal constant day degrees
Larva	Bean	$Y=2.37x-30.12$	0.99	12.7	40-45
	Gypsophila	$Y=1.37x-12.45$	0.75	9.1	70-75
Pupa	-	$Y=0.60x- 5.16$	0.99	8.6	167-173

TABLE 9. NUMBER OF LEAVES, LEAF AREA, OVIPOSITION, DEVELOPMENT AND PUPATION OF
LIRIOMYZA TRIFOLII ON GYPSOPHILA AND BEANS IN NON CHOICE AND CHOICE TESTS.

Test	Host	Number of leaves	% infested leaves	Leaf area cm ² Total infested	Number of eggs Total /cm ²	Development days	Number of pupae
No choice	Bean	24	83.3	563	462 143	9	86
	Gypsophila	58	27.6	410	113 45	15	2
	Bean	23	100	454	454 158	9	141
	Gypsophila	36	41.7	174	73 52	15	2
Choice	Bean	15	100	230	230 233	8	174
	Gypsophila	33	24.2	213	52 21	15	16
	Bean	13	100	210	210 195	8	184
	Gypsophila	41	34.1	280	96 26	15	19

Table 10. Response of *L. trifolii* to chrysanthemums grown under short (8L:16D) and long (16L:8D) day photoperiods.^{ab}

Cultivar	Photoperiod	Leaf Area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults/ 100 cm ²
Iceberg ^c	SD	813 [*]	77	9	8	6
	LD	1267	60	7	6	5
Beauregard ^c	SD	922 [*]	58 [*]	9 [*]	8 [*]	5 [*]
	LD	1221	33	3	1	1
Starburst ^c	SD	932 ^{**}	83 [*]	11 [*]	6 [*]	5 [*]
	LD	1194	16	7	2	1
Iceberg ^d	SD	862 ^{**}	112 [*]	16 ^{**}	14 ^{**}	10
	LD	968	50	7	6	5
Anne ^d	SD	817	70 [*]	13 [*]	3	3
	LD	879	22	5	2	1
Knight ^d	SD	786 [*]	78 [*]	16 [*]	4 [*]	3 [*]
	LD	970	9	1	0	0

^aValues represent means from four plants.

^bPairs of values within a cultivar are significantly different if followed by asterisks (* P=0.05; ** P=0.1), Student's t-test.

^cCultivar grown as sprays.

^dCultivar grown as standards.

Table 11. Comparison of L. trifolii damage on chrysanthemums within a long day or short day photoperiod.^{ab}

Photoperiod	Cultivar	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults/ 100 cm ²
Long day (16L:8D)	Iceberg ^c	1267a	60a	7a	6a	5a
	Beauregard ^c	1221a	33ab	3a	1b	1b
	Starburst ^c	1194a	16b	7a	2b	1b
Short day (8L:16D)	Iceberg ^c	813a	77a	9a	8a	6a
	Beauregard ^c	922a	58a	9a	8a	5a
	Starburst ^c	932a	83a	11a	6a	5a
Long day (16L:8D)	Iceberg ^d	968a	50a	7a	6a	5a
	Anne ^d	879a	22b	5b	2b	1b
	Knight ^d	970a	9b	1c	0b	0c
Short day (8L:16D)	Iceberg ^d	862a	112a	16a	14a	10a
	Anne ^d	817a	70a	13a	3b	3b
	Knight ^d	786a	78a	16a	4b	3b

^aValues represent means from four plants.

^bMeans within column and photoperiod followed by same letter are not significantly different by Duncan's Multiple Range test (P=0.05).

^cCultivar grown as sprays.

^dCultivar grown as standards.

Table 12. Response of *L. trifolii* on pinched and unpinched chrysanthemum cultivars grown under short (8L:16D) and long (16L:8D) photoperiods.^{ab}

Cultivar	Photoperiod	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults 100 cm
Iceberg ^c	SD	1162.1	253.6*	35.4*	32.8*	22.1*
	LD	1192.3	145.8	11.2	6.8	5.2
Knight ^c	SD	991.4	211.6*	31.0*	1.3*	1.0*
	LD	911.1	58.8	2.5	0.6	0.0
Iceberg ^d	SD	1194.0	81.4*	7.5*	6.5*	4.3*
	LD	1276.3	43.8	2.4	1.3	0.9
Tuneful ^d	SD	791.5	46.2*	3.4*	0.5*	0.2*
	LD	753.3	35.5	0.6	0.1	0.0

^aValues represent means from six plants.

^bPairs of values within a cultivar are significantly different if followed by an asterisk (P=0.01), Student's t-test.

^cCultivar grown as standards.

^dCultivar grown as sprays.

Table 13. Response of *L. trifolii* on chrysanthemums to pinching of plants.^{ab}

Cultivar	Pinched	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults 100 cm
Iceberg ^c	No	1154.8	208.7	24.7	19.9	13.7
	Yes	1199.6	190.7	21.9	19.6	13.6
Knight ^c	No	966.1	122.8	15.8	1.0	0.7
	Yes	936.4	147.6	17.8	0.4	0.3
Iceberg ^d	No	1199.0	56.4	4.1	3.5	2.4
	Yes	1270.8	68.8	5.7	4.3	2.7
Tuneful ^d	No	744.5	44.2	1.8	0.2	0.1
	Yes	800.2	37.5	2.2	0.3	0.1

^aValues represent means from six plants.

^bNo significant differences between pairs of means within cultivars by Student's t-test.

^cCultivar grown as standards.

^dCultivar grown as sprays.

Table 14. Comparison of *L. trifolii* damage on pinched and unpinched chrysanthemums within long and short day photoperiods.^{ab}

Photoperiod	Pinched	Leaf area/ (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults 100 cm
Long day ^c (16L:8D)	No	1089.7	102.7	7.9	3.4	2.8
	Yes	1013.7	102.0	5.7	3.5	2.5
Short day ^c (8L:16D)	No	1031.2	228.9	32.5	17.6	11.6
	Yes	1122.3	236.4	33.9	16.5	11.4
Long day ^d (16L:8D)	No	971.9	39.0	1.1	0.4	0.3
	Yes	1058.4	40.4	1.9	0.9	0.6
Short day ^d (8L:16D)	No	972.9	61.7	4.9	3.3	2.2
	Yes	1012.6	65.9	6.0	3.7	2.2

^aValues represent means from six plants.

^bNo significant differences between pairs of means within photoperiods by Student's t-test.

^cIceberg and Yellow Knight cultivars used.

^dIceberg and Bright Yellow Tuneful cultivars used.

Table 15. Response of *L. trifolii* on chrysanthemum cultivars treated with a plant growth regulator (B9) and water check.^{ab}

Cultivar	Treatment	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults 100 cm
Iceberg	Water	1192 [*]	62	14	13	11
	B9	1007	74	10	9	7
Beauregard	Water	938 [*]	41 [*]	8 [*]	6 [*]	5 ^{**}
	B9	839	22	6	5	4
Starburst	Water	818	75	7	5 [*]	4 [*]
	B9	863	57	7	4	3

^aValues represent means from four plants.

^bPairs of values within a cultivar are significantly different if followed by asterisks (* P=0.05; ** P=0.1), Student's t-test.

Table 16. Comparison of *L. trifolii* damage within water-treated or plant growth regulator (B9)-treated chrysanthemum cultivars.^{ab}

Treatment	Cultivar	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults 100 cm
Water	Iceberg	1193a	62ab	14a	13a	11a
	Beauregard	938a	41b	8a	6b	5b
	Starburst	818b	75a	7a	5b	4b
B9	Iceberg	1007a	74a	10a	9a	7a
	Beauregard	839b	22b	6b	5b	4b
	Starburst	863b	57a	7ab	4b	3b

^aValues represent means from four plants.

^bMeans within columns and treatment followed by the same letter are not significantly different by Duncan's Multiple Range test (P=0.05).

Table 17. Summary of Kjeldahl and macro-nutrient analysis from leaf tissue of chrysanthemum cultivars treated with different levels of nitrogen.^{ab}

Cultivar	Nitrogen level (ppm N)	Nutrient				
		Nitrogen	Potassium	Phosphorus	Calcium	Magnesium
Iceberg ^c	High (800)	5.5*	4.7	1.6	1.5	0.7
	Low (400)	4.7	5.0	1.7	1.1	0.6
Beauregard ^c	High (800)	5.9*	4.4*	1.5	0.9	0.4
	Low (400)	5.3	4.8	1.4	0.9	0.4
Tuneful ^c	High (800)	5.8**	5.1	1.3	0.8	0.5
	Low (400)	4.9	5.4	1.5	0.9	0.5
Iceberg ^d	High (800)	5.4*	4.5	1.5	1.6	0.7
	Low (400)	4.4	4.7	1.5	1.2	0.6
Anne ^d	High (800)	5.5*	4.2*	1.0	1.0	0.5
	Low (400)	4.6	4.7	1.0	1.0	0.5
Knight ^d	High (800)	5.0*	4.2	0.9	0.7	0.4
	Low (400)	4.2	4.5	1.0	0.6	0.4

^aValues represent means from three plants.

^bPairs of means within a cultivar are significantly different if followed by asterisks (* P=0.05; ** P=0.1), Student's t-test.

^cCultivar grown as sprays.

^dCultivar grown as standards.

Table 18. Response of *L. trifolii* on chrysanthemum cultivars treated with different nitrogen fertilizers.^{ab}

Cultivar	Nitrogen level (ppm N)	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults 100 cm
Iceberg ^c	High (800)	915 ^{**}	24	4	4	3
	Low (400)	1032	31	5	5	4
Beauregard ^c	High (800)	570	24	5 ^{**}	5 ^{**}	4
	Low (400)	599	29	3	3	2
Tuneful ^c	High (800)	576	12	2 ^{**}	2 [*]	2 [*]
	Low (400)	578	10	1	1	1
Iceberg ^d	High (800)	1304	50	11 ^{**}	11 ^{**}	9 [*]
	Low (400)	1154	47	7	6	5
Anne ^d	High (800)	888	23	4	4 [*]	2 ^{**}
	Low (400)	890	18	3	2	1
Knight ^d	High (800)	697 [*]	23 [*]	3 [*]	2 [*]	2 [*]
	Low (400)	864	9	1	1	1

^aValues represent means from five plants.

^bPairs of means within a cultivar are significantly different if followed by asterisks (* P=0.05; ** P=0.1), Student's t-test.

^cCultivar grown as sprays.

^dCultivar grown as standards.

Table 19. Comparison of L. trifolii damage on chrysanthemum cultivars within nitrogen level.^{ab}

Nitrogen level (ppm N)	Cultivar	Leaf area (cm ²)	Mean densities			
			Stipples/ 100 cm ²	Mines/ 100 cm ²	Pupae/ 100 cm ²	Adults/ 100 cm ²
Low (400)	Iceberg ^c	1032a	31a	5a	5a	4a
	Beauregard ^c	599b	29a	3ab	3ab	2ab
	Tuneful ^c	578b	10b	1b	1b	1b
High (800)	Iceberg ^c	915a	24a	4a	4ab	3ab
	Beauregard ^c	570b	24a	5a	5a	4a
	Tuneful ^c	576b	12b	2b	2b	2b
Low (400)	Iceberg ^d	1154a	47a	7a	6a	5a
	Anne ^d	890b	18b	4b	4b	2b
	Knight ^d	864b	9b	1b	1b	1b
High (800)	Iceberg ^d	1304a	50a	11a	11a	9a
	Anne ^d	888b	23b	4b	4b	2b
	Knight ^d	697c	23b	3b	2b	2b

^aValues represent means from five plants.

^bMeans within columns and nitrogen level followed by the same letter are not significantly different by Duncan's Multiple Range test (P=0.05).

^cCultivar grown as sprays.

^dCultivar grown as standards.

II. CONTROL OF L. TRIFOLII

A COMPARISON OF DIFFERENT POSITIONS AND HEIGHTS OF YELLOW STICKY TRAPS FOR SAMPLING LEAFMINER POPULATIONS

INTRODUCTION

As L. trifolii is a new pest in Israel, little is known of its phenology and seasonal occurrence under various outdoor, greenhouse or shadehouse conditions. One way to assess population densities is by estimating adult activity. This can be used in monitoring invasions of flies into a crop (Tryon et al 1980); it can also be helpful in predicting the occurrence and intensity of subsequent larval densities for timing spray applications (Bene & Rumine 1985). These can be aimed at either immediate adult control or planning for control of the following stages.

Attraction of leaf miners to yellow color was long known and was studied in the past (Chandler 1981, Tryon et al 1980). The technique was already used for monitoring (Parrella & Jones 1984, Schuster & Beck 1981) and also as a control measure (Herbert et al 1984, MacClanahan 1983).

On the basis of information available the present study was undertaken to develop a rapid and easy method for noting population changes in crops. It was aimed at finding the preferable position and height of traps relative to the plants.

MATERIALS AND METHODS

The study was conducted in the spring of 1985 in the coastal plain in Israel, in a 0.25 ha greenhouse with mature gerbera plants at the end of the cropping season. There were various varieties with

flowers of different colours. Many leaves showed past and present damage caused by leafminers. L. trifolii flies were observed on the plants, especially those with yellow flowers situated at the north-eastern corner.

The traps used were yellow plastic boards (20x14 cm) with an over 90% reflectance in the visible wave length spectrum of 535-685 nm. The boards were coated both sides with "Rimifoot"* glue. These were attached to garden stakes and placed among the plants, along the eastern bed, at distances of 3 m.

The traps were changed every 3-4 days. Upon removal the number of flies on each side of the board was counted and recorded. Although visible, no effort was made to sex the flies trapped.

The experiment was carried out in two stages. In the first stage traps were installed March 24, 1985, and were changed 3 times in 10 days till April 3. Two heights of traps were tried, top plant level and 30 cm above top of the plants. At each height 3 positions were tested, e.g. horizontal, a 45° angle and a vertical position. The horizontal and 45° angle boards had upper and lower surfaces, while the vertical position surfaces faced south and north. This was replicated four times.

The second stage experiment went on from April 4 to May 14 covering a period of 40 days, during which time traps were changed 9 times. Three heights were tried, top plant level, 30 cm and 70 cm above top of the plants. At each height 4 positions were installed, a horizontal one, a 45° angle one and two vertical positions, one fixed

*Yevnin Jaffe Chemical Ltd. Tel Aviv

facing south and north, the other hanging free and subject to movement by wind. This was replicated five times.

All counts, y , were transformed into $\ln(y+1)$ and the transformed data were analyzed by 3-way ANOVA model. The analysis were performed for each date separately.

RESULTS AND DISCUSSION

Mean catches $\pm$ SE of the various treatments in the first stage experiment are presented in Table 20. The coefficient of variation (C.V.) of the 3-way ANOVA analysis for these dates are 11.16, 12.74 and 9.31 respectively.

Regarding the effect of height, at 30 cm above top of plants catches were higher than at top plant level ($p < 0.0001$).

As for positions and sides, in the horizontal and 45° angle traps, the catches were higher on the upper side than on the one facing downward ($P < 0.01$) and higher than in the vertical south and north sides. However, the vertical one side catches were higher than in the horizontal and 45° angle ones on the lower side ($P < 0.05$).

The second stage experiment lasted 40 days, catches, fluctuated from very low to very high numbers. Mean catches $\pm$ SE of the various treatments are shown in Table 21 for 3 dates representing medium, low and high catches. The coefficient of variation (C.V.) of the 3-way ANOVA analysis for these dates are 12.50, 22.70 and 10.00 respectively.

Of the three heights, catches at 70 cm above top of the plants were lower than at 0 and 30 cm and this at all population levels.

Catches at 30 cm and at top of plants were quite close or equal, the opposite of what was observed in the first part. However, Chandler (1985) testing the vertical flight zone of L. trifolii found that traps placed about 30 cm above

ground in bell peppers caught significantly more than did traps placed at heights of 60, 90, 120 and 150 cm above ground, regardless of height of plants which fluctuated between 1.5 and 38.9 cm. He found highest catches when plants were tallest, but he trapped much lower numbers than in the present study.

Regarding the effect of position, at 30 and 70 cm above the plants, total catches of the vertical traps were higher than those of the horizontal and 45° angle traps. At top plant level no clear trend could be detected. Total catches of the horizontal traps did not significantly differ from the 45° angle traps at all heights and population levels. Among the vertical traps, free hanging traps showed higher catches than the fixed ones at 30 and 70 cm above the plants, while at top plant level the opposite occurred.

Not many studies have been reported relating to trap placement and adult L. trifolii catches at optimal trap height. Herbert et al found fewer flies trapped by boards hung in the horizontal position than the vertical, but orientation of the yellow sticky traps did not significantly affect the number of flies trapped at higher populations in chrysanthemum greenhouses.

Parrella and Jones (1985) placed their traps in chrysanthemum greenhouses in a vertical position just above crop canopy, and caught very high numbers, up to 1948 flies on large 30.5x30.5 cm traps, and up to 620 on small ones 11.4x14.0 cm.

As to sides, in the horizontal and 45° angle traps catches were significantly higher on the upper side of the board, and this at all heights and at all population levels as seen in Tables 20 & 21. In the vertical traps, either fixed or free, there was no effect of side. A maximum of 1507 and 1683 flies was trapped on the upper side of a horizontal and a 45° angle trap respectively, on 20x14 cm boards at top plant level, while on each side of the vertical free traps 1026 and 1155 were found on that date. Although upper side

catches were higher than on one side vertical traps, total catches of vertical traps did not significantly differ from the horizontal totals. In addition traps hung vertically are more practical as they involve less work and thus would be more readily accepted by growers.

Table 20. Mean numbers $\pm$ S.E. of *Liriomyza trifolii* flies caught on yellow sticky board traps in a gerbera greenhouse in the coastal plain in Israel.

Treatments			Dates		
Height above top of plants (cm)	Position	Side	26.3.85	29.3.85	3.4.85
0	Horizontal	Upper	136.75 $\pm$ 38.12	217.75 $\pm$ 31.99	176.50 $\pm$ 20.74
		Lower	9.75 $\pm$ 4.09	20.50 $\pm$ 6.66	41.25 $\pm$ 11.89
	45° angle	Upper	100.00 $\pm$ 17.34	173.25 $\pm$ 37.64	197.25 $\pm$ 32.56
		Lower	17.75 $\pm$ 6.34	44.00 $\pm$ 21.67	46.00 $\pm$ 12.46
	Vertical	South	69.75 $\pm$ 11.16	97.75 $\pm$ 14.33	131.75 $\pm$ 20.41
		North	60.50 $\pm$ 6.39	90.50 $\pm$ 9.89	122.25 $\pm$ 5.36
30	Horizontal	Upper	123.50 $\pm$ 8.35	190.75 $\pm$ 29.14	256.00 $\pm$ 32.01
		Lower	34.50 $\pm$ 8.61	44.75 $\pm$ 10.79	84.25 $\pm$ 30.70
	45° angle	Upper	140.25 $\pm$ 14.18	194.00 $\pm$ 5.46	294.50 $\pm$ 59.30
		Lower	54.50 $\pm$ 8.61	101.25 $\pm$ 16.25	155.00 $\pm$ 30.41
	Vertical	South	91.00 $\pm$ 16.13	140.00 $\pm$ 11.92	212.75 $\pm$ 12.93
		North	77.25 $\pm$ 8.88	156.25 $\pm$ 4.40	267.25 $\pm$ 10.93

Table 21. Mean numbers of *Liriomyza trifolii* flies caught on yellow sticky board traps in a gerbera greenhouse in the coastal plain in Israel on different dates, representing medium, low and high populations.

Treatments			Dates		
Height cm	Position	Side	8.4.85	18.4.85	7.5.85
0	Horizontal	Upper	180.20 $\pm$ 48.49	36.00 $\pm$ 10.77	798.20 $\pm$ 181.63
		Lower	53.20 $\pm$ 7.72	6.80 $\pm$ 2.03	122.80 $\pm$ 22.45
	45° angle	Upper	191.20 $\pm$ 18.65	25.60 $\pm$ 7.61	550.60 $\pm$ 176.73
		Lower	84.80 $\pm$ 14.59	6.60 $\pm$ 2.28	192.20 $\pm$ 47.34
	Vertical fixed	South	161.60 $\pm$ 31.97	23.60 $\pm$ 6.16	413.80 $\pm$ 54.23
		North	146.80 $\pm$ 18.31	22.00 $\pm$ 3.69	394.80 $\pm$ 72.25
	Vertical free	1	96.80 $\pm$ 20.63	17.80 $\pm$ 4.81	325.00 $\pm$ 62.64
		2	143.40 $\pm$ 24.14	13.80 $\pm$ 4.60	184.84 $\pm$ 33.13
	Horizontal	Upper	143.40 $\pm$ 24.33	22.20 $\pm$ 5.36	596.40 $\pm$ 154.65
		Lower	61.80 $\pm$ 14.98	6.20 $\pm$ 0.66	137.80 $\pm$ 15.19
	45° angle	Upper	108.80 $\pm$ 22.58	14.60 $\pm$ 1.86	387.20 $\pm$ 95.09
		Lower	78.60 $\pm$ 4.95	9.20 $\pm$ 1.46	248.60 $\pm$ 60.65
30	Vertical fixed	South	81.80 $\pm$ 11.89	14.20 $\pm$ 3.52	406.20 $\pm$ 59.45
		North	85.60 $\pm$ 12.47	16.20 $\pm$ 3.45	431.20 $\pm$ 42.60
	Vertical free	1	131.20 $\pm$ 19.59	21.40 $\pm$ 6.11	483.00 $\pm$ 93.92
		2	147.20 $\pm$ 14.44	24.80 $\pm$ 3.45	433.00 $\pm$ 77.29
	Horizontal	Upper	76.40 $\pm$ 15.58	11.00 $\pm$ 1.89	274.40 $\pm$ 37.97
		Lower	24.40 $\pm$ 5.94	6.60 $\pm$ 1.43	127.20 $\pm$ 28.48
	45° angle	Upper	55.00 $\pm$ 20.45	8.40 $\pm$ 1.96	235.00 $\pm$ 43.59
		Lower	35.00 $\pm$ 5.23	3.60 $\pm$ 1.12	114.40 $\pm$ 26.86
	Vertical fixed	South	38.60 $\pm$ 15.27	6.20 $\pm$ 2.33	231.00 $\pm$ 90.36
		North	48.20 $\pm$ 17.26	6.00 $\pm$ 2.07	155.20 $\pm$ 62.68
	Vertical free	1	60.40 $\pm$ 16.22	14.20 $\pm$ 3.70	289.60 $\pm$ 69.95
		2	84.00 $\pm$ 28.86	8.60 $\pm$ 2.27	254.80 $\pm$ 69.25

B. NETS FOR PROTECTING GREENHOUSES FROM LIRIOMYZA TRIFOLII

Liriomyza trifolii is an important pest of various vegetable and flower crops including gypsophila which is an important export item. Export countries employ strict quarantine regulations demanding gypsophila not only free of L. trifolii infestation but also "symptomless". Damage in gypsophila may be difficult to detect, so growers have undertaken a strict sanitation and spray regime using pyrazophos, cyromazine and abamectin alternately.

One method of reducing insecticide applications and the labor involved is the use of protecting nets as window screens, or to enclose entire insect proof shadehouses.

High mesh nets prevent passage of insects, but may interfere with ventilation. Various size nets were tested to find those that would prevent flies, especially the females, which are bigger than males, from passing.

Materials and Methods

Nets ranging from 42 to 176 mesh/cm² were tested in a greenhouse in Israel at 25°C. Flies were obtained from a L. trifolii permanent culture maintained at the Department of Entomology. The tests were based on the positive reactions of L. trifolii flies to light (phototropism) and to plants suitable for feeding and oviposition.

Wooden cages (30x35x45 cm) with one glass wall were used, two such cages, separated by the net to be tested (45x35 cm) were joined to form one unit. Into one cage, the target cage three pots with bean seedlings with the first two true leaves were introduced. Into the other cage, beyond the screen, 50 flies were liberated.

The doubled cages were placed in the center of a naturally well lighted greenhouse. The glass walls of the target cages faced the windows on the south,

and those of the liberation cages faced north windows. The flies were liberated at noon, 50 flies/cage. They were not sexed, but the majority were females. After 48 h the live flies were collected and sexed.

The seedlings from the target cages were kept for observation on development of leafminer damage, and development of the offspring of the flies introduced.

The nets were evaluated by:

1. The number of flies recovered in the target cages 48 h after liberation in the adjoining cages.
2. Damage caused to leaves in the target cages, rated as follows: a-leaves totally free of leafminer damage, b-some damage, mines conspicuous but separate, c-the total leaf area criss-crossed with mines of mature larvae.
3. The number of pupae produced on the leaves in the target cages served as an estimation of the offspring of the flies that had reached the plants.

The test was carried out in two stages. In the first stage (A) the liberation cages were darkened by a black plastic sheet, it was assumed the flies would be attracted to the plants in the lighted target cages. At the second stage (B) the liberation cages were not darkened.

Results

In some of the target cages, those with low density nets (42 mesh/cm^2) flies were observed within 30 min after liberation. When removed after 48 h they were sexed, as the smaller males were expected to pass more readily.

The number of live flies found after 48 h, the rates of damage according to damage levels and the number of offspring, displayed by the number of pupae - are presented in Table 22, for both stages.

Stage A. Only the low density nets (42 and 84 mesh/cm^2) allowed passage of male

of the trifolii flies. Their offspring caused heavy damages and yielded

hundreds of pupae. The three high density nets prevented all flies from reaching the plants in the target cages. No damage was caused and no pupae formed. With the 98 mesh/cm² net, at least one female L. trifolii had passed along with the males found, as some damage occurred and one pupa was formed.

Stage B. Results obtained with undarkened liberation cages were almost the same as in Stage A. The high density nets allowed no passage of flies, no damage and no offspring. The 98 mesh/cm² net did not prevent individual flies, both male and female, from getting into the target cage, but no ensuing damage was found. With the 84 mesh/cm² net less flies were recovered than in Stage A, and the number of pupae was smaller as were also the damage rates, suggesting that perhaps less ovipositing females had reached the target cage when attracted only by the plants without added attraction of light. The 42 mesh/cm² net yielded results identical to those found in Stage A, in damage rates as well as in the close numbers of pupae.

In conclusion: nets from 100 mesh/cm² stop passage of female L. trifolii flies, attracted to suitable host plants, thus preventing oviposition and damage caused by the larvae.

Fig 3: Differential leafminer injury to leaves protected by nets of different mesh size (control to the right).

TABLE 22. EFFICACY OF NETS AGAINST LIRIOMYZA TRIFOLII FLIES

a - leaves totally free of damage, b - some damage, c - leaves totally eaten up by larvae.

Liberation cages	Mesh cm ²	Number of flies		Degree of damage			Number of pupae
		recovered		(%)			
		o o	o o	a	b	c	
A (Darkened)	Control	19	13	0	4	96	452
	42	15	9	0	13	87	388
	84	6	7	0	18	82	270
	98	2	0	90	10	0	1
	140	0	0	100	0	0	0
	144	0	0	100	0	0	0
	176	0	0	100	0	0	0
B (Undarkened)	Control	16	15	0	2	98	689
	42	8	9	0	14	86	424
	84	3	0	0	70	30	191
	98	2	2	100	0	0	0
	140	0	0	100	0	0	0
	144	0	0	100	0	0	0
	176	0	0	100	0	0	0

C. CHEMICAL CONTROL

Introduction

Various insecticides were used and are used to control Liriomyza trifolii in vegetable and flower crops in Israel. When the pest was first introduced into the country in 1978, many insecticides were tested on a trial and error basis. Thus soil treatments were recommended (Brosh et al, 1981), and various organophosphate and pyrethroid cover sprays were applied. Results were unreliable and unpredictable. Methamidophos proved affective against both the adults and the larvae and supplied good protection. It could not always be used as it was found to be phytotoxic to some of the most susceptible crops (Brosh et al, 1980).

It was thus important to evaluate the recommended practices and test new compounds if they became available. Soil applications and cover sprays were tested, using contact insecticides as well as insect growth regulators (IGRs).

In order to supply flies and immature stages of the leafminer for these tests a L. trifolii culture was established.

Culture of L. trifolii

Young plants from a permanent culture of bean seedlings (Phaseolus vulgaris, Bulgarian variety) in pots (height 9 cm, diam 10 cm) were used both for rearing L. trifolii and for laboratory tests.

A L. trifolii culture, originating in Chrysanthemum leaves in the Jordan Valley was maintained in the laboratory in a transparent perspex rearing cage (125x55x60 cm) kept at 27°C and at a 16:8 LD photoperiod. Potted bean seedlings were exposed to an adult fly population in the rearing cage for 24 h. After excluding the flies the plants were kept under the same environmental conditions until the larvae were ready to pupate. The infested leaves were then cropped and

kept on trays. Close to adult emergence the trays were placed in the rearing cage at the darkened end.

SOIL TREATMENTS

The soil treatments tested were aimed to test two different approaches to control. One was the use of contact insecticides applied in the soil and intended to affect the emerging flies, from the pupae in the soil. The second was the use of systemic granular insecticides applied to the soil and intended to be absorbed by the roots and moved to the target area in the leaves to control the larvae.

A. CONTACT INSECTICIDES

Soil treatment to prevent emergence from L. trifolii pupae in the ground were tested under laboratory conditions and artificial infestation, with pupae of known age.

MATERIALS AND METHODS

Insecticides tested included granular or powder formulations applied at a rate equaling 40 kg/ha, and spraying formulations applied at the recommended concentrations.

The tests were carried out in transparent containers into which soil was introduced and the insecticides added or sprayed. Each container was then infested with 20 L. trifolii pupae of known age, slightly watered to wet the soil and move the insecticide downwards. A yellow sticky board to attract and trap the emerging flies, was put into each container. There were 5 replicates, and the number of flies stuck to the boards served as an indication of efficacy. The containers were kept outdoors under naturally hot conditions of early summer (maximum daily temperatures around 30°C).

RESULTS

The number of flies that did emerge from treated soil are presented in Table 23. When 2-day-old pupae were used it was assumed that the insecticides deteriorated till emergence occurred. Tests with older pupae revealed inconsistent results and were discontinued, as they were unpromising.

B. SYSTEMIC INSECTICIDES

As the eggs and larvae of L. trifolii spend their development period within the leaf there are difficulties in reaching them with insecticides. One way of affecting the larvae would be by introducing a systemic insecticide to the leaf tissue they feed on.

Tests were carried out to assess the effect of soil application of systemic insecticide on L. trifolii control.

MATERIALS AND METHODS

Insecticides tested were systemic granulated carbamates, aldicarb 15%, butocarboxym 15%, carbofuran 10% and oxamyl 10%. The rate applied was 15 mg/pot (a.i.) except for butocarboxym which was applied at the rate of 30 mg/pot. Cyromazine, an insect growth regulator (IGR) was tested at rates of 20, 10 and 5 mg/pot.

Bean seedlings in pots (height 9 cm, diam 10 cm) were exposed to ovipositing L. trifolii female flies for 48 h. In each pot there were two plants with two leaves, altogether 4 leaves. Each treatment was thrice replicated. After infestation, when still at the egg stage, the insecticides were applied to the soil and then watered. The plants were regularly checked and when pupae began to form the leaves were cropped and kept for further recording or till emergence stopped.

RESULTS

The number of flies that emerged from infested plants after soil treatment with systemic carbamates is presented in Table 24. Carbofuran proved ineffective, butocarboxym, applied at a double rate, reduced the number of larvae that reached the adult stage, but provided only partial control. Aldicarb and oxamyl totally prevented development and allowed no flies.

The number of mines and larvae recorded, and the number of pupae collected when aldicaarb and oxamyl were compared to cyromazin, are presented in Table 25.

The high rate of cyromazin (20 mg/pot) prevented development of larvae, but was phytotoxic. With lower doses of 10 and 5 mg/pot many mines were observed, but they were separate and could easily be counted, while in the control the whole leaf area was one big blotch. The larvae found in the cyromazine treated leaves were quite small while in the control all have already pupated. Only in the low dose were some pupae found.

The carbamates, aldicarb and oxamyl reduced the number of mines, probably due to immediate mortality of neonates and some older larvae, but some survived to pupate.

All insecticides had a retarding effect on development of the fly, as larvae were present when in the controls all had already pupated.

COVER SPRAYS

The most common practice of chemical control for controlling Liriomyza trifolii is by cover sprays. The adult flies which are exposed in the open are quite susceptible to insecticides, but their progeny left inside the leaf, the egg and larvae, are well protected there.

A method was developed to assess the effect of insecticides on eggs and

MATERIALS AND METHODS

A series of preliminary tests was carried out to develop a standard routine method for evaluating insecticides applied to control L. trifolii larvae. Groups of 30, 40, 50 and 100 L. trifolii female flies were taken from the permanent L. trifolii culture and introduced into oviposition cages, and allowed to oviposit for 1, 2 or 24 h on 12 bean seedling with the first two true leaves. The combination adopted and used henceforth was exposing 12 bean seedlings for 24 h to 50 ovipositing female L. trifolii, in a cage 45x35x37-27 (with a glass slanting top). The resulting infestation avoided intraspecific competition that could affect the rate of emergent pupae to exposed larvae (Parrella, 1983).

The tests were carried out in a greenhouse at 27°C and under a 16:8 LD photoperiod regime, using plants that had been infested as follows. Each treatment included three pots with four seedlings with their first two true leaves. Altogether 12 seedling with 24 leaves. These were exposed for 24 h to 50 ovipositing female flies. Infested plants were treated either at the egg stage or were kept until early larvae of the required larval instar appeared, and then sprayed with aqueous dilutions of the insecticide tested, the concentration range depended on the compound tested.

Efficacy was established using two methods, one was based on an immediate examination and another on a follow up of the treated plants.

1. Examination of the immediate effect of insecticide treatment was carried out 24 h after application. Infested leaves were removed and each mine opened under magnification to confirm whether the larvae was alive or dead. If mortality was not full, another sample was examined 48 and again 72 h after application. Each examination included 50 mines which were ripped open.

2. Another set of infested plants was kept intact until all the next generation

2.1. The rate of feeding and the resultant damages were graded according to the size and number of mines and the portion of leaf area they occupied, as follows: a-leaves totally free of leafminer damage, b-some damage due to either neonate feeding mines or bigger, but separate and countable mines, c-the total leaf area, or a great part of it criss-crossed with mines of mature larvae.

2.2. The number of larvae that survived and did pupate was established by collecting all pupae on the leaves and underneath.

2.3. The number of adults emerging from the pupae was recorded to assess pupal viability.

Pesticides tested included contact and stomach insecticides as well as insect growth regulators (IGRs), or insect growth inhibitors.

Contact and stomach insecticides tested were ethion 50% EC, monocrotophos 60% SC, methamidophos 60% SC, pyrazophos 30% EC, carbosulfan 25% EC, thiocyclam 50% WSP and abamectin 1.8% EC.

Insect growth regulators tested were Cyromazin 75% WP, diflubenzuron (dimilin) 2% WP and 5% liquid, triflumuron (Alsystin) 25% WP and 6.5% EC, chlorfluazuron (IKI-7899) 25% WP and 50% EC and XRD-473 50% EC.

ORGANIC PHOSPHATES

The effect of non-selective organophosphate compounds was first tested on the egg and on the third larval instar Liriomyza trifolii. The insecticides tested were:

1. Ethion a non-systemic insecticide with relatively long residual effects (Worthing, 1986). A 50% EC formulation was tested at the rate of 2500 ppm.
2. Monocrotophos - a fast acting systemic and contact insecticide. The 60% SC was used at a concentration of 2400 ppm.

3. Methomidophos (Parrella & Keil, 1985) - a systemic residual insecticide. The 60% SC was tested at 2400 ppm.

RESULTS

The distribution of leaves according to degree of feeding and damage by L. trifolii after applications of organophosphates is presented in Table 26. When treated at the egg stage only methamidophos provided full protection and prevented any damage by larvae. Monocrotophos, and to some extent also ethion affected some of the eggs or neonate larvae and some damage was caused.

When plants infested with third instar larvae were sprayed, damage was already present, but all treatments prevented further damage, as compared to the control, which reached grade "c" level of damage.

Survival results confirmed those of the accumulated damage. No pupae were found in the methamidophos treated leaves, when applied at the egg stage. Ethion and monocrotophos greatly reduced the number of pupae, but still some pupae gave rise to adults, as seen in Table 27. When treated at third larval instar dead larvae and few abnormal pupae were found in the methamidophos treated leaves. Ethion and monocrotophos greatly reduced the number of pupae, emergence too was low.

Methamidophos was further tested for the immediate effect after spraying plants with the immature stages with concentrations of 150, 300 and 600 ppm.

Results are presented in Table 28. Egg stage examination was done 48 h after spraying, as nothing could be detected earlier. At 600 ppm no eggs hatched, at 150 and 300 ppm eggs had hatched, but the neonates died immediately.

With first instar larvae high mortality was found after 24 h, while with second and third instar larvae this took longer. Third instar larva treated have

PYRAZOPHOS 30% EC

Pyrazophos (Afugan, Curamil) is an organophosphate pyridamin compound with systemic properties for control of powdery mildew. Pyrazophos has limited insecticidal activity and as it is absorbed by foliage and translocated within the plant (Worthing, 1986) it can reach the eggs and leafminer larvae. This insecticidal activity against leafminers was simultaneously reported by several workers (Lindquist and Casey, 1982, Parrella, 1982, Price, 1982). It is now recommended for control of L. trifolii in Israel, especially in gypsophila, chrysanthemum and gerbera. It was tried at concentrations ranging between 150-2400 ppm against the eggs and larval stages of L. trifolii.

RESULTS

1. Examination of larval mortality 24 h after application of pyrazophos revealed high mortality rates of 1st instar larvae, and of neonates in the egg stage treated leaves, as seen in Table 29. With 2nd and 3rd instar larvae pupae were formed and gave rise to adults.

2.1 Distribution of infested leaves according to damage degree are presented in Table 30. When applied to leaves at the egg stage damages reached grade "b", but the higher the concentration the lower the damage level. With 1st instar larvae the final damage remained at grade "b", while in the control damage levels reached level "c".

When leaves with 2nd and 3rd instar larvae were treated heavy damage was already present, and only the higher concentrations seemed to stop larval feeding. Although damage levels were seemingly high larvae were affected and only few abnormal or dead pupae were obtained as seen in Table 31.

CARBOMATES

Carbosulfan 25% EC

Carbosulfan (Marshal) is a carbamate compound with a broad spectrum of stomach, contact and systemic properties, (Worthing, 1986) as a 25% EC it was tested against the eggs and larval instars of L. trifolii at doses of 168-2700 ppm.

Results

When mortality was examined every 24 h after applicaiton of carbosulfan, only the 2500 ppm dose caused total mortality of neonates when applied at the egg stage. All larval instars were not much affected, and mortality rates were low even after 72 h, and many pupated and gave rise to adults as seen in Table 32.

2. Distriubtion of leaves according to degree of damage are presented in Table 33 and survival rates in Table 34.

Doses of 50-150 ppm applied to leaves infested with 1st instar larvae somewhat reduced damage and development, but many larvae did pupate, although at lower rates than the control, and emergence rate was not affected.

Higher doses of 125-500 ppm applied to leaves infested with eggs or 1st or 2nd larval instars resulted in reduced damage only with the 500 ppm dose which also reduced the number of pupae formed and the emergence rate.

Doses ranging between 168 to 2700 ppm were more effective against the egg and 1st instar larva, whereas with 2nd and 3rd instar larvae feeding continued and damage accumulated to levels "b" and "c", as seen in Table 33. Accordingly high numbers of pupae were obtained from the 2nd and 3rd instar larvae, and emergence rates too were high as seen in Table 34.

Abamectin 1.8% EC

Abamectin (Agrimec, Dynamec, Vertimec) is a novel insecticide based on Avermectin, a natural product originally derived from the soil microorganism Streptomyces avermitilis. It's major site of action is the neuro and neuromuscular junctions in arthropods (Parrella, 1982, Putter et al, 1981; Strong and Brown, 1987). This mode of action differs from that of conventional organophosphate, carbamate and pyrethroid compounds. Affected insects are first immobilized, then paralysis advances till mortality. With sublethal doses feeding is arrested and damage is reduced. Abamectin is absorbed in the leaf and acts as a stomach poison, but also by contact. The high intrinsic activity allows the use of low concentration sprays or low use rates/ha.

Abamectin in the form of 1.8% EC was tested against the egg and larval stages of L. trifolii using doses of 9-36 ppm.

Results

1. When mortality was examined 24 and 48 h after application, eggs did not hatch at 18 or 36 ppm, while at 9 ppm mortality occurred following egg hatch in foliage mines, as seen in Table 35.

The larval instars too were badly affected and 72 h after spray all were dead. Some of the 3rd instar larvae pupated and even gave rise to adults, but the numbers dropped with increase in dose, as seen in Table 35.

2. Distribution of accumulated damage in the sprayed leaves is presented in Table 36. At the egg stage a high percentage of leaves did not show any damage symptoms, confirming the observations in Table 35. of excellent larval mortality either prior to exlosion or following hatch.

When leaves with 1st and 2nd instar larvae were sprayed some damage was already present, but it was arrested and did not reach level "c" as in the control.

When leave with 3rd instar larvae were sprayed noticeable damage was already noted, and treatment to some extent stopped additional feeding and damage.

All doses applied at the egg and 1st or 2nd larval instars prevented larvae from reaching the pupal stage, as shown in Table 37, in accordance with results obtained by examining immediate effects (Table 35). When treated at the 3rd larval instar abnormal pupae were formed, but none gave rise to adults, while as seen in Table 35 some viable pupae were obtained, but the actual number of flies was very small.

Thiocyclam 50% SP

Thiocyclam (Evisect) is a new insecticide belonging to a novel class of pesticides related to nereistoxin, a naturally occurring substance in the marine annelid-worm Lumbrinereis spp. It possesses contact and stomach activity, and is absorbed through roots and foliage and carried by acropetal translocation in the sap stream, which improves its stomach action. It does not affect cholinesterase activity and offers a safety level for man (Thomson, 1985-86; Worthing, 1986).

Results

1. Mortality rates found 48 and 72 h after spraying with thiocyclam are presented in Table 38. The 500 ppm dose resulted in total mortality of all stages; the 250 ppm dose, too, resulted in high mortality.

2. Distribution of damage in the infested leaves is given in Table 39. Damage was high in the leaves infested with eggs and the number of larvae that reached the pupal stage was relatively high, and many gave rise to adult flies.

When leaves infested with 1st or 2nd instar larvae were sprayed, damage was already present, but the sprays had stopped further damage, which did not reach level "c" as in the control. The few pupae formed were abnormal and did not give rise to flies.

When leaves with 3rd instar larvae were sprayed, damage was already conspicuous, but concentrations of 300 ppm and up arrested additional damage as seen in Table 39. Many larvae reached the pupal stage and gave rise to adult flies, but many of the pupae were not viable. No flies were obtained with 400 ppm and up. Emergence rate was reduced compared to the control, as seen in Table 40.

Neem seed extracts

The extract of seeds from the neem tree Azadirachta indica A. Juss was found to have diverssified insecticidal effects on many insect species (Warthon, 1979). The active compound responsible is a terpenoid azadirachtin. The effect of an ethanol extract redissolved in water was tested on L. trifolii and L. sativa (Webb et al, 1983), while an aqueous extract was tested in a field trial (Fagoony and Toory, 1984).

The insecticidal activity of foliage sprays formulated from various extracts of neem obtained with a series of polar, nonpolar or dual solvents, as foliage sprays on the development of L. trifolii was investigated. Systemic effects obtained by drenching the soil with the aqueous extract only, were also studied.

Neem seed kernel extracts were obtained by decortivating and then grinding 50 g Neem seed kernels (from Togo, Africa) to a powder, which was stirred for 3 h at room temperature with a magnetic stirrer in one liter of the following solvents: water, methanol, ethanol, acetone, isopropyl alcohol, n-butanol, chloroform, carbon tetrachloride or n-pentane. The mixture was allowed to stand for 20 h, then stirred again for 1 h and filtered through a fluted filter paper. The solvents were allowed to evaporate from the filtrates in porcelain dishes and the residues were dried to constant weight by placing the dishes near an electric fan. The dried methanolic neem seed kernel was redissolved in 80% aqueous methanol which was also used for dissolving the other extracts (except the aqueous one, which was redissolved in water). For control experiments 80% aqueous methanol or water (in the case of the aqueous extract) was used. To obtain the concentrations desired were equal amounts of the dried extracts dissolved in 8 parts methanol, to which two parts of an aqueous solution of Triton X-100 (2 drops in 100 ml H₂O) had been added.

All tests were conducted at 25°C. Bean plants were grown in a glass house in plastic pots containing vermiculite (for the foliage treatments) or sandy loam soil (for the systemic experiments). When the primary leaves appeared, the plants were thinned to one seedling per pot; then either the leaves were painted with a hair brush or the plants were sprayed until runoff with a Desaga spray gun with different extracts of neem. The plants were allowed to dry for 3 h and then introduced into cages (55 x 35 x 34 cm). Into each cage 5 pots treated with the same extract or 5 control plants were introduced, together with 50 female flies. The experiments were thus conducted as a no-choice situation, the plants treated with different neem extracts in separate cages being compared with water-treated (control)

plants in another cage. After a 5-day exposure to the flies, the inoculated plants were transferred to screened cages and checked periodically for mines and finally the number of pupae on the leaves was recorded. The mean percent reduction in the pupal yield in the different neem extracts from that of the control served as an indication of comparable efficacy.

The experiments conducted were basically of two types:

(i) foliage treatment, by painting or spraying bean leaves before exposure to adults (preinfestation application) or after the appearance of the first mines (postinfestation application); (ii) soil treatment, to test the systemic effect of the aqueous Neem extract. In the preinfestation treatment the aqueous, methanolic and ethanolic extracts were tested at 1.0, 0.5 and 0.1% (w/v); n-pentane, acetone, carbon tetrachloride and isopropyl alcohol at 1.0 and 0.5%, whereas dioxane, chloroform and n-butanol at 1.0% only.

To test the neem extracts in postinfestation application, bean leaves were exposed to female flies and upon the appearance of the first mines, the leaves were painted either on both sides or on the upper side only. In these experiments only the 1% aqueous, methanolic and ethanolic extracts were tested. These extracts were tested also in postinfestation spraying experiments, but in this case 5 drops of Triton X-100 were added to 100 ml of solution of the aqueous extract.

To investigate the effect of soil treatment with the aqueous extract of the neem seed kernel, 20 ml of 1% (approximately 700 ppm a.i.) of this extract was drenched into 290 g wet sandy loam/pot. One, 3 or 5 days after soil treatment the plants were exposed to infestation by the female flies as described above.

Results

Table 41 presents data on the number of pupae found on bean leaves painted on both sides with various concentrations of different neem seed extracts before infestation. The ethanol, methanol and acetone extracts at 1.0% and the first two extracts also at 0.5%, totally prevented pupation. The aqueous and the carbon tetrachloride extracts at 1.0% prevented pupation nearly completely, with a reduction in pupal yield of 98.1% and 96.0%, respectively.

Table 42 presents the reduction in pupal yield on the leaves which had been painted with 1% aqueous methanolic and ethanolic extracts immediately after the appearance of the first mines. The ethanolic and methanolic extract were more active than the aqueous one, when applied either on both sides of the leaves or on the upper side only.

Table 43 shows the reduction in pupal yield found on the leaves of plants sprayed with aqueous, methanolic and ethanolic extracts of neem seed kernel, before their exposure to ovipositing females, in comparison with the pupal yield found on the control leaves. Leaves sprayed with 1.0 and 0.5% aqueous extract yielded none or only very few pupae, respectively. The methanolic extract was also active, with a 90.7% reduction in pupal yield at 1.0%, and a 94% reduction at 0.5% extract concentration. The ethanolic extract, tested only at 1.0% had similar activity, with 95.6% reduction in pupal yield.

Table 44 presents data on the number of pupae found on the leaves which were sprayed immediately after the appearance of the first mines, with 1.0% or 0.5% aqueous, methanolic or ethanolic extracts of neem. Only the 1% methanolic extract was highly active, with a 98.5% reduction in pupal yield.

introduced into the soil 1, 3 or 5 days before exposure of the plants to ovipositing females. The highest reduction in pupal yield was obtained when the plants were exposed to ovipositing females 5 days after the soil treatment, reduction in pupal yield being 95.4%. Less striking results were obtained when the plants were exposed to the adults 1 and 3 days after treatment (74.4% and 79.2% reduction in pupal yield, respectively).

Insect growth regulators

Chemical control of Liriomyza trifolii is based on use of contact and stomach insecticides (Methamidophos, pyrazophos, triazophos and abamectin) which do affect adults as well as larvae, if they penetrate into the mines. The larvae which cause the damage are also affected by insect growth regulators (IGRs).

Tests were carried out to study the effect of a group of IGRs, the benzoyl phenylurea (BPU) chitin synthesis inhibitors. The BPU compounds affect different insect orders through stomach or contact poisoning. They act by interfering with chitin synthesis and molting processes of the larvae. BPUs may reduce or completely inhibit fertility in the adult, or may have a direct ovicidal effect (Thomson, 1985-86).

Insect growth regulators are known not to affect the adult stage, tests with BPUs began with preinfestation treatment and exposure of treated plants to female L. trifolii flies to oviposit on.

To test the ability of BPUs to prevent infestation by acting on the egg, bean seedlings were sprayed with aqueous dilutions of concentrations ranging from 500 to 1.95 ppm. After spraying sets of treated plants were exposed to ovipositing L. trifolii female flies as described. This was done on the day of spraying, 0, and in order to study persistence also on 1,4,7,10 and 20 days later. Eight or ten days after infestation the infested leaves were cut off.

damage and number of pupae recorded and ultimately adult emergence was recorded.

In the early screening tests six compounds were immediately dropped. Work went on with chlorfluazuron (IKJ 7899), diflubenzuron (Dimilin), triflumuron (Alsystine), flubenzuron (CME 134), XRD 473 and cyromazin (Trigard).

Results

Chlorfluazuron (IKJ 7899)

As seen in Table 46, 500 and 250 ppm a.i. chlorfluazuron E.C. reduced the number of pupae and no adult emergence was obtained. The W.P. was less active at 500 ppm in reducing pupal yield.

Diflubenzuron (Dimilin) triflumuron (Alsystine) and flubenzuron (CME 134).

Tests carried out with these compounds are presented in Table 47. The W.P. formulations were tested versus E.C. or liquid formulations. Diflubenzuron W.P. vs a liquid formulation, triflumuron W.P. vs E.C. and teflubenzuron S.C. vs E.C. all showed that at 500 ppm a.i. they were practically inactive against L. trifolii.

XRD 473

Preliminary tests have shown that XRD 473 was by far the most effective among the BPU's tested against L. trifolii. It's ability to prevent infestation was tested up to 20 days after treatment against new infestation.

Preinfestation treatment

Damage. Distribution of leaves according to feeding damage after exposing XRD 473 treated leaves to L. trifolii infestation is presented in Table 48. At 500, 375 and 250 ppm heavy damage (grade "c") was prevented on day 0, lower concentrations were ineffective. The 500 ppm concentration prevented heavy

damage (grade "c") up to 10 days, but with 250 ppm only for one day. At lower concentrations there was heavy leaf damage.

Survival. The mean number of pupae/leaf and % emergence when treated leaves were exposed to oviposition after various aging periods of XRD 473 residues are presented in Table 49. Concentrations of 500 and 250 ppm prevented formation of viable pupae up to 20 days after application. At lower concentrations pupae were formed, but except with 1.95 ppm none gave rise to adults.

Of all the BPU's tested, only XRD 473 was further tested against 2nd instar larvae.

Post infestation treatment

Damage. Distribution of leaves according to the feeding and damage by L. trifolii 2nd instar larva is presented in Table 28. Only the 500 ppm prevented additional damage, to the damage present at the time of application.

Survival. The mean number of pupae/leaf and % emergence after XRD 473 spraying of leaves infested with 2nd instar larvae are shown in Table 50. Pupation was not prevented even with a 500 ppm concentration, in some cases the number of pupae was comparable to the controls. However, at 15.6 ppm and up all pupae formed were abnormal and only a negligible number of flies emerged from these pupae.

Cyromazine (Trigard)

Cyromazine is a triazine compound active and selective against dipterous larvae (Schlapfer and Cotti, 1986). Applied to the leaves it has a strong translaminar effect. In the form of a 75% WP cyromazine was tested against Liriomyza trifolii. Two aspects of cyromazine activity were studied: i) The effect of different concentrations on development of the leafminer when applied

at each of its larval stages (postinfestation treatment). ii) Persistence of various concentrations of cyromazine and their efficacy in preventing a new infestation after various aging periods (preinfestation treatment).

(i) Postinfestation treatment

To study the effect of various concentrations of cyromazine on the various larval instars, bean seedlings were infested as described above and kept until larvae of the required instar appeared. The plants were then sprayed with aqueous dilutions of the cyromazine WP at concentrations ranging from 500 to 0.975 ppm a.i. The treated plants were observed for feeding damage, and the number of pupae developing on the leaves was recorded. The leaves were then cut off the plants and placed in petri dishes and, ultimately, adult emergence was recorded.

(ii) Pre Postinfestation treatment

To test the persitence of cyromazine and its ability to prevent infestation, bean seedlings were sprayed as above with the same aqueous dilutions of cyromazine. Sets of treated plants were exposed to L. trifolii flies on the day of treatment or 1,4,7,10 and 20 days later. The number of larvae that developed and pupated as well as the rate of adult emergence were recorded.

RESULTS

(i) Postinfestation treatment

Leaf damage. Distribution of leaves according to the degree of feeding and damage by L. trifolii larvae is presented in Table 5]. When leaves infested with first-instar larvae were sprayed, some damage was already present, but concentrations from 3.9 ppm and up prevented additional damage. At lower

concentrations larval activity continued and a greater percentage of the leaves, although less than in the controls, showed higher feeding damage (grade b). When leaves with second-instar larvae were sprayed, results were similar.

Leaves with third-instar larvae already exhibited considerable damage (b and c grades) when sprayed.

Survival. The total number of pupae formed, their mean number per leaf, and their emergence rate are presented in Table 52. When leaves with first-instar larvae were sprayed, some viable pupae, with an emergence rate as high as in the controls, were formed only at the lowest concentration, 0.975 ppm.

When leaves with second-instar larvae were sprayed, pupae were found at 7.8 ppm, but they were deformed; only at low concentrations of 1.9 and 0.975 ppm did flies emerge, although the emergence rate was lower than in the controls.

When leaves with third-instar larvae were sprayed, pupae were found at all concentrations, although a few at the high concentrations, but from those formed between 500 to 125 ppm no flies emerged. At lower concentrations (3.9 ppm and less) the number of pupae increased, as did as the emergence rate.

(ii) Preinfestation treatment

Damage. Distribution of leaves according to feeding damage after exposure of cyromazine treated plants to L. trifolii infestation is presented in Table 53. At 500 and 250 ppm, many of the leaves showed no feeding damage (grade a) and the rest showed only initial neonate feeding (grade b), up to 20 days after treatment, vs the majority of leaves heavily damaged (grade c) in the controls. No heavy feeding (grade c) occurred at concentrations of 62.5 and 15.6

leaves that showed heavy feeding damage, but their number was much smaller than in the controls. The 0.975 ppm spray proved to be inactive already after one day.

Survival. The mean number of pupae/leaf and the emergence rate, when treated plants were exposed after different aging of the residues to ovipositing females, are presented in Table 54. Concentrations of 500 to 15.6 ppm prevented formation of viable pupae up to 20 days after application; the few pupae found were dead. Formation of pupae was prevented by 1.95 ppm when infestation took place 4 days after spraying, but when leaves were infested 7 days after application pupae were formed but flies did not emerge. From the infestation on the 10th day after treatment a few flies emerged. 0.975 ppm did not prevent formation of pupae even when the plants were infested on the day of treatment.

Conclusion and discussion

Soil treatments

Contact insecticides used as soil treatments proved ineffective in reducing emergence from pupae in the soil. Systemic insecticides, aldicarb and oxamyl, reached the leaves and affected immature stages, thus affording good protection as reported (Oetling, 1985).

Results obtained with a neem aqueous extract were promising, in accord with the results of Larew et al, (1985) using crude neem extracts, and those of Knodel et al, (1986) using a commercial formulation of neem, Margosan O (Adler and Uebel, 1985).

Cover sprays

Foliar sprays proved methamidophos still very effective against L. trifolii in Israel. Pyrazophos provided good protection as in France and Italy (Villevieille, 1986; Calabretta and Firullo, 1983).

Triazophos, although showing high mortality of larvae in preliminary studies was not tested further, as it was unlikely it would be registered in Israel, in spite of its reported activity (Lindquist and Casey, 1982; Vrie van de, 1981).

Among insecticides of biological origin abamectin proved very active as elsewhere (Hara, 1986; Strong and Brown, 1987) even at very low doses. Its disadvantage is that its use is limited to nonedible crops.

Thiocyclam (Evisect) seemed to affect 1st and 2nd instar larvae and less so the egg and 3rd larval instar.

Neem extracts of ethanol and methanol were more active than the aqueous extract when applied to the leaves, exerting antifeedant and/or IGR effects on the larvae.

Insect Growth Regulators

Benzoyl phenylurea (BFU) IGRs tested were mostly ineffective, except for XRD-473, which did show some promise for L. trifolii control. The emulsifiable formulations of the BFU's tested were in all cases more active than the corresponding wettable powder formulations.

Among the IGR compounds tested cyromazine was by far the most effective against L. trifolii. It was efficient both when applied as a preinfestation or postinfestation treatment. It provided long lasting efficacy and protection to crops as reported (Oetling, 1986; Schapfer et al, 1986).

TABLE 23. NUMBER OF FLIES THAT EMERGED FROM PUPAE IN PESTICIDE TREATED SOIL

Number of flies ($\pm$ SE) tht emerged from pupae
introduced to treated soil at the age of

Insecticide	2 day	4 days	5 days
Control	13.6 $\pm$ 0.1	13.8 $\pm$ 1.3	16.0 $\pm$ 1.0
1% Heptachlor (25% EC)	13.0 $\pm$ 2.6		12.6 $\pm$ 2.0
0.1 gr Heptachlor (4% P)	-	11.4 $\pm$ 1.9	5.4 $\pm$ 1.1
1% Dimethoate (40% EC)	12.6 $\pm$ 1.2	-	-
1% Diazinon (25% EC)	7.6 $\pm$ 2.0	9.0 $\pm$ 1.0	10.2 $\pm$ 1.4
0.5 g Diazinon (10% G)	9.6 $\pm$ 3.3	-	14.6 $\pm$ 1.5
0.5% Trichlorfon (80% SP)	-	15.4 $\pm$ 1.5	-
0.5% Methamidophos (60% SC)	-	9.8 $\pm$ 0.6	-

TABLE 24. NUMBER OF FLIES EMERGING FROM PLANTS INFESTED WITH LIRIOMYZA TRIFOLII EGGS AFTER SOIL TREATMENT WITH GRANULAR INSECTICIDES

Insecticide	Number of flies emerged	
	Test 1	Test 2
Control	34	24
Aldicarb 15%	1	0
Butocarboxym 15%	12	13
Carbofuran 10%	29	-
Oxamyl 10%	0	0

TABLE 25. NUMBER OF MINES, LIRIOMYZA TRIFOLII LARVAE AND PUPAE IN INFESTED BEAN LEAVES AFTER SOIL TREATMENT WITH SYSTEMIC INSECTICIDES

Insecticide	Dose/pot mg a.i.	Number of		
		Mines	Larvae	Pupae
Control	0	*	0	138
Cyromazine	20**	0	0	0
"	10	128	100+3***	0
"	5	144	94	8+6***
Aldicarb	15	49	15	15
Oxamyl	15	33	14+10***	9+21***

*The whole leaf area

**Phytotoxic symptoms

***Dead

TABLE 26. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER SPRAYING BEAN LEAVES INFESTED WITH VARIOUS INSTARS OF LIRIOMYZA TRIFOLII a-NO DAMAGE, b-SMALL LEAF AREA AFFECTED, c-STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Treatment and concentration (ppm)	Egg			3rd instar larva		
	a	b	c	a	b	c
Control	15	41	44	13	59	28
Ethion 2500	32	65	3	19	81	0
Monocrotophos 2400	72	28	0	28	72	0
Methamidophos 2400	100	0	0	31	69	0

TABLE 27. NUMBER OF PUPAE AND % EMERGENCE OF L. TRIFOLII FLIES AFTER SPRAYING LEAVES INFESTED WITH EGGS OR THIRD INSTAR LARVAE

Instar treated	Egg		Third instar larvae	
	Number of pupae	% emergence	Number of pupae	% emergence
Treatment and concentration				
Control	96	61.5	135	50.4
Ethion 2500	21+2*	71.4	37+21*	21.6
Monocrotophos 2400	9+2*	100	21+2*	14.3
Methamidophos 2400	0	-	2*	-

*Abnormal

TABLE 28. MORTALITY (%) OF LIRIOMYZA TRIFOLII IN BEAN LEAVES SPRAYED AT EGG OR 1ST- 2ND- OR 3RD-LARVAL INSTAR 24, 48 AND 72 HOURS AFER METHAMIDOPHOS APPLICATION

Instar treated	Dilution ppm a.i.	% kill hours after spray			Number of pupae	% emergence
		24	48	72		
Egg	Control 0		0	0		
	150		100	100		
	300		93	96		
	600		*	*		
1st larva	0	0	0	0	**	
	150	96	71	52		
	300	94	86	96		
	600	100	100	98		
2nd larva	0	0	0	0	80	25
	150	52	82	62	0	-
	300	38	89	80	2	0
	600	89	96	-	0	-
3rd larva	0	0	0	-	87	46
	150	62	90	47	38	32
	300	61	76	-	48	19
	600	75	85	-	13	61

*Killed in the egg stage

**None pupated after 72 hours

TABLE 29. MORTALITY (%) OF LIRIOMYZA TRIFOLII IN BEAN LEAVES SPRAYED AT EGG OR 1ST-, 2ND- OR 3RD-LARVAL INSTAR 24, 48 AND 72 HOURS AFTER PYRAZOPHOS APPLICATION

Instar treated	Concentration ppm a.i.	% kill hours after spray			Number of pupae	% emergence
		24	48	72		
Egg	Control 0		0	0		
	150		80	47		
	300		81	59		
	600		98	82		
1st larva	0	0	0	0	44	
	150	60	32	62	1	
	300	80	58	70	1	
	600	87	74	47	0	
2nd larva	0	0	0	0	102	58
	150	54	40	46	42	14
	300	52	37	62	26	8
	600	48	50	82	7	0
3rd larva	0	0	0	0	133	61
	150	48	72	57	39	36
	300	50	64	64	37	11
	600	66	71	88	16	0

TABLE 30. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE CAUSED BY LEAFMINERS AFTER PYRAZOPHOS SPRAYS OF DIFFERENT CONCENTRATIONS ON BEAN LEAVES INFESTED WITH EGGS OR VARIOUS LARVAL INSTARS OF LIRIOMYZA TRIFOLII a-NO DAMAGE, b-SMALL LEAF AREA AFFECTED, c-STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Instar treated	Egg			1st larva			2nd larva			3rd larva			
Concentration ppm	a	b	c	a	b	c	a	b	c	a	b	c	c
0 Control	4	29	67	0	26	74	0	35	65	4	50	46	
150	-	-	-	0	100	0	14	86	0	0	37	63	
300	29	63	84	17	83	0	0	100	0	9	39	52	
600	46	50	4	4	96	0	0	100	0	0	54	46	
1200	75	25	0	17	83	0	8	79	13	0	14	86	
1800	59	33	8	17	83	0	0	58	42	9	48	43	
2400	100	0	0	0	100	0	8	29	63	0	73	27	

TABLE 31. EFFECT OF PYRAZOPHOS SPRAYED ON LEAVES INFESTED WITH EGGS OR 1ST-, 2ND- AND 3RD INSTAR LIRIOMYZA TRIFOLII LARVAE

Concentration ppm	1st larva			2nd larva			3rd larva			Total Mean/leaf (+SE)	Total Mean/leaf (+SE)	% emer- gence
	Number of pupae		% emer- gence	Number of pupae		% emer- gence	Number of pupae		% emer- gence			
	Total	Mean/leaf (+SE)		Total	Mean/leaf (+SE)		Total	Mean/leaf (+SE)				
0 (Control)	122	5.1+0.2	90	136	5.9+0.5	73	144	6.3+1.0	69	102	6.3+	81
150	-			0			0			0		
300	17*			0			0			0		
600	3*			0			0			0		
1200	3*			0			0			0		
1800	13*			0			0			8*		
2400	0			0			0			6**		

***Dead**

*****Abnormal**

TABLE 32. MORTALITY (%) OF LIRIOMYZA TRIFOLII IN BEAN LEAVES SPRAYED AT EGG OR 1ST-, 2ND- OR 3RD LARVAL INSTARS 24, 48 AND 72 HOURS AFTER CARBOSULFAN APPLICATION.

Instar treated	Concentration ppm	% kill hours after spray			Number of pupae		% emergence
		24	48	72			
Egg	0 (Control)		0	0			
	625		50	12			
	1250		50	73			
	2500		100	100			
1st larva	0 (Control)	0	0	0	51	*	
	625	17	0	10	53	25	
	1250	53	20	10	21	14	
	2500	50	31	54	5	0	
2nd larva	0 (Control)	0	0	0	38	*	
	625	18	14	40	47	30	
	1250	29	13	30	34	24	
	2500	30	38	19	75	5	
3rd larva	0 (Control)	0	0	0	76		
	625	18	38	32	67	18	
	1250	15	22	27	67	0	
	2500	30	43	62	63	13	

*Emergence not recorded

TABLE 33. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER CARBOSULFAN SPRAYS OF DIFFERENT CONCENTRATIONS ON BEAN LEAVES INFESTED WITH EGGS OR VARIOUS LARVAL INSTARS OF LIRIOMYZA TRIFOLII. a-NO DAMAGE, b-SMALL LEAF AREA AFFECTED, c-STRONG FEEDING TO TOTALA LEAF AREA AFFECTED.

Concentration ppm	Egg			1st larva			2nd larva			3rd larva		
	a	b	c	a	b	c	a	b	c	a	b	c
0 (Control)				0	0	0						
50				0	50	50						
100				0	88	12						
150				0	86	14						
0 (Control)	0			8	58	33	12	42	46			
125	21			4	31	65	33	50	17			
250	13			25	67	8	0	50	50			
500	-			48	52	0	13	83	4			
0 (Control)	0	50	50	0	0	100	0	26	74	4	50	46
168	-	-	-	8	75	17	0	56	44	35	30	35
337	8	46	46	8	63	29	4	17	79	29	21	50
675	17	83	0	0	87	13	0	33	67	5	36	59
1350	32	68	0	13	87	0	0	48	52	4	25	71
2025	52	44	4	0	100	0	4	17	79	13	30	57
2700	63	37	0	9	91	0	0	40	60	0	38	62

TABLE 36. EFFECT OF CARBOSULFAN SPRAYS ON LEAVES INFESTED WITH EGGS OR 1ST-, 2ND- AND 3RD- INSTAR LIRIOZYIA TRIFOLII LARVAE.

Concen- tration ppm	Egg		1st larva		2nd larva		3rd larva	
	Number of pupae		Number of pupae		Number of pupae		Number of pupae	
	Total	Mean/leaf ($\pm$ SE)	Total	Mean/leaf ($\pm$ SE)	Total	Mean/leaf ($\pm$ SE)	Total	Mean/leaf ($\pm$ SE)
		% emer- gence		% emer- gence		% emer- gence		% emer- gence
0 (Control)	222	9.2 $\pm$ 1.0	69					
50	120	5.0 $\pm$ 0.7	61					
100	51	2.0 $\pm$ 0.3	73					
150	71	3.2 $\pm$ 0.5	59					
0 (Control)	160	6.7 $\pm$ 0.7	54		113	4.7 $\pm$ 0.7	74	
125	83	3.5 $\pm$ 0.6	37		45	1.9 $\pm$ 0.5	50	
250	71	3.1 $\pm$ 0.4	43		125	5.4 $\pm$ 0.8	50	
500	-	-			34	1.4 $\pm$ 0.3	32	
0 (Control)	116	4.8 $\pm$ 0.6	61		160	6.7 $\pm$ 0.8	76	
168	-	-			124	5.4 $\pm$ 1.0	65	
337	70*	2.6 $\pm$ 0.4	47		176*	7.0 $\pm$ 0.7	66	
675	36*	1.6 $\pm$ 0.8	64		154	7.3 $\pm$ 1.2	54	
1350	21		43		156	6.5 $\pm$ 1.5	64	
2025	4		75		141	6.1 $\pm$ 0.9	82	
2700	6*		0		105	4.6 $\pm$ 0.9	67	
							102	4.6 $\pm$ 1.0
							56	2.3 $\pm$ 0.5
							65	2.7 $\pm$ 0.5
							85	3.5 $\pm$ 0.6
							95	3.9 $\pm$ 0.8
							105	4.6 $\pm$ 0.9
							118	4.9 $\pm$ 0.5

*Many abnormal

**Dead

TABLE 35. MORTALITY (%) OF LIRIOMYZA TRIFOLII IN BEAN LEAVES SPRAYED AT EGG OR 1ST-, 2ND- OR 3RD-LARVAL INSTARS 24 AND 48 HOURS AFTER ABAMECTIN APPLICATION

Instar treated	Concentration ppm	% kill hours after spray		Number of pupae	Number of flies
		24	48		
Egg	0	0	15		
	9	*	100		
	18	*	*		
	36	*	*		
1st larva	0	0	5	11**	
	9	84	96		
	18	95	94		
	36	100	100		
2nd larva	0	0	23	33*	
	9	63	23		
	18	84	94		
	36	64	100		
3rd larva	0	4	15	88	31
	9	55	68	19	5
	18	70	78	16	3
	36	86	93	9	4

*No hatching

**Emergence not recorded

TABLE 36. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE CAUSED BY LEAFMINERS AFTER ABAMECTIN SPRAYS OF DIFFERENT CONCENTRATIONS ON BEAN LEAVES INFESTED WITH VARIOUS STAGES OF LIRIOMYZA TRIFOLII. a-NO DAMAGE, b-SMALL LEAF AREA AFFECTED, c-STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Concentration ppm	Egg			1st instar larva			2nd instar larva			3rd instar larva		
	a	b	c	a	b	c	a	b	c	a	b	c
0 (Control)	12	50	38	0	17	83	0	52	48	0	13	87
9	92	8	0	0	100	0	35	65	0	0	39	61
18	96	4	0	0	100	0	39	61	0	9	13	78
36	87	13	0	0	100	0	35	65	0	4	54	42

TABLE 37. EFFECT OF ABAMECTIN SPRAYED ON LEAVES INFESTED WITH EGGS OR 1ST-, 2ND- AND 3RD- INSTAR LIRIOMYZA TRIFOLII LARVAE

Concen- tration ppm	Instar treated											
	Egg			1st larva			2nd larva			3rd larva		
	Number of pupae		%	Number of pupae		%	Number of pupae		%	Number of pupae		%
	Total	Mean/leaf ($\pm$ SE)	emer- gence	Total	Mean/leaf ($\pm$ SE)	emer- gence	Total	Mean/leaf ($\pm$ SE)	emer- gence	Total	Mean/leaf ($\pm$ SE)	emer- gence
0 (Control)	69	2.6 $\pm$ 0.4	60	149	6.2 $\pm$ 0.7	*	79	3.8 $\pm$ 0.7	*	157	6.3 $\pm$ 0.5	73
9	0			0			0			11+9*		
18	0			0			0			2+4**		
36	0			0			0			12**		

*Not recorded

**Abnormal

TABLE 38. MORTALITY OF (%) OF LIRIOMYZA TRIFOLII IN BEAN LEAVES SPRAYED AT EGG OR 1ST-, 2ND- OR 3RD LARVAL INSTAR 48 AND 72 HOURS AFTER THIOCYCLAM APPLICATION.

Instar treated	Concentration ppm	% kill hours after spray	
		48	72
Egg	0	0	0
	125	*	40
	250	*	*
	500	*	*
1st larva	0	0	4
	125	87	65
	250	94	64
	500	91	100
2nd larva	0	0	0
	125	67	52
	250	82	73
	500	100	100
3rd larva	0	0	0
	125	85	40
	250	96	100
	500	100	100

*No mines, only stipples

TABLE 39. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE CAUSED BY LEAFMINERS AFTER THIOCYCLAM SPRAYS OF DIFFERENT CONCENTRATIONS ON BEAN LEAVES INFESTED WITH VARIOUS INSTARS OF LIRIOMYZA TRIFOLII. a-NO DAMAGE, b-SMALL LEAF AREA AFFECTED, c-STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Instar treated	Egg			1st larva			2nd larva			3rd larva		
Concentration ppm	a	b	c	a	b	c	a	b	c	a	b	c
0 Control	13	50	38	0	24	76	0	52	48	0	13	87
100	4	39	57	0	90	10	9	91	0	0	14	86
200	8	50	42	18	78	4	23	77	0	0	27	73
300	0	38	62	-			9	91	0	0	56	44
400	66	0	33	4	96	0	32	59	0	0	50	50
500	4	74	22	9	91	0	13	87	0	0	50	50

TABLE 40. EFFECT OF THIOCYCLAM SPRAYED ON LEAVES INFESTED WITH EGGS OR 1ST-, 2ND- AND 3RD INSTAR LIRIOMYZA TRIFOLII LARVAE.

Concen- tration ppm	Instar treated											
	Egg			1st larva			2nd larva			3rd larva		
	Number of pupae		% emer- gence	Number of pupae		% emer- gence	Number of pupae		% emer- gence	Number of pupae		% emer- gence
	Total	Mean/leaf ($\pm$ SE)		Total	Mean/leaf ($\pm$ SE)		Total	Mean/leaf ($\pm$ SE)		Total	Mean/leaf ($\pm$ SE)	
0 (Control)	69	2.6 $\pm$ 0.4	88	142	6.2 $\pm$ 0.7	**	79	3.8 $\pm$ 0.7	**	157	6.3 $\pm$ 0.5	48
100	74	2.8 $\pm$ 0.6	30	11*		0	3+3*		0	118	4.9 $\pm$ 0.4	27
200	82+4*	3.4 $\pm$ 0.4	43	0		-	0		-	74	3.4 $\pm$ 0.3	23
300	50	2.2 $\pm$ 0.4	36	-		-	2*		-	31	1.6 $\pm$ 0.4	29
400	45	2.4 $\pm$ 0.4	49	0		-	4*		-	23	1.0 $\pm$ 0.3	0
500	11+10*	1.25 $\pm$ 0.5	43	0		-	0		-	2+1*		0

*Abnormal

**Not recorded

Table 41. THE EFFECT OF NEEM EXTRACTS ON THE PUPAL YIELD OF LIRIOMYZA TRIFOLII: LEAVES WERE PAINTED ON BOTH SIDES BEFORE EXPOSURE TO FEMALE FLIES

Neem treatment, extract	Extract solution (%)	Total mean number of pupae/plant		% Reduction in pupal yield in comparison with control
		Treatment $\pm$ SE	Control $\pm$ SE	
Aqueous	1.0	0.2 $\pm$ 0.2*	10.7 $\pm$ 1.9	98.1
	0.5	5.2 $\pm$ 1.1*	21.0 $\pm$ 0.6	75.2
	0.1	4.2 $\pm$ 1.2	11.2 $\pm$ 4.9	62.0
Methanolic	1.0	0*	12.7 $\pm$ 3.3	100
	0.5	0*	9.7 $\pm$ 1.5	100
	0.1	3.4 $\pm$ 1.5*	11.7 $\pm$ 2.6	71
Ethanollic	1.0	0*	16.6 $\pm$ 2.2	100
	0.5	0*	19.7 $\pm$ 3.1	100
	0.1	2.0 $\pm$ 1.0*	21.2 $\pm$ 2.3	90.6
Acetone	1.0	0*	8.6 $\pm$ 1.0	100
	0.5	5.0 $\pm$ 1.3	9.0 $\pm$ 2.3	44.5
<u>I</u> sopropyl alcohol	1.0	0.4 $\pm$ 0.2	4.2 $\pm$ 2.1	90.5
	0.5	5.6 $\pm$ 3.0	14.4 $\pm$ 4.4	61.1
<u>n</u> -Butanol	1.0	1.4 $\pm$ 0.7*	23.0 $\pm$ 3.6	93.9
Chloroform	1.0	2.2 $\pm$ 0.9*	16.0 $\pm$ 1.8	86.3
Carbon tetra-chloride	1.0	0.4 $\pm$ 0.2*	9.8 $\pm$ 2.2	96.0
	0.5	4.2 $\pm$ 2.1	7.4 $\pm$ 2.9	43.3
Dioxane	1.0	10.0 $\pm$ 2.2	24.2 $\pm$ 4.2	54.6
Pentane	1.0	1.4 $\pm$ 1.1*	10.6 $\pm$ 1.9	86.8
	0.5	11.4 $\pm$ 1.5	15.0 $\pm$ 3.8	25.0

*Significantly different from control (solvent-only treated leaves) at the 0.05 level of probability.

Table 42. THE EFFECT ON THE PUPAL YIELD OF LIRIOMYZA TRIFOLII OF 1% NEEM EXTRACTS PAINTED ON BOTH SIDES (a) OR ONLY ON THE UPPER SIDE (b) OF THE LEAVES AFTER THE APPEARANCE OF THE FIRST MINES

Neem treatment, extract	Total number of pupae/ plant		% Reduction in pupal yield
	Treated $\pm$ SE	Control $\pm$ SE	
<hr/>			
<u>a. Both sides of leaves painted</u>			
Aqueous	2.5 $\pm$ 0.4*		86.0
Methanolic	1.4 $\pm$ 1.4*	17.8 $\pm$ 3.3	91.0
Ethanollic	0.2 $\pm$ 0.2*		98.9
 <u>b. Upper side of leaves painted</u>			
Aqueous	11.6 $\pm$ 2.3		43.2
Methanolic	2.8 $\pm$ 0.8*	20.4 $\pm$ 3.5	86.3
Ethanollic	0.4 $\pm$ 0.2*		98.1

* Significantly different from control (solvent-only treated leaves) at the 0.05 level of probability.

Table 43. THE EFFECT ON THE PUPAL YIELD OF LIRIOMYZA TRIFOLII, OF 1.0 AND 0.5% NEEM EXTRACTS SPRAYED ON BEAN LEAVES BEFORE EXPOSURE TO FEMALE FLIES

Neem treat- ment, extract	Dosage (%)	Total number of pupae/plant		% Reduction in pupal yield
		Treatment $\pm$ SE	Control $\pm$ SE	
Aqueous	1.0	0*		100
	0.5	0.2*	25.6 $\pm$ 3.4	99.3
Methanolic	1.0	3.4 $\pm$ 2.7*		90.7
	0.5	2.2 $\pm$ 1.2*	36.6 $\pm$ 2.7	94.0
Ethanollic	1.0	1.8 $\pm$ 1.4*	40.2 $\pm$ 7.2	95.6

*Significantly different from control (solvent-only treated leaves) at the 0.05 level of probability.

Table 44. THE EFFECT ON THE PUPAL YIELD OF LIRIOMYZA TRIFOLII, OF 1.0 AND 0.5% NEEM EXTRACTS SPRAYED ON BEAN LEAVES AFTER THE APPEARANCE OF MINES

Neem treat- ment, extract	Dosage (%)	Total number of pupae plant		% Reduction in pupal yield
		Treatment $\pm$ SE	Control $\pm$ SE	
Aqueous	1.0	6.6 $\pm$ 1.2*	25.6 $\pm$ 3.4	75.0
	0.5	20.0 $\pm$ 4.5		22.0
Methanolic	1.0	0.4 $\pm$ 0.4*	25.6 $\pm$ 3.4	98.5
	0.5	12.7 $\pm$ 6.7*		50.4
Ethanolic	1.0	9.0 $\pm$ 3.9*	40.2 $\pm$ 7.2	77.7
	0.5	22.6 $\pm$ 0.8*		43.8

*Significantly different from control (solvent-only treated leaves) at the 0.05 level of probability.

Table 45. THE SYSTEMIC EFFECT ON THE PUPAL YIELD OF LIRIOMYZA TRIFOLII, OBTAINED UPON SOIL TREATMENT WITH A 1% AQUEOUS NEEM EXTRACT

Infested on days after soil treatment	Total number of pupae/ plant		% Reduction in pupal yield
	Treatment $\pm$ SE	Control $\pm$ SE	
1	5.6 $\pm$ 1.9*	21.8 $\pm$ 4.0	74.4
3	4.7 $\pm$ 4.1*	22.5 $\pm$ 3.3	79.2
5	1.4 $\pm$ 3.1*	30.4 $\pm$ 4.8	95.4

* Significantly different from control (solvent-only treated leaves) at the 0.05 level of probability.

Table 46. PERSISTENCE OF DIFFERENT CONCENTRATIONS OF CHLORFLUAZURON RESIDUES SPRAYED ON BEAN LEAVES PRIOR TO EXPOSURE TO INFESTATION WITH LIRIOMYZA TRIFOLII (PREINFESTATION TREATMENT).

		Infested on:					
		Days after treatment					
		0		1		4	
Concen-		Mean number pupae/leaf $\pm$ S.E. and % emergence					
tration	Formulation	Pupae	Emergence	Pupae	Emergence	Pupae	Emergence
ppm							
0 (Control)		6.3 $\pm$ 0.8	90				
500	W.P.	3.5 $\pm$ 0.6	5.7				
			0				
0		5.0 $\pm$ 0.5	70	2.5 $\pm$ 0.3	44	9.3 $\pm$ 1.4	36
500	E.C.	1.0 $\pm$ 0.3**	0	0.7 $\pm$ 0.2**	0	1.2 $\pm$ 0.2*	0
0		2.8 $\pm$ 0.4	86				
250	E.C.	0.9 $\pm$ 0.3*	0				

* Dead pupae

** Abnormal pupae

Table 47. PERSISTENCE OF DIFLUBENZURON AND TRIFLUMURON DIFFERENT CONCENTRATIONS RESIDUES SPRAYED ON BEAN LEAVES PRIOR TO EXPOSURE TO INFESTATION WITH LIRIOMYZA TRIFOLII (PREINFESTATION TREATMENT).

Infested on:					
Days after treatment					
Compounds, concentration ppm	Formulation	0 Mean number pupae/leaf $\pm$ S.E. Pupae	1 Mean number pupae/leaf $\pm$ S.E. Emergence	1 Mean number pupae/leaf $\pm$ S.E. Pupae	1 Mean number pupae/leaf $\pm$ S.E. Emergence
0 (Control)		5.3 $\pm$ 0.4	83		
500 Diflubenzuron W.P.		4.5 $\pm$ 0.4	44		
0		5.3 $\pm$ 0.6	66		
500 Diflubenzuron liq.		2.0 $\pm$ 0.4	50		
0		2.7 $\pm$ 0.4	89		
250 Diflubenzuron liq.		1.5 $\pm$ 0.4	27		
0		7.8 $\pm$ 0.8	68	2.8 $\pm$ 0.7	43
500 Triflumuron W.P.		8.6 $\pm$ 0.9	67	2.5 $\pm$ 0.5	24
0		12.0 $\pm$ 1.3	68	2.8 $\pm$ 0.7	43
500 Triflumuron E.C.		10.0 $\pm$ 1.2	56	5.1 $\pm$ 0.9	39
0		2.4 $\pm$ 0.7	56	4.2 $\pm$ 0.5	79
500 Teflubenzuron S.C.		1.2 $\pm$ 0.2	36	0.7 $\pm$ 0.2	17
0				3.6 $\pm$ 0.8	36
500 Teflubenzuron E.C.				8.0 $\pm$ 2.1	29
0				3.6 $\pm$ 0.8	36
1000 Teflubenzuron E.C.				2.4 $\pm$ 0.5	10

Table 48. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE CAUSED BY LEAFMINERS TO XRD-473-TREATED BEAN LEAVES EXPOSED TO *LIRIOZYIA TRIFOLI* INFESTATION (PRE-INFESTATION TREATMENT): a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - FROM STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Concen- tration ppm	Infested on:																	
	Days after treatment																	
	0			1			4			7			10			19		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Control																		
1.95				9	41	50				15	0	85	0	4	96			
				4	14	82				7	7	86	0	0	100			
0				0	50	50	0	0	100	0	0	100						
15.6				0	68	32	9	14	77	17	16	67						
0							0	13	87									
62.5				0	42	58				0	14	86						
0				4	4	92												
125				9	22	69												
0	6	20	74	0	0	100	26	13	61	5	5	90	5	0	95	0	5	95
250	29	71	0	4	96	0	20	45	35	61	11	28	25	33	42	29	18	53
0				4	4	92												
375				42	58	0												
0	1	18	81	0	0	100	0	0	100	0	0	100	5	0	95	0	5	95
500	57	43	0	43	40	17	54	41	5	25	75	0	39	61	0	58	16	26

Table 49. PERSISTENCE OF DIFFERENT CONCENTRATIONS OF XKD-473 RESIDUES SPRAYED ON BEAN LEAVES PRIOR TO EXPOSURE TO INFESTATION WITH LIRIDOMYZA TROPICALIS (PREINFESTATION TREATMENT).

Concentration ppm	Infested on:									
	Days after treatment									
	0	1	4	7	10	19	Mean number/pupae leaf $\pm$ S.E. and % emergence			
Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence	Pupae % emergence
0		3.4 $\pm$ 0.7	70	6.4 $\pm$ 0.3	72	4.3 $\pm$ 0.6	65			
1.95		1.3 $\pm$ 0.2	15	3.8 $\pm$ 0.7**	1.5	7.8 $\pm$ 2	10			
		0.3 $\pm$ 0.1**				1.5 $\pm$ 1.4				
0		2.4 $\pm$ 0.5	-	16.0 $\pm$ 1.8**	62	2.7 $\pm$ 0.7*	52			
15.6		0.6 $\pm$ 0.2*	-	3.1 $\pm$ 1.3	0	1.3 $\pm$ 0.3				
				3.9 $\pm$ 1.4	0					
0	11.0 $\pm$ 1.2	70	4.2 $\pm$ 0.8	62						
62.5	2.0 $\pm$ 0.3*	0	0.4 $\pm$ 0.2	0						
			4.1 $\pm$ 0.5*	0						
0	8.5 $\pm$ 1.1	83								
125	1.8 $\pm$ 0.5**	0								
0	5.4 $\pm$ 0.6	81	6.0 $\pm$ 1.0	50	3.0 $\pm$ 0.1	97	5.0 $\pm$ 0.9	60	8.0 $\pm$ 2	57
250	0.5 $\pm$ 0.1**	0	0		0		0		2.0 $\pm$ 0.8*	0
0	8.5 $\pm$ 1.1	83								
375	0	0								
0	6.2 $\pm$ 0.1	77	7.3 $\pm$ 1.0	55	4.0 $\pm$ 0.2	50	8.8 $\pm$ 1.0	55	11.0 $\pm$ 1.2	60
(Control)										
500	0	0	0		0		0		0	

* Dead pupae

** Abnormal pupae

- not examined

Table 50. EFFECT OF DIFFERENT CONCENTRATIONS OF XRD-473 ON LIRIOMYZA TRIFOLII
2ND INSTAR LARVAE.

I MEAN NUMBER OF PUPAE/LEAF AND % EMERGENCE.

II DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS.

a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING TO TOTAL
LEAF AREA AFFECTED.

Concentration ppm	I		II		
	Mean number Pupae/leaf	% emergence	Degree of damage		
			a	b	c
0	7.0±1.2	61	0	29	71
0.975	3.0±0.6*	60	9	36	55
0	7.0±1.2	61	0	29	71
1.95	7.5±1.3	63	0	4	96
0	12.0±1.6	75	0	0	100
15.6	5.5±0.8*		0	17	83
0	12.0±1.6	75	0	0	100
31.5	2.5±0.4*		4	42	54
0	6.4±1.0	50	2	10	88
125	8.0±0.1*	1	8	17	75
0	6.4±1.0	50	2	10	88
250	5.7±0.7*		10	16	74
0 (control)	3.8±0.5	66	2	12	86
500	3.9±0.7*	1	24	33	43

* Abnormal pupae

TABLE 51. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE
BY LEAFMINERS AFTER CYROMAZINE SPRAYS OF DIFFERENT
CONCENTRATIONS ON BEAN LEAVES INFESTED WITH VARIOUS
INSTARS OF LIRIOMYZA TRIFOLII (POSTINFESTATION
TREATMENT)., a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED,
c - STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Larval instar									
treated:	1st			2nd			3rd		
Concentration	Degree of damage								
(ppm)	a	b	c	a	b	c	a	b	c
0 control	13	13	74	4	42	54	0	20	80
0.9	4	50	46	0	50	50	0	38	62
1.9	13	55	32	0	40	60	5	20	75
3.9	0	90	10	17	83	0	0	55	45
7.8	0	94	6	0	100	0	-	-	-
15.6	0	100	0	0	100	0	17	21	62
31.2	0	100	0	0	100	0	0	39	61
125	0	100	0	0	75	25	12	25	63
250	0	100	0	0	100	0	0	33	67
500	0	100	0	0	100	0	13	52	35

- not examined

TABLE 52. EFFECT OF CYROMAZINE SPRAYED ON LEAVES INFESTED WITH 1ST-, 2ND- AND 3RD-INSTAR LIRIOMYZA TRIFOLII LARVAE (POSTINFESTATION TREATMENT).

Larval instar treated:	1st			2nd			3rd		
Concen- tration (ppm)	Number of pupae		% Emer- gence	Number of pupae		% Emer- gence	Number of pupae		% Emer- gence
	Total	Mean/ leaf		Total	Mean/ leaf		Total	Mean/ leaf	
0 control	159	6.9±0.6	60	171	7.1±1.9	68	117	5.8±0.2	80
0.9	75**	2.5±0.6	65	84**	3.8±0.8	35	132	6.3±1.1	57
1.9	22*		0	34**	2.7±1.0	44	108	5.1±1.1	19
3.9	0			1*		0	92	4.2±0.9	9
7.8	0			25**	1.3±0.4	0	-	-	-
15.6	0			0			73	3.0±1.0	14
31.2	0			0			1		
125	0			0			9**		
250	0			0			6**		
500	0			0			10**		

*Dead

**In part deformed and abnormal

- not examined

TABLE 53. DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE CAUSED BY LEAFMINERS TO CYROMAZINE TREATED BEAN LEAVES EXPOSED TO LIRIOMYZA TRIFOLII INFESTATION (PREINFESTATION TREATMENT) a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING TO TOTAL LEAF AREA AFFECTED.

Infested on:																		
day after treatment																		
Degree of damage																		
Concen- tration (ppm)	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
0	0	37	63	32	62	6												
0.975	27	68	5	5	40	55												
0	0	36	64	13	57	30	4	38	58	0	18	82	0	48	52			
1.95	0	90	10	0	92	8	17	70	13	0	87	13	48	43	9			
0	-	-	-	0	75	25	0	6	94	0	62	38	0	48	52	0	21	79
15.6	-	-	-	33	67	0	100	0	0	0	100	0	15	85	0	0	100	0
0	0	0	100	0	36	64	0	43	57	10	85	5	0	48	52	0	21	79
62.5	0	100	0	20	80	0	17	83	0	4	96	0	26	74	0	0	100	0
0	10	74	16	0	24	76	26	26	48	5	9	86	0	10	90	0	14	86
250	62	38	0	50	50	0	38	62	0	86	14	0	4	96	0	14	86	0
0	0	67	33	0	0	100	0	10	90	0	14	86	0	10	0	0	14	86
500	42	58	0	4	96	0	0	100	0	14	86	0	21	79	0	29	71	0

TABLE 54. PERSISTENCE OF CYROMAZINE RESIDUES FROM DIFFERENT CONCENTRATIONS SPRAYED ON LEAVES BEFORE EXPOSURE TO INFESTATION BY LIRIOMYZA TRIFOLII (PREINFESTATION TREATMENT)

Infested on:												
day after treatment												
	0	1st	4th	7th	10th	20th						
Concen- tration (ppm)	Number of pupae/ leaf	Number of pupae/ leaf	Number of pupae/ leaf	Number of pupae/ leaf	Number of pupae/ leaf	Number of pupae/ leaf						
	% Emer- gence	% Emer- gence	% Emer- gence	% Emer- gence	% Emer- gence	% Emer- gence						
0	4.9±0.8	58	2.2±0.7	-								
0.975	0.8±0.1	47	4.1±0.6	-								
0	-	-	3.5±0.7	74	4.1±0.9	34						
1.95	-	-	3**	-	0	5.4±1.2						
					0	86						
					3.2±0.3	0						
					2.8±0.9	17						
0	-	-	2.4±0.5	-	14.8±2.2	57						
15.6	-	-	0		0	3.3±0.7						
					0	44						
					0	-						
0	11.4±1.2	63	5.0±0.1	73	3.9±0.8	66						
62.5	9*		0		1*	1.6±0.3						
					0	76						
					0	-						
0	1.2±0.3	39	6.9±0.9	55	2.4±0.7	85						
250	0		0		0	7.8±3.4						
					0	91						
					0	-						
0	4.9±1.1	72	16.8±0.4	36	4.1±0.8	32						
500	0		0		0	8.8±1.0						
					0	56						
					0	10.6±1.22						
					0	63						
					0	7.8±1.3						
					0	43						

*Dead pupae (total number per experiment).

**Deformed and abnormal pupae (total number per experiment).

-- not examined

D. Response of adults to chemical and physical factors

1. Effect of neem upon adults

MATERIALS AND METHODS

Neem seed extract dissolved in Triton X-100 (emulsifier) and water was topically applied to the thorax of individual adult females (< 3 d old). Technical formulations of the insecticides dissolved in acetone were topically applied with a microapplicator to the thorax of individual adult females (<3 d old), 0.6 microliter per fly. Three concentrations, 0.4, 0.8 and 2.0% neem, and a water control were used. Three replications consisting of 12 females each were tested for each concentration. Treated flies were held after application in plastic vial recovery units at 25°C, ca 50% RH and a photoperiod of 14L:10D. Mortality was assessed 24 h after treatment. Data were analyzed with the SAS PROC PROBIT and PROC REG procedures. LD₅₀ values were considered significantly different if the 95% fiducial limits did not overlap.

RESULTS

All rates of topically applied neem extract failed to produce adult mortality. Neem is known to act as an IGR upon immature stages, however, it appears to have no effect upon adults.

2. Sublethal effects of neem upon surviving adults

MATERIALS AND METHODS

Potted chrysanthemum plants (cv. Iceberg) previously exposed to adult L. trifolii and containing eggs were

treated with a soil drench (300 ml/pot) of neem seed extract solution (one part neem and one part Triton X-100 in water). Concentrations of 1.0 and 2.25 ppm azadirachtin, one of the active insecticidal components of neem, and a water control were used. Plants were held in a greenhouse at temperatures ranging from 30° C (day) to 10° C (night). Surviving leafminers were collected as pupae. Fecundity and longevity of resulting adult females were determined by placing a single treated female and two untreated males into a 15 cm height by 10.5 cm diameter plexiglass cage with a screen top. The cage contained a chrysanthemum seedling (cv. Iceberg). A female was provided a fresh seedling daily until her death. Males dying during the study were replaced. Number of resulting first instar larvae were noted. Fecundity and longevity of control (untreated as immatures) adults were determined in the same manner. Cages with plants and females were held at 25° C, ca 50% RH and a photoperiod of 14L:10D.

Effects on surviving males were determined by placing two treated male L. trifolii and one untreated female in a 148 ml polystyrene vial with a screen top. Honey smeared on the screen and a moistened sponge within the vial provided nutrition and water. The adults were held in this manner for 48 h, considered adequate time for mating to occur. Untreated males were used for a control treatment.

After 48 h, the females were placed individually into tube cages, previously described, containing a chrysanthemum

seedling. Fresh plants were provided for 5 days. Exposed plants were held in an environmental chamber at the previously mentioned conditions. Resulting first instar progeny were noted. Males were held in the vials until death. Sponges within vials were moistened regularly and the honey nutrient source was maintained.

All procedures were replicated 10 times. Data were analyzed by analysis of variance and means were separated with Duncan's multiple range test.

RESULTS

Adult emergence for the 1.0 ppm, 2.0 ppm, and control treatments were 34.6, 12.7 and 78.2%, respectively. Control females produced significantly more larval progeny than treated adults (Table 55). Females surviving the 1.0 ppm treatment did not produce significantly more progeny than the 2.0 ppm-treated individuals. Female longevity was not significantly affected by neem treatments, although the untreated females lived > 7 d longer than the 1.0 ppm-treated females (Table 55).

Effects of neem upon surviving males based on larval progeny produced by untreated females mated to treated males were not significant ($P=0.05$) although females mated to control (untreated) males produced more than twice as many progeny in 5 d than those mated to 2.0 ppm-treated males (Table 55).

Results indicate neem when applied as a soil drench can lessen L. trifolii infestations by adversely affecting the

reproductive capabilities of individuals surviving treatments as eggs.

3. Effects of cold temperatures and CO₂ on adult survival

MATERIALS AND METHODS

Adult female L. trifolii (< 3 d old) contained in plastic vials with screen tops were placed in environmental chambers at 0, -5 and -10° C. Females were held for 0.25, 0.5, 0.75, 1.0, 2.0 and 4.0 h. Mortality was assessed 24 h after exposure. Four replications consisting of 12 flies each were tested for each exposure time. A control group of flies was held at room temperature (ca. 24° C). Honey smeared on the screen top and a small water-soaked sponge held in the vials were provided as nutrient sources.

Adult L. trifolii females (< 3 d old) held in plastic vials with screen tops were exposed to CO₂ for 1.0, 1.5, 2.0 and 4.0 minutes. Four reps consisting of 12 flies each were used for each exposure time. Mortality was assessed at 2h and 24 h. Honey smeared on the screen top and a small water-soaked sponge held in the vial were provided as a nutrient source.

To determine effects of handling on adult L. trifolii, females (<3 d-old) were aspirated into 148 ml polystyrene vials. Groups were then aspirated into other vials a specified number of times: 1, 2, 4, and 6 times. After the last aspiration, a moist sponge was placed in the vial with the flies and honey water was smeared on the screened lid of the vial. Effects of handling were ascertained by noting

mortality 24 h after aspiration. Four replications of 12 flies each were used for each handling treatment.

Data were analyzed by analysis of variance and means separated with Duncan's multiple range test. Data from the cold exposure study were transformed by arcsine (square root (x)) transformation before analysis.

RESULTS

No significant differences in mortality occurred at 0°C for all exposure periods (Table 56). Significantly more females died at 4.0 and 2.0 h exposures at -5°C than at lesser exposure periods (Table 56). Mortality of greater than 98% at -10°C occurred at 4.0 h which was significantly greater than mortality at shorter exposure periods (Table 56). Mortality was significantly greater at -10°C than at -5°C and 0°C for all exposure periods.

Exposure to CO₂ for 1.0, 1.5, 2.0 and 4.0 minutes resulted in 2.1, 4.2, 4.2 and 8.3% adult mortality, respectively, at 24 h post-exposure. Mean percent mortality did not differ significantly (P=0.05) for exposure periods. Handling (aspiration) of adult female L. trifolii resulted in 2.2, 0.0, 13.3, and 19.2% mortality for flies experiencing 1, 2, 4 and 6 aspirations, respectively. Six aspirations resulted in significantly more mortality than one or two aspirations.

Results indicate adult L. trifolii should be aspirated no more than two times to minimize "naturally"-occurring mortality or control mortality when maintaining a colony or

conducting studies. Exposure to CO₂ should not exceed ca. one minute to decrease undesired mortality which may affect data analysis.

4. Response of populations to pyrethroids

MATERIALS AND METHODS

Populations of L. trifolii originating from commercial chrysanthemum greenhouses in southern California (CA), southwestern Florida (FL) and northeastern Maryland (MD) were compared based on their susceptibilities to the pyrethroids permethrin and bifenthrin. Technical formulations of the insecticides dissolved in acetone were topically applied with a microapplicator to the thorax of individual adult females (< 3 d old), 0.6 microliter per fly. Five concentrations plus a solvent control were used for each insecticide. Four replications consisting of 15 females each were tested for each concentration. Treated flies were held after application in plastic vial recovery units at 25° C, ca 50% RH and a photoperiod of 14L:10D. Mortality was assessed 24 h after treatment. Data were analyzed with the SAS PROC PROBIT and PROC REG procedures. LD₅₀ values were considered significantly different if the 95% fiducial limits did not overlap.

RESULTS

The MD population proved least susceptible to both pyrethroids with a LD₅₀ for permethrin 33 times that of the FL population (Table 57) while the CA and FL populations exhibited similar susceptibilities. All populations were

more susceptible to the much less used bifenthrin. These findings may indicate a greater use of insecticides, particularly of pyrethroids, in MD greenhouses. However, this greater resistance may be a result of the MD population having been more recently obtained from greenhouses, thus more recently exposed to insecticide selection pressure.

Table 55. Mean larval progeny produced by and mean survival of adult *L. trifolii* after neem treatment (ppm azadirachtin) as eggs.

	Treatment	No. larvae ^a	Survival (d) ^{a,b}
Female ^c	Control	339.5 a	20.6 a
	1.0 ppm	137.0 b	13.4 a
	2.0 ppm	111.4 b	12.1 a
Male ^d	Control	43.1 a	13.1 a
	1.0 ppm	28.3 a	10.6 ab
	2.0 ppm	18.3 a	9.1 b

^aMeans in columns for each sex not significantly different if followed by same letter, Duncan's multiple range test ($p=0.05$).

^bN for male survival = 18, 16, and 16 for control, 1.0, and 2.0 ppm treatments, respectively.

^cFemale progeny production based on total number of first instar larvae produced per female in a lifetime ($n=10$).

Table 56. Mean percent mortality of adult female L. trifolii (< 3 d-old) when exposed to cold temperatures for varying periods of time^a.

Exposure period (h)	Temperature (°C) ^b		
	0	-5	-10
0.25	0.0 a	0.0 a	20.6 a
0.50	0.0 a	0.0 a	66.5 b
0.75	0.0 a	2.1 a	77.4 b
1.0	1.9 a	4.2 ab	76.5 b
2.0	3.9 a	10.4 b	93.8 c
4.0	5.8 a	11.4 b	98.2 c

^aData transformed by arcsine(square root(x)) transformation before analysis; untransformed data presented.

^bMeans in columns followed by same letter not significantly different by Duncan's multiple range test (P=0.05)

Table 57. Probit analysis statistics for three L. trifolii populations treated with technical permethrin and bifenthrin dissolved in acetone.

Insecticide	Population ^a	LD ₅₀ (mg/ml)	95% Fiducial limits	Slope	SE
Permethrin	CA	0.14	0.11-0.16	1.90	0.29
	FL	0.10	0.05-0.15	0.94	0.10
	MD	3.35	2.92-3.83	2.76	0.33
Bifenthrin	CA	0.05	0.04-0.06	1.77	0.31
	FL	0.06	0.04-0.12	2.10	0.47
	MD	0.77	0.66-0.90	2.31	0.29

^aCA, southern California; FL, southwestern Florida; MD, northeastern Maryland.

D. EFFECT OF GAMMA RADIATION ON LIRIOMYZA TRIOFOLII BURGESS

1. EFFECT ON IMMATURE STAGES

INTRODUCTION

The American serpentine leafminer Liriomyza trifolii Burgess was introduced into Israel in 1978 in Gerbera cuttings. Since then it spread to other flower and vegetable crops (Yathom et al., 1983). At present it is considered a major pest of gypsophila, chrysanthemum and gerbera, causing damage to other flower and vegetable crops.

Flowers have become an important export item in Israel, including flowers that are heavily attacked by L. trifolii. The polyphagous habits of L. trifolii make it a threat to various vegetable and ornamental glasshouse crops in Northern European countries (Akersson, 1983, Bartlett and Powell, 1981, Nedstam 1980 and Powell 1981). Some of these countries import cut flowers from Israel and their quarantine regulations demand plant material free from leafminer damage ("symptomless"). In some cases imports are permitted only under the terms of a license with specific conditions, designed to reduce the risk of introducing infestation. These terms may involve a treatment to be applied before cuttings are exported or immediately after importation (Mortimer & Powell, 1984).

To meet the quarantine demands of export countries, which ban the entry of flowers infested by L. trifolii, gypsophila cut flowers for export are fumigated in Israel. As the use of ethylene-dibromide has been banned by the EPA in 1984 (Anonymous, 1983) methyl bromide is the only fumigant available: its use poses some problems as for cut flowers the margin between the effective and phytotoxic dose is even narrower than for other plant material (Carmi, 1985).

Following the banning of EDB for fumigation (Anonymous 1983), irradiation has assumed major importance as one alternative. Low dose irradiation is the most feasible quarantine treatment among existing alternatives (Anonymous, 1985).

Quarantine security following irradiation treatment can be considered as:

- a. Lethality - or killing of insects at the stage at which they are treated, may not be necessary to provide quarantine security.
- b. Non emergence of adult insects - this is sometimes inappropriate, since insects in the adult stage may initially be present on the product.
- c. Inability of adult insects to produce viable offspring - this will technically statisfy quarantine security, but the presence of live, though sterile, insects, may be disturbing.

Use of gamma radiation as a quarantine measure began in Hawaii about 30 years ago by Balock et al, (1963). They found that radiating various fruit flies was either lethal or resulted in sterility of the flies that emreged. A similar effect was found after radiating fruit infested with eggs and maggots. Radiating grape fruit infested with Caribbean fruit fly eggs with a 75 gray dose prevented hatching, and 300 gray prevented pupation (Balock et al. 1966).

Radiation of flower crops was, to our knowledge, very little tested. When carnation flowers, infested with larvae and pupae of the South African and Mediterranean Tortricids were irradiated, doses over 90 gray caused total mortality of Thrips palmi in orchids was achieved with a 1500 Gray dose (Piriyathamrong & Shouvalitrongporm).

The effect of various doses of gamma radiation on the immature stages of L. trifolii was tested.

METHODS

The tests, except for the actual irradiation treatment were carried out in a greenhouse at $27 \pm 2^{\circ}\text{C}$ on artificially infested plants, so as to obtain uniform infestation as far as possible.

As L. trifolii flies oviposit only in live leaf tissue and the larvae develop there, the tests on these stages were carried out when they were inside the leaf. Potted bean seedlings, with the first two true leaves were infested.

For each treatment 3 pots with 4 seedling, altogether 12 seedlings with 24 leaves were used. These 3 pots with 12 seedlings were put in an oviposition cage into which 50 female flies were introduced, and the plants were thus exposed to their oviposition for 24 hours.

Eggs were irradiated within the seedlings 24 hours after exposure. The three larval stages were irradiated when mines of the required stage were noted.

The infested plants were exposed to gamma radiation from a Co source at the Soreq Nuclear Research Center using various doses ranging between 2000–25 Gray (Gy), at a dose rate of 620 Gy/hr.

After irradiation the plants were returned to the greenhouse for further observation. No phytotoxic effects were observed in the seedlings.

As the prepupal stage is very short, mature larvae were collected early in the morning, when leaving the mines, and were irradiated before noon. Pupae of known ages were irradiated. Both prepupae and pupae were irradiated in glass vials, 50/treatment. Emergence was recorded.

The effect of various radiation doses on the different leafminer stages was assessed in several ways.

- a. The immediate effect of various doses of radiation was established by opening 50 mines in order to confirm death or survival. This was done every 24 hours after irradiation.
- b. Infested and irradiated plants were kept for observation on the development and survival of larvae that hatched from irradiated eggs, or of the irradiated larvae. This was carried on till development of accompanying control ended.
 - b.1 The rate of larval feeding and the resulting damage was graded according to the size and number of mines as follows: a-leaves totally free of leafminer damage; b-some damaged leaf area, caused either by beginnings of feeding mines and if bigger mines-separate ones and countable; c-total leaf area or big part of it taken up by criss crossing mines of mature larvae.
 - b.2 The number of larvae that survived radiation and did pupate was established by collecting all pupae on the leaves and underneath, including the deformed and dead ones.
 - b.3 The pupae that did have a history of radiation at some stage were observed for percentage of adult emergence. If live flies emerged they were kept for further observation.

RESULTS

Egg stage

- a. When leaves infested with L. trifolii eggs were radiated with doses of 2000 or 1000 Gy no eggs hatched and no larval damage could be detected. When doses of 750, 500 and 250 Gy were applied the beginnings of few mines were observed, but only beginning, indicating death shortly after hatching.
- b. Observations on the development of damage after irradiation of the egg stage are presented in Table 58. With doses of 2000-750 Gy no damage to the leaves by

mining, occurred. At 500 Gy some damage was noted, but not a single larva reached the pupal stage. Doses of 250 and 150 Gy caused similar results as regards damage, and although pupae were formed at 150 Gy, none gave rise to adult flies.

With a 100 Gy dose damage rates were higher, (mostly grade "b") indicating that most eggs had hatched and the larvae fed and developed to pupation, but the pupae were not viable, and out of 157 pupae only 2 flies emerged (exp. nos. 2 and 4), while in the controls 172 flies emerged out of 527 pupae (32.7% emergence rate). At a 50 Gy dose damages reached grades "b" and "c" and larvae in all tests reached the pupal stage. The number of pupae in the treated leaves was much lower than in the accompanying controls, in all 179 pupae in controls. In 3 out of 5 experiments no flies emerged, and emergence rate was always low.

A dose of 25 Gy resulted in damage levels "b" and "c", pupae were formed in all tests but emergence rate was low.

When 3 day old eggs were irradiated the results were similar to those of 1 day old eggs. Doses of 750 and 500 Gy prevented formation of pupae, 250 Gy enabled development of many pupae, but no flies emerged, as seen in Table 59

CONCLUSIONS

Radiating eggs of L. trifolii with 2000-500 G doses resulted in immediate death of the eggs or the neonate larvae. 250-100 Gy doses allowed development of larvae and pupation, but these occurred in low numbers, and the pupae did not give rise to adults. 50 and 25 Gy doses allowed development of larvae, pupation and adult emergence, but the rate of success at each stage was low compared to the controls.

First instar larva

- a. When leaves with first instar larvae were irradiated, doses of 2000, 1500 or 1000 Gy caused total death within 24 hours, while at 750 Gy about 20% of the larvae were still alive, but they were dead within another 24 hours. With a 500 Gy dose most larvae were alive after 24 hours, and at 250 Gy all were alive, and remained so 72 hours after irradiation.
- b. Results obtained by irradiating leaves infested with first instar larvae are presented in Table 60. Application of doses between 2000 to 750 Gy resulted in no larvae reaching the pupal stage as shown in Table 60. With a 500 Gy dose only 8 unviable pupae were formed compared to 690 in the controls.

When irradiating leaves infested with first instar larve, damage was already present, at level "b", and with doses of 2000-750 Gy damages remained at this level, as also in most trials with 500 Gy. Lower doses of 250-75 Gy resulted in additional damages being accumulated after treatment, up to level "c", and in many pupae being formed, although less than in the controls. These pupae were deformed and abnormal and did not give rise to adults, except for one fly at 150 Gy. Only doses of 50 and 25 Gy resulted with viable pupae. Emergence rate was 2.8%, 33.1% and 44.6% at 50, 25 and the control respectively.

CONCLUSIONS

Irradiation of first instar L. trifolii larvae with 2000-1000 Gy doses caused immediate death. Lower doses of 750 Gy allowed development and pupation, but the pupae were deformed or nonviable. Only at doses of 50 and 25 Gy were many pupae formed, and they gave rise to a new generation, but at a lower rate than the controls.

Second instar larva

Plants infested by L. trifolii were kept until mines of the second larval instar appeared and damage could easily be noticed. The plants were then irradiated with doses of 2000-25 Gy.

- a. Doses of 2000, 1500 or 1000 Gy, applied to leaves infested with second instar larvae killed all larvae within 24 hours, 750 Gy killed 60% of the larvae and 72 hours after treatment some larvae were still alive. With doses of 50 and 25 Gy half the larvae were still alive.
- b. The number of pupae, emergence rate and damage levels after irradiation are shown in Table 61.

At the time of irradiation visible damage was already present, and with doses of 2000 and 1000 Gy the damage remained at the same level. With lower doses that did not kill the larvae, feeding continued and damages increased, in some cases exceeding the controls, as seen in Table 61.

With the lethal dose of 2000 Gy no larva reached pupation, but with 1000 and 750 Gy pupae were found, but out of 300 no fly emerged. At a dose of 500 Gy 1 fly emerged out of 200 pupae, and with doses of 250, 150 and 75 Gy 1 fly emerged out of 557 pupae formed. At a 50 Gy a 4% emergence rate occurred. A 25 Gy dose did not have any effect, the rate of larvae reaching the pupal stage as well as emergence rate were about equal to the controls.

CONCLUSIONS

When second instar larvae were irradiated only high doses of 2000 Gy stopped feeding and additional damage. Lower doses allowed only part of the larvae to develop and pupate, but the pupae were abnormal and deformed and did not give rise to a new generation, although feeding continued and damage increased. Doses of 50 Gy and down did not affect pupation and emergence.

Third instar larvae

- a. When leaves infested with third instar L. trifolii larvae were irradiated with doses of 2000 or 1500 Gy all larvae were dead within 24 hours. With lower doses live larvae were present even after 72 hours.
- b. The number of pupae, emergence rate and damage levels after irradiating leaves infested with third instar larvae are presented in Table 62. As the larvae had reached the third instar their damage was quite conspicuous when irradiated, and not much additional damage could be prevented. Only high doses of 2000-1000 Gy resulted in damage levels differing from the controls, as seen in Table 62 and only at these doses no larvae pupated. At doses of 750-100 Gy many larvae pupated, although less than in the control. Out of 1200 pupae from treated larvae no fly emerged, while in the control an emergence rate of 59.7% was found.

At a dose of 75 Gy a single fly emerged, and at 50 and 25 Gy many pupae were found, in some cases their numbers exceeded those in the controls. Emergence rate too, equaled or exceeded the controls.

CONCLUSIONS

Irradiation of plants with third stage larvae does not stop additional damage, and the larvae may develop into pupae, but at doses over 100 Gy the pupae don't give rise to flies of the following generation. Doses of 75 Gy and less had no effect, as was also the case with second instar larvae.

Prepupal and pupal stages

Results obtained after irradiating prepupae or pupae with doses ranging between 25 to 2000 Gy are presented in Table 63. The prepupal stage was most sensitive to radiation. So were young pupae irradiated after 20% of the pupal period had elapsed, which did not give rise to adults at doses of 100 Gy and up.

Older pupae, which had passed about 40 or 70% of the pupal period before being irradiated yielded flies, up to 50% emergence at 200-250 Gy. Observations and preliminary studies have indicated that these flies were short lived: the number of stipules they left was reduced compared to controls, and they did not reproduce.

CONCLUSIONS

The prepupal stage is most sensitive to radiation, less so young pupae irradiated at the beginning of the pupal period. The older the pupae the more resistant they are to the immediate effect of radiation. However, the flies emergent from irradiated pupae have a shortened life span and have difficulties in feeding and reproduction.

2. EFFECT OF RADIATION ON LIRIOMYZA TRIFOLII INFESTING GYPOSOPHILA PLANTS (BURGESS)

Preliminary experiments were carried out to test the effects of gamma radiation on Liriomyza trifolii larvae infesting gypsophila leaves.

In the first test heavily naturally infested gypsophila were irradiated with doses of 500, 1000 and 1500 gray in order to check immediate mortality of the larvae present in the leaves.

Three days after treatment mines in the leaves were opened to establish whether the larvae were killed.

In the next experiments immediate mortality was not examined, so the fate of the larvae could be followed.

Gypsophila plants naturally infested with L. trifolii were packed May 25 and one part was irradiated May 27 while another part was irradiated May. 29. Doses tested were 250, 500, 750, 1000 and 1500 gray. The plants were kept at 27°C and the pupae were collected May 29 after shaking the plants. Emergence was later recorded.

Another batch of infested plants was brought and treated on June 25, and the pupae were collected June 29.

RESULTS

Immediate mortality found when opening leafminer mines after irradiation is presented in Table 64 Mortality increased with dosage, but the fate of the larvae alive when examined remained unknown, they might have died at a later stage.

When plants were irradiated and the larvae left to continue their development the pupae were collected. Their number in the irradiated plants was lower than in the accompanying controls as seen in Table 65. The higher total of pupae found in the plants treated May 29 is probably due to more larvae accomplishing development and pupating before irradiation. Emergence at all doses was either nil or very low.

Discussion

Quarantine treatments, including irradiation are not intended to replace good agricultural practices in the field. The purpose of quarantine treatment is to prevent establishment of an insect pest in a new area (Anonymous, 1985).

The criterion of security should be the inability of the insect to produce viable offspring. Table 66 summarizes minimum doses of radiation required to cause immediate mortality or prevent pupation or emergence of L. trifolii

irradiated at the egg and larval stages. Thus disinfestation can be achieved with the low doses required to prevent adult emergence.

Fig 4: Normal (left) and abnormal *Liriomyza trifolii* pupae after being irradiated at the larval stage.

TABLE 58. EFFECTS OF GAMMA RADIATION ON *LIRIOMYZA TRIFOLII*.

I TOTAL NUMBER OF PUPAE MEAN/LEAF AND % EMERGENCE AFTER RADIATION OF 1 DAY OLD EGGS

II DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER RADIATION OF INFESTED BEAN LEAVES

a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING, TOTAL LEAF AREA AFFECTED

No.	Dose Gray	I Number of pupae			II Degree of damage		
		Total	Mean/leaf ($\pm$ SE)	% Emergence	a	b	c
1	0	305	9.8 $\pm$ 1.5	63	0	40	60
	2000	0		-	100	0	0
1	0	305	9.8 $\pm$ 1.5	63	0	40	60
	1000	0		-	100	0	0
1	0	127	6.0 $\pm$ 1.2	74	0	46	54
	750	0		-	100	0	0
1	0	23	1.0 $\pm$ 0.2	83	29	63	8
	500	0		-	100	0	0
2	0	105	5.0 $\pm$ 2.3	31	14	72	14
	500	0		-	87	13	0
3	0	127	6.0 $\pm$ 1.2	74	0	46	54
	500	0		-	5	95	0
1	0	105	5.0 $\pm$ 2.3	31	14	72	14
	250	0		-	92	8	0
2	0	127	6.0 $\pm$ 1.2	74	0	46	54
	250	0		-	100	0	0
3	0	175	8.7 $\pm$ 1.5	43	15	5	80
	250	15	0.7 $\pm$ 0.2	0	19	81	0

1	0	175	8.7 ± 1.5	43	15	5	80
	150	25	1.2 ± 0.0	0	18	64	18
2	0	132	5.5 ± 0.9	47	0	46	54
	150	0		-	100	0	0

1	0	23	1.0 ± 0.2	83	29	63	8
	100	5		20	20	80	0
2	0	105	5.0 ± 2.3	31	14	72	14
	100	0		-	71	29	0
3	0	175	8.7 ± 1.5	43	15	5	80
	100	95	4.7 ± 1.1	0	75	25	0
4	0	62	3.6 ± 0.3	52	0	24	76
	100	8		12	17	83	0
5	0	162	6.7 ± 1.1	10	0	32	68
	100	49	1.3 ± 0.2	0	18	82	0

1	0	211	9.3 ± 1.3	62	0	0	100
	75	0		-	100	0	0

1	0	175	8.7 ± 1.5	43	15	5	80
	50	34	1.4 ± 0.4	0	15	5	80
2	0	132	5.5 ± 0.9	47	0	46	54
	50	9		0	52	48	0
3	0	211	9.3 ± 1.3	62	0	0	100
	50	72	3.0 ± 0.7	22	0	83	17
4	0	62	3.6 ± 0.3	52	0	24	76
	50	31	1.4 ± 0.1	10	9	64	27
5	0	162	6.7 ± 1.1	10	0	32	68
	50	33	1.0 ± 0.2	0	18	82	0

1	0	211	9.3 ± 1.3	62	0	0	100
	25	59	2.5 ± 0.8	13	21	79	0
2	0	62	3.3 ± 0.3	52	0	24	76
	25	112	5.3 ± 0.9	29	0	26	65
3	0	162	6.8 ± 1.1	10	0	32	68
	25	41	1.2 ± 0.3	0	24	76	0

TABLE 59. EFFECTS OF GAMMA RADIATION ON LIRIOMYZA TRIFOLII

I TOTAL NUMBER OF PUPAE MEAN/LEAF AND % EMERGENCE AFTER RADIATION OF 3 DAY OLD EGGS

II DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER RADIATION OF INFESTED BEAN LEAVES INFESTED

a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING, TOTAL LEAF AREA AFFECTED

No.	Dose	I Number of pupae			II Degree of damage		
		Total	Mean/leaf ($\pm$ SE)	% Emergence	a	b	c
	Gray						
	0	52	2.2 $\pm$ 0.4	58	12	63	25
	750	0		-	8	92	0
	500	0		-	25	75	0
	250	99*	4.6 $\pm$ 1.0	0	8	54	38

*abnormal

TABLE 60. EFFECTS OF GAMMA RADIATION ON LIRIOMYZA TRIFOLII

I TOTAL NUMBER OF PUPAE MEAN/LEAF AND % EMERGENCE AFTER RADIATION OF FIRST INSTAR LARVAE

II DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER RADIATION OF INFESTED BEAN LEAVES

a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING, TOTAL LEAF AREA AFFECTED

No.	Dose Gray	I Number of pupae		% Emergence	II Degree of damage		
		Total	Mean/leaf ($\pm$ SE)		a	b	c
1	0	100	4.7 ± 0.7	70	5	43	52
	2000	0		-	0	100	0
1	0	195	8.2 ± 1.2	72	4	25	71
	1500	0		-	22	78	0
1	0	195	8.2 ± 1.2	72	4	25	71
	1000	0		-	0	100	0
2	0	x		x	0	22	78
	1000	x		x	0	100	0
3	0	151	8.0 ± 2.1	63	0	42	58
	1000	0		-	0	100	0
1	0	x		x	0	22	78
	750	x		x	0	100	0
2	0	151	8.0 ± 2.1	63	0	42	58
	750	0		-	0	100	0
1	0	195	8.2 ± 1.2	72	4	25	71
	500	5		0	0	100	0
2	0	x		x	0	22	78
	500	x		x	0	100	0
1	0	151	8.1 ± 2.1	63	0	42	58
	500	8		0	0	75	25
2	0	344	15.6 ± 3.1	68	0	0	100
	500	0		-	9	87	4

1	0	x		x	0	22	78
	250	x		x	0	78	22
2	0	151	8.0 ± 2.1	63	0	42	58
	250	137	6.2 ± 0.7	0	0	96	4
3	0	344	15.0 ± 2.1	68	0	0	100
	250	117	4.9 ± 0.8	0	0	63	37

1	0	115	4.8 ± 1.2	28	8	38	54
	150	27	1.3 ± 0.4	39	0	41	59

1	0	x		x	0	22	78
	100	x		x	0	86	14
2	0	151	8.0 ± 2.1	63	0	42	58
	100	126	9.0 ± 2.1	0	0	29	71
3	0	344	15.0 ± 2.1	68	0	0	100
	100	168	7.0 ± 1.5	0	25	42	33
4	0	22	1.0 ± 0.2	59	41	50	9
	100	16	0.7 ± 0.2	0	54	42	4
5	0	144	6.3 ± 1.8	40	22	4	74
	100	68	3.4 ± 1.0	0	25	45	30

1	0	56	2.5 ± 0.3	52	0	73	27
	75	11		0	9	74	17

1	0	22	1.0 ± 0.2	59	41	50	9
	50	13		0	27	73	0
2	0	56	2.5 ± 0.3	52	0	73	27
	50	25	1.0 ± 0.3	8	4	63	33
3	0	144	6.3 ± 1.8	40	22	4	74
	50	34	2.3 ± 0.5	0	50	16	34

1	0	22	1.0 ± 0.2	59	41	50	9
	25	73	3.0 ± 0.5	59	8	92	0
2	0	56	2.5 ± 0.3	52	0	73	27
	25	33	1.6 ± 0.3	30	5	60	35
3	0	144	6.3 ± 1.8	40	22	4	74
	25	54	2.6 ± 1.1	0	38	14	48

x = pupae eaten by ants

TABLE 61. EFFECTS OF GAMMA RADIATION ON *LIRIOMYZA TRIFOLII*

I TOTAL NUMBER OF PUPAE MEAN/LEAF AND % EMERGENCE AFTER RADIATION OF SECOND INSTAR LARVAE

II DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER RADIATION OF INFESTED BEAN LEAVES a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING, TOTAL LEAF AREA AFFECTED

No.	Dose	I Number of pupae			II Degree of damage		
		Total	Mean/leaf ($\pm$ SE)	% Emergence	a	b	c
1	0	164	1.8 $\pm$ 1.2	52	5	20	75
	2000	0			0	100	0
1	0	43	1.8 $\pm$ 0.5	70	10	55	35
	1000	69	3.2 $\pm$ 0.6	0	0	95	5
2	0	122	5.8 $\pm$ 0.7	75	0	38	62
	1000	0		-	5	95	0
1	0	122	5.8 $\pm$ 0.7	75	0	38	62
	750	0		-	17	83	0
2	0	296	12.3 $\pm$ 1.8	79	0	8	92
	750	88	3.6 $\pm$ 0.7	0	0	13	87
3	0	199	9.1 $\pm$ 1.4	65	0	18	82
	750	141	7.4 $\pm$ 1.0	0	0	21	79
1	0	43	1.8 $\pm$ 0.5	70	10	55	35
	500	104	4.3 $\pm$ 0.9	1	12	63	25
2	0	122	5.8 $\pm$ 0.7	75	0	38	62
	500	29	1.2 $\pm$ 0.4	0	4	96	0
3	0	296	12.3 $\pm$ 1.8	79	0	8	92
	500	66	2.7 $\pm$ 0.9	0	2	38	50

1	0	296	12.3 ± 1.8	79	0	8	92
	250	127	3.6 ± 0.8	0	0	61	39
2	0	199	9.1 ± 1.4	65	0	18	82
	250	106	4.8 ± 1.0	0	0	59	41
3	0	91	3.8 ± 0.5	74	0	79	21
	250	26		0	0	25	75

1	0	91	3.8 ± 0.5	74	0	59	41
	150	92	4.0 ± 0.9	1	4	52	44

1	0	248	10.8 ± 1.8	51	0	4	96
	100	73	3.2 ± 0.7	0	8	17	75
2	0	117	4.9 ± 0.8	45	0	17	83
	100	66	3.5 ± 1.0	0	0	0	100

1	0	91	3.8 ± 0.5	74	0	79	21
	75	92	3.8 ± 0.4	0	4	67	29

1	0	248	10.8 ± 1.8	51	0	4	96
	50	31	1.3 ± 0.2	0	0	25	75
2	0	117	4.9 ± 0.8	45	0	17	83
	50	89	5.9 ± 0.8	4	0	0	100

1	0	117	4.9 ± 0.8	45	0	17	83
	25	104	5.2 ± 1.0	57	0	10	90

TABLE 62. EFFECTS OF GAMMA RADIATION ON LIRIOMYZA TRIFOLII.

I TOTAL NUMBER OF PUPAE MEAN/LEAF AND % EMERGENCE AFTER RADIATION OF THIRD INSTAR LARVAE

II DISTRIBUTION OF LEAVES (%) ACCORDING TO DEGREE OF DAMAGE BY LEAFMINERS AFTER RADIATION OF INFESTED BEAN LEAVES

a - NO DAMAGE, b - SMALL LEAF AREA AFFECTED, c - STRONG FEEDING T TOTAL LEAF AREA AFFECTED

No.	Dose Gray	I Number of pupae			II Degree of damage		
		Total	Mean/leaf ($\pm$ SE)	% Emergence	a	b	c
1	0	238	10.4 $\pm$ 1.9	73	0	8	92
	2000	0		-	0	65	35
1	0	238	10.4 $\pm$ 1.9	73	0	8	92
	1000	4		0	0	100	0
1	0	139	5.6 $\pm$ 0.9	74	0	58	42
	750	144	6.0 $\pm$ 0.8	0	0	44	56
2	0	164	6.8 $\pm$ 1.0	67	8	38	54
	750	67	2.8 $\pm$ 0.6	0	8	50	42
3	0	105	4.6 $\pm$ 0.7	62	8	17	75
	750	54	2.5 $\pm$ 0.6	0	0	36	64
1	0	238	10.4 $\pm$ 1.9	73	0	8	92
	500	203	8.8 $\pm$ 1.2	0	0	50	50
2	0	139	5.6 $\pm$ 0.9	74	0	58	42
	500	256	10.7 $\pm$ 1.3	0	0	17	83
3	0	164	6.8 $\pm$ 1.0	67	8	38	54
	500	47	2.0 $\pm$ 0.6	0	22	43	35

TABLE 63. PERCENT EMERGENCE OF LIRIOMYZA TRIFOLII PREPUAE AND PUPAE THAT HAD PASSED 20, 40 AND 70% OF THEIR PUPAL PERIOD BEFORE IRRADIATED.

Dose (Gray)	Prepupa	Pupal age (% development)		
		20	40	70
0 (Control)	69	78	72	94
25	-	38	66	62
50	1	0	72	76
100	0	0	66	94
150	0	0	52	58
200	0	0	54	72
250	0	0	48	44
500	0	0	0	34
750	0	0	0	20
1000	0	0	2*	4*
2000	0	-	-	0

*Death following emergence

TABLE 64. MORTALITY OF L. TRIFOLII LARVAE AFTER IRRADIATION OF INFESTED GYPSOPHILA

Dose (Gray)	Numbers of larvae	% mortality
0 control	42	7
500	31	45
1000	27	85
1500	26	96

TABLE 65. NUMBER OF PUPAE AND PERCENT EMERGENCE OF L. TRIFOLII FOUND IN GYPSOPHILA PLANTS AFTER IRRADIATION

Cutting date	May 25				June 24	
Irradiation date	May 27		May 29		June 25	
Dose (Gray)	No. pupae	% emergence	No. pupae	% emergence	No. pupae	% emergence
0 control	24	54	43	35	22	59
250	12	0	15	47	34	3
500	9	10	15	0	4	0
750	14	0	21	10	12	0
1000	0		6	0	0	
1500	0		2	0	0	
Total:	59		102		72	

TABLE 66. EFFECTS OF VARIOUS GAMMA RADIATION DOSES ON LIRIOMYZA TRIFOLII IMMATURE STAGES

Stage irradiated	Dose (gray) causing		
	Immediate	Prevention of	
	kill	Pupation	Emergence
Egg	500	250	100
1st larva	750	250	50
2nd larva	1000	750	50
3rd larva	1000	750	75

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f. Description of Cooperation

The principal investigator, S. L. Poe visited Israel during the first year for discussions and a change in the plan of work was decided. It was agreed that Post Harvest Radiation should be included, as an alternative quarantine method. Since then the cooperators have regularly exchanged research plans and results. This has enabled both groups to maintain a higher level of productivity and has facilitated a higher level of coordination in research planning. It was deemed unwise to ship biological material from Israel to the U.S. for testing, even though quarantine facilities were

available. We could not have detected the potential escape of a new biotype. Therefore, we concluded that the prompt exchange of ideas and results was optimal.

g. Evaluation of Research Achievements

1. Life history of L. trifolii on gypsophila which is a major export crop in Israel was studied.
2. Efficacy of yellow sticky traps for detecting and monitoring adult populations was improved by establishing optimal position and height of traps relative to the plants.
3. A list of 9 parasitoids, mostly Eulophids, and 3 dipteran predators in Israel was published prior to this work (Freidberg and Gijswijt, 1983). However, the frequent insecticide application undertaken during the cropping season prevented buildup of their populations and activity.
4. The influence of various biotic factors like plant nutrition, plant growth regulators, cultivar, and how it is grown (e.g. pot, cut, standard or pompom) on leafminer populations was studied, as an aid in developing more effective management strategies.
5. The strict demands of export countries for plant material free of leafminer damage resulted in frequent insecticide applications against all stages of L. trifolii. In some cases an additional fumigation treatment is required to meet quarantine demands. Thus work in Israel concentrated on testing insecticides on one hand and on trying an alternative method for fumigation, e.g. radiation, on the other hand.
6. LD 50 's of the widely used pyrethroid insecticide permethrin and the newly registered bifenthrin for leafminer populations from three widely scattered locations in the U.S. showed that the population from Maryland was much more resistant than those from Florida or California. The flies were all more susceptible to bifenthrin.
7. Neem, a naturally occurring, plant-derived insecticide failed to produce mortality when applied to adults. When used in a soil drench on the roots of leafminer infested plants, neem resulted in reduced production and viability of leafminer pupae.

h. List of Published or Accepted Manuscripts

1. Ascher, K.R.S., S. Yathom and V. Melamed-Madjar. 1986.

Effect of some benzoylphenylureas on larvae and eggs of

different insect species. p. 166 in Chitin in Nature and Technology. Plenum Press. New York and London.

Editors: R. Muzzarelli, C. Jeuniaux and G. W. Gooday.

2. Meisner, J., S. Yathom, S. Tal and K.R.S. Ascher. 1986.
The effect of various extracts of neem seed kernel on Liriomyza trifolii (Burgess) (Diptera: Agromyzidae)
Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz
93:146-152.
3. Yathom, S., K.R.S. Ascher, S. Tal and N.E. Nemny. 1986.
The effect of cyromazin on different stages of Liriomyza trifolii (Burgess) (Diptera: Agromyzidae).
Israel Journal of Entomology 20:85-93 (also in Hebrew, Hassadeh 67-372-376).
4. Ascher, K.R. S. , S. Yathom, N.E. Nemny and S. Tal. The
effect of XRD-473 and other benzoylphenyl urea chitin
synthesis inhibitors on a serpentine leafminer,
Liriomyza trifolii. Zeitschrift fur
Pflanzenkrankheiten und Pflanzenschutz - in press.
5. Yathom, S., R. Marcus, M. Chen and S. Tal. Comparison of
different positions and heights of yellow sticky traps
for sampling leafminer populations. Phytoparasitica -
in press.