MANAGEMENT OF THE AMERICAN SERPENTINE LEAF MINER, *Liriomyza trifolii* (Burgess) Dietars ON COWPEA, *Vigna unguiculata* (L.) Walp.

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DECLARATION

I hereby declare that this thesis entitled "**Management of the American Serpentine Leaf Miner, *Liriomyza trifolii* (Burgess) Dietars on Cowpea, *Vigna unguiculata* (L.) Walp.**" is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Management of the American Serpentine Leaf Miner, *Liriomyza trifolii* (Burgess) Dietars on Cowpea, *Vigna unguiculata* (L.) Walp.**" is a record of research work done independently by Ms. Reji, G. V. (2000–11–12) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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TO FARMERS OF KERALA

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LIST OF ABBREVIATIONS

kg	kilo gram
g	gram
mg	milli gram
l	litre
ml	milli litre
m	metre
cm	centi metre
mm	milli metre
@	at the rate of
µg	microgram
IU	International Unit
%	percentage
^0C	degree celsius
Fig.	Figure
N	Nitrogen
P	Phosphorus
K	Potassium
CRD	Completely Randomized Design
RBD	Randomised Block Design
LD	Lethal Dose
LC	Lethal Concentration
a.i	active ingredient
CD	Critical Difference
ppm	Parts per million
h	hour
viz.	namely
et al.	and others
No.	Number

INTRODUCTION

1. INTRODUCTION

Unrestricted transport of plants and plant materials in the early days paved the way for the introduction of several pests into countries where they were unknown. Often, an insect which was apparently harmless in its native place turned to be a potential pest in the new country. The exotic pests inflicted greater damage to the crops then the indigenous ones. Realising the danger lurking behind the introduction of foreign pests, quarantine measures were enforced in many countries to prevent their invasion. Unfortunately, several pests still continued to gain entry through imported consignments of plants in spite of the strict regulations. One potential pest of recent introduction in India is the American serpentine leaf miner, *Liriomyza trifolii* (Burgess) Dietars (Diptera: Agromyzidae).

Leaf miners are insects which lay eggs in the spongy layer between the upper and lower surfaces of leaves. On hatching, the larvae tunnel the leaf lamina, eating chlorophyll rich mesophyll cells. The mining activity not only leaves irregular tracks of dead tissues but also reduce as photosynthetic capacity of the plants leading to yield loss. Most of the leaf miners belong to the orders Diptera, Lepidoptera and Coleoptera. Among these, the dipteran agromyzid leaf miners in the genus *Liriomyza* have become serious pests of ornamental and vegetable crops throughout the world.

Erected in 1854 the genus *Liriomyza* contains more than 300 species of which 23 are economically important. Though commonly found in the temperate regions, several species are seen in the tropics too. Among the five highly polyphagous tropical species *viz*., *Liriomyza strigata* (Meigen), *Liriomyza bryoniae* Kaltenbach, *Liriomyza trifolii* (Burgess) Dietars, *Liriomyza sativae* Blanchard and *Liriomyza huidobrensis* (Blanchard), *L. trifolii* is the predominant one. A native of Florida and the Caribbean islands (Spencer, 1973), *L. trifolii* has been

(Spencer, 1973), *L. trifolii* has been reported from several countries (Elmore and Ranney, 1954; Musgrave *et al.*, 1975; Cheng, 1994). Its ability to disperse rapidly and adapt easily to different habitats expanded the distribution of *L. trifolii*. Further, the miner has assumed the status of a major pest in many countries (Trumble, 1985b). Several factors accounted for this status of the pest. The harmful stage of the miner is well protected from the vagaries of nature as it is spent in seclusion in the larval mines. Hence the possibility of a natural decline in the population at this stage is low. Besides, the short life cycle enables *L. trifolii* to complete several generations in a year. In addition, the pest easily develops resistance to insecticides (Mason and Johnson, 1987). Moreover, destruction of the natural enemies due to frequent application of insecticides for pest control has increased the complexity of the situation, often leading to outbreak of the leaf miner.

L. trifolii was accidentally introduced into India along with the cut flowers imported from United Kingdom (Anon., 1991). The pest was first reported from Andhra Pradesh where an unusual incidence of a pest was observed in castor which was confirmed to be *L. trifolii* (Lakshminarayana *et al.*, 1992). Later, it was recorded from cotton, tomato and cucurbits (Reghupathy *et al.*, 1994) and seventy host plants belonging to 16 families from South India (Srinivasan *et al.*, 1995). Since its introduction in India, *L. trifolii* has emerged as a key pest of cotton, tomato, grain legumes and cucurbits (Jeyakumar and Uthamasamy, 2000). Incidence of *L. trifolii* on cowpea (Reghunath and Gokulapalan, 1996; Nair, 1999) and cucurbits (Nair, 1999) was noticed in Kerala. Incessant application of insecticides for controlling other pests of cowpea created an environment free of natural enemies of *L. trifolii*, thus aggravating the situation. At present, the pest has become an important miner of cowpea in the state.

The information available on the pest in Kerala is meagre. Knowledge of the seasonal occurrence, extent of damage caused and host range are needed for developing effective management strategies. Since development of resistance to insecticides is a major obstacle in the control of *Liriomyza* spp., biological control would be a desirable option. Successful adoption of the method is dependent on identification of potential indigenous natural enemies. Exploitation of host plant resistance would also be an ideal approach for tackling the fly. Together with the natural enemies, the resistant varieties would offer a durable economical and ecologically sound component of IPM. Newer and safer insecticides too need to be located as an alternative for the conventional insecticides for controlling the resistant population in exigency.

Considering the above, the study was undertaken with the following objectives

1. To assess the extent of damage caused by *L. trifolii* in cowpea
2. To determine the influence of season, stage of crop and practices adopted by the farmers on the extent of damage.
3. To record the indigenous natural enemies of the pest.
4. To evaluate local and high yielding accessions of cowpea for their relative resistance / tolerance to the pest.
5. To identify effective insecticides of plant origin and newer and safer synthetic insecticides for managing the pest.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The damage caused by *L. trifolii* in cowpea, its parasitoids, relative resistance / tolerance of different varieties and efficacy of insecticides of plant origin and synthetic insecticides in controlling the pest were studied in the present investigation. The literature related to these aspects is briefly reviewed.

2.1 DAMAGE

2.1.1 Nature of Damage

The leaf miner, *L. trifolii* damages crops in several ways. Its mining activity killed young plants of bell pepper (Elmore and Ranney, 1954), celery (Trumble *et al.*, 1985) and muskmelon (Cheng, 1994) and reduced photosynthetic rates in chrysanthemum (Parrella *et al.*, 1981) and celery (Trumble *et al.*, 1985). Severe leaf mining also caused defoliation in cotton (Palumbo, 1992) and field bean (Srinivasan *et al.*, 1995).

Aesthetic value of ornamentals was reduced by the mining activity of the pest (Parrella *et al.*, 1981). Besides, the import of chrysanthemum, aster and peas was prevented and strict quarantine measures were imposed due to infestation of leaf miners (Parrella and Bethke, 1984). Wounds caused by the feeding and oviposition of *L. trifolii* provided entry sites for *Pseudomonas cichorii*, causing bacterial blight in chrysanthemum (Matteoni and Broadbent, 1988). Similarly, infestation of *L. trifolii* resulted in increased infection by *Alternaria alternata* in potato (Deadman *et al.*, 2000). The pest not only delayed harvest in celery (Trumble, 1985b), but also resulted in reduction in yield in potato (Wolfenbarger, 1954), cowpea (Price and Dunstan, 1983) and cotton (Palumbo, 1992).

2.1.2 Extent of Damage

L. trifolii caused collapse of cowpea plants (Singh and Merret, 1980). The extent of mining on cowpea leaves was observed to be fifty per cent in Tanzania (Price and Dunstan, 1983), while only one per cent infestation was noticed in India (Patnaik, 2000).

A loss of 19 – 20 million dollars was incurred in celery (Trumble *et al.*, 1985) and 93 million dollars over a period of four years in chrysanthemum (Newman and Parrella, 1986) due to infestation of *L. trifolii*. On faba beans, the percentage of infestation by the pest was 50.7 – 85.7 in Canakkale, 100 in Balikosio and 10 in Ayalin in Turkey (Kaya and Hincal, 1991). Field surveys in India revealed the widespread occurrence of *L. trifolii* in all the castor growing areas and the mines covered 20 – 60 per cent of the leaf area (Lakshminarayana *et al.*, 1992). In a survey conducted for assessing the incidence and severity of leaf miner in Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, 70 plants including fibre crops, pulses, vegetables, ornamentals, green manure crops, fodder crops, narcotics and weeds were identified as host plants (Srinivasan *et al.*, 1995).

2.1.2.1 Influence of Season and Stage of Crop

The extent of damage caused by the serpentine leaf miner is greatly influenced by the season. Maximum damage in bell pepper occurred during the summer season (Chandler and Gilstrap, 1987). In lettuce, larvae of *Liriomyza* were seen abundantly in the fall season in Arizona (Palumbo *et al.*, 1994). Similarly, incidence of *L. trifolii* was higher in summer than in winter in cotton in India (Jeyakumar and Uthamasamy, 2000). While crop loss due to *L. trifolii* during summer was 15 – 70 per cent in french bean, 41 per cent in cucumber and 35 per cent in tomato (IIHR, 1998), leaf damage was 35.7, 37 and 31.7 per cent in cucumber, watermelon and bottle gourd, respectively in India (Patnaik, 2000).

Obviously, the high temperature prevailing during summer favoured the multiplication of the pest. A temperature regime of 20 – 33^{0}C was observed to accelerate the development of *L. trifolii* larvae (Minkenberg and Lenteren, 1986). Shortened duration of life cycle of *L. trifolii* and an increase in the number of eggs per female per day was also noticed with increasing temperature (Zoebisch *et al.*, 1992).

The stage of the crop at which *L. trifolii* caused significant damage depended on the host plant. The mining activity of the pest was observed to be high in the cotyledonary stage in celery (Musgrave *et al.*, 1975) and french bean (IIHR, 1998). Increased damage was seen in the vegetative phase in castor and the severity of attack was low to negligible as the crop growth progressed (Lakshminarayana *et al.*, 1992). Heavy stippling and mining killed muskmelon seedlings under field conditions and significant reduction in yield as noticed when the plants were injured before the fruit setting stage (Cheng, 1994). Similarly, in bitter gourd the highest damage score for *L trifolii* was observed three weeks after sowing (Nandakumar, 1999). Though at times early mining activity killed the young plants of bell pepper, *Capsicum annuum* L., maximum number of larvae per plant was seen in the reproductive stage of the plant (Chandler and Gilstrap, 1987). Severe incidence of the pest was seen at the fag end of the crop in celery (Musgrave *et al.*, 1975) and cantaloupe (Chandler and Thomas, 1983).

2.1.2.2 Influence of Cultivation Practices

The leaf miner fly has a feeding and oviposition preference for plants with high nitrogen (Harbaugh *et al.*, 1983). When the females were exposed to tomato plants containing 3.4, 3.9, 4.6 and 4.9 per cent leaf nitrogen, they responded with significantly increased feeding and fecundity, longer oviposition period and higher oviposition rates. Their offsprings on the same plants showed reduced development time, lower mortality and increased pupal size (Minkenberg and Lenteren, 1986).

Fertilizer application increased the preference of *L. trifolii* to less preferred varieties (Bethke *et al.*, 1987). When nitrogen was applied according to farmer's practice (240 kg N ha^{-1}) and based on soil testing (150 kg N ha^{-1}) in potato, an increase in leaf miner population was seen in the former case (Zambon *et al.*, 1991).

Weeds too played an important role in the population build up of the leaf miner (Schuster *et al.*, 1991). *Portulaca oleraceae* was recorded as a weed host of *Liriomyza* in Australia (Mc Fadyen, 1994). In India, 22 species of weeds had been reported to be hosts of *L. trifolii* (Srinivasan *et al.*, 1995). Several species of weeds that host leaf miner may be considered as a natural reservoir of leaf miner parasitoids too (CIP, 1995).

2.2 PARASITOIDS OF *L. trifolii*

The natural enemies play a good role in maintaining the population of pests below damaging levels. A number of parasitoids of *L. trifolii* have been reported from different countries.

In India, the Eulophid, *Chrysonotomyia* sp. was reported from the leaf miner on cotton (Shankar *et al.*, 1992) and long gourd (Kapadia, 1995) and *Hemiptarsenus varicornis* (Girault) (Eulophidae) and *Gonotoma* sp. (Eucoilidae) on vegetables (Viraktamath *et al.*, 1993 ; Srinivasan *et al.*, 1995). *Chrysonotomyia appani, Closterocerus phytomyzae, Teleopterus* sp. and *Tetrastichus* sp. were recorded as larval parasitoids of *L. trifolii* in tomato and cucumber (Jagannatha, 1994). Similarly, *Chrysonotomyia* sp., *H. varicornis* and *Quedestichus* spp. were identified from the pest in rajma (Men *et al.*, 1998). Parasitoids of *L. trifolii* reported from other countries are presented in Table 1.

Table 1. Continued

Scientific name	Habit	% Parasitism	References
Diglyphus isaea (Walker)	"	90	Bene, 1989; Bene, 1990
Diglyphus popoea	"	--	"
Diglyphus crassinervis	"	--	"
Diglyphus albiscapus	"	--	Ohno *et al.*,1999
Chrysocharis parksi Crawford	Larval – pupal endoparasitoid	6	Lynch and Johnson, 1987
Pedobius acantha (Walker)	Larval parasitoid	--	Bene, 1989
Trisecodes agromyzae	Larval parasitoid	--	Delvare and Lasalle, 2000
Eucoilidae *Ganaspidium hunteri* (Doult)	Larval –pupal endoparasitoid	43.8	Beardsley, 1985
Ganaspidium utilis (Doult)	Larval –pupal endoparasitoid	--	Johnson, 1993
Cynipidae *Cothonaspis pacifica*	Endoparasitic on larvae later ectoparasitic on pupae	1.2	Johnson, 1987
Pteromalidae *Halticoptera circulus* Walker	Endoparasitic on larvae, later ectoparasitic on pupae	22.4	Johnson, 1987
Halticoptera patellana Walker	" "	--	Johnson, 1987
Cirrospilus vittatus (Westwood)	Larval parasitoid	--	Bene, 1989
Tetracampidae *Epiclerus nomocerus* (Holiday)	Larval endoparasitoid	--	Franco and Panis, 1991

Table 1. Parasitoids of *Liriomyza trifolii*

Scientific name	Habit	% Parasitism	References
Braconidae *Opius brunipes* Gah	Larval-pupal endoparasitoid	100	Lindquist and Casey, 1983
Opius dissitus Musebeck	Larval –pupal endoparasitoid	1.4	Johnson, 1987
Opius dimidiatus Musebeck	Larval –pupal endoparasitoid	--	Lin and Wang, 1992
Dacnusa sibrica (Telenga)	Larval parasitoid	--	Minkenberg and Lenteren, 1986
Dacnusa areolaris (Nees)	Larval –pupal endoparasitoid	--	Bene, 1989
Eulophidae *Hemiptarsenus dropion* (Walker)	Larval endoparasitiod	--	Bene, 1987
Hemiptarsenus semialbiclavus (Girault)	Larval endoparasitioid	0.4	Lynch and Johnson, 1987
Chrysonotomyia punctiventris Crawford	Larval - pupal endoparasitoid	45.2	Johnson, 1987
Chrysonotomyia syngenesiae (Hardy)	Larval parasitoid	--	Bene, 1989
Chrysonotomyia horticola (Goureau)	Larval parasitoid	--	Bene, 1990
Chrysonotomyia formosa Walker	Larval – pupal endoparasitoid	0.9	Fu *et al.*, 1999
Diglyphus begini (Ashmead)	Larval ecto parasitoid	0.07	Johnson, 1987

2.3 VARIETIES RESISTANT / TOLERANT TO THE PEST

Utilisation of host plant resistance is a low cost and effective method of pest management. Varieties of several crops have been identified as resistant to *L. trifolii*.

2.3.1 Cowpea

Among the 50 varieties of cowpea screened, Vita-3 had the lowest per cent leaf area damaged by *L. trifolii* with a lower score of 1.3 (Score 1 = 0 – 7 per cent damage of leaf area and score 2 = 7 – 25 per cent damage of leaf area) (Moraes *et al.*, 1981). Cowpea variety TK –1 was found to be more resistant compared to 4R-026-IR (Price and Dunstan, 1983).

2.3.2 Other Crops

Tomato varieties *viz.*, Clark's Early Special, Rio Grande and Pearson VF – 6 (Wolfenbarger, 1966), Roma and VF 145-B (Webb and Smith, 1969) were reported as resistant to *L. trifolii*. Lowest survival of pupae of *L. trifolii* was observed in cultivar VF 7718 of tomato (Bethke *et al.*, 1987). Several *Lycopersicon* accessions, especially lines with genes for increased density of non glandular leaf trichomes were found to be resistant to *L. trifolii* (Eigenbrode *et al.*, 1993) and molecular markers for resistance were located on chromosome 2 (Moreira *et al.*, 1999). The Indian variety of tomato 'Pusa Ruby' was less susceptible to *L. trifolii* while Abinash II was susceptible and 'Arjuna' was tolerant to most of the pests including *L. trifolii* (Choudhuri *et al.*, 2000).

The celery variety 16 – 24 was observed to be less attractive to adults of *L. trifolii* as indicated by fewer mines in the leaves (Musgrave *et al.*, 1975). Similarly, 'Improved Rivalry' was resistant while Yellow Iceberg was susceptible (Tyron and Poe, 1981). Of the several species of *Apium* tested, *Apium nodifolium* (L.) accession 87 A 236 was resistant with less larval survival (Trumble *et al.*, 1990). Among 11 genotypes of ridge gourd screened against the leaf miner, Raichur local-2, Deodurg local and Poona local were recorded as resistant to *L. trifolii* (Nandihalli *et al.*, 1995). Leaf miner infestation was comparatively low in muskmelon variety DMDR – 2 in the field (Satpathy *et al.*, 2000).

Snap bean (*Phaseolus vulgaris* L.) variety V 5003 was resistant than Cocorubico (Anon., 1986) and the variety Eagle had fewer leaf mines than Nemasnap (Hanna *et al.*, 1987). Among 24 genotypes of indian bean (*Lablab purpureus* L.) screened for their resistance against *L. trifolii*, Edar Papadi did not show any mines whereas JDl-73, Papadi Rani, Virpur, No.7022, JDL-77, Nylone Deshival and JDL-79 showed 0.13 to 0.80 mines per leaf and were recorded as resistant. Higher number of stomata was positively correlated with the resistance (Kapadia *et al.*. 1995). Reina Blanca of faba bean (*Vicia faba* L.) had higher infestation of *L. trifolii* while Gaza-3 and breeding line 716 / 1039 had the lowest infestation (El-Khouly *et al.*, 1997). Arka Harit of bitter gourd was identified as a tolerant variety to *L. trifolii* (Nandakumar, 1999).

A high level of resistance was observed in Bornholm and Bornholm Bronze cultivars of chrysanthemum, which could be used as a source of resistance in breeding programme (Baranowski, 1987). Non-preference and reduced oviposition by adult *L. trifolii* was detected in resistant chrysanthemum cultivars and only the survival of first and second instar larvae was influenced by resistance (Dijk *et al.*, 1993). Mountain Peak, a cultivar of chrysanthemum was observed to be resistant to *L. trifolii* with the lower leaf showing more toxicity to larvae of leaf miner (Hawthorne, 1999). Feugo variety of gerbera was resistant to *L. trifolii* with fewer adults caught, less feeding punctures and damaged area (Chaun and Hong, 2000).

Fourteen advanced lines of castor having few mines (0.6 – 8 mines per10 plants) were found tolerant to *L. trifolii* and CK 950013 had the least number of mines (Razak, 2000).

2.4 EFFICACY OF INSECTICIDES

2.4.1 Botanical Insecticides

2.4.1.1 Neem

Crude neem extract 0.4 per cent caused significant mortality to late instar larvae and pupae of *L. trifolii* in chrysanthemum and the effect lasted for three weeks (Larew *et al.*, 1985). One per cent methanolic and ethanolic extracts of neem seed kernel were effective when sprayed on beans before exposure *to L. trifolii* adults and one per cent methanolic extract showed highest activity when sprayed after appearance of the mines (Meisner *et al.*, 1986). Soil drench with one and two ppm azadirachtin reduced female fecundity and male longevity in chrysanthemum (Parkman and Peinkowski, 1990). The fecundity of females of *L. trifolii* was reduced when early instar larvae were treated with 0.1 per cent and late instar with 0.4 per cent of methanolic neem seed kernel extract (Schmutterer, 1990). Neem Azal-S and Margosan-O showed significant feeding deterrent activity against *L. trifolii* when applied at two per cent and the effect lasted for five days after treatment. Both formulations also deterred the females from laying eggs and percentage oviposition deterrent index reached 80.7 and 52.6 for Neem Azal-S and Margosan-O respectively. Post infestation treatment of bean seedlings led to the formation of malformed pupae (Dimetry *et al.*, 1995).

Oil emulsion (10 per cent) of *A. indica* reduced leaf miner incidence on cowpea in Kerala (Reghunath and Gokulapalan, 1996). Neem seed kernel extract five per cent was effective for controlling *L. trifolii* in vegetable crops in India (Jeyakumar and Uthamasamy, 1997; IIHR, 1998; Choudary and Rosaiah, 2001). Treating *Phaseolus* plants with 0.1 per cent of Neemix – 45 (Azadirachtin, 4.5 per cent) before exposure to egg laying adults had a greater effect on inhibiting the development of pupae and adult eclosion than treatment at first larval instar. Drenching plants with one ppm azadirachtin 24 hours before exposure to adults had a greater effect (0 per cent adult eclosion) than leaf dipping for the same period and concentration (15.6 per cent adult eclosion) (Weintraub and Horowitz, 1997). Soil drenching with Nimbecidine 0.4 per cent + dimethoate 0.025 per cent reduced the incidence of *L. trifolii* in bitter gourd (Nandakumar, 1999). Neemazal 0.5 per cent gave very good control of *L. trifolii* in snap bean (Omar and Faris, 2000) and tomato (Choudary and Rosaiah, 2001). Similarly, application of neem seed kernel extract at five per cent concentration at 10 days interval in the field controlled leaf miner (28.35 per cent damaged leaves) and recorded the highest yield (32.71 q ha^{-1}) in ridge gourd (Rosaiah, 2001).

2.4.1.2 Other Plant Products

Oil emulsion (10 per cent) of *Samadera indica* reduced leaf miner incidence on cowpea in Kerala (Reghunath and Gokulapalan, 1996). Illupai oil (*M. longifolia*) at three per cent caused significant mortality of larvae of *L. trifolii* in cotton (Jeyakumar and Uthamasamy, 1997). Aqueous extracts of fruits and leaves of chinaberry tree, *Melia azedarach* L. were effective against the leaf miner (Hammad *et al.*, 2000). Rhodojaponin III and extracts of *Rhododendron molle G. Don* flowers possessed significant feeding inhibition and insecticidal properties against larvae and adults of leaf miners (Ying *et al.*, 2000). Spraying of karanj oil 0.5 per cent at 10 days interval effectively controlled *L. trifolii* in ridge gourd with less percentage of infested leaves (29.68 per cent) (Rosaiah, 2001).

2.4.2 Synthetic Insecticides

Several insecticides of chlorinated hydrocarbons, organophosphates, carbamates, synthetic pyrethroids, insect growth regulators and insecticides of microbial origin were reported to control *L. trifolii*.

Acephate, 0.12 and 0.99 per cent was effective against *L. trifolii* causing 84 and 94 per cent mortality respectively, in vegetables (Lidquist and Krueger, 1975). Foliar application and drip irrigation delivery of oxamyl (2.25 kg a.i. ha^{-1}) effectively checked *L. trifolii* population in bell pepper and drip irrigation delivery system reduced the cost of insecticide application (Royer *et al.*, 1988). Effectiveness of dimethoate (0.4 ml a.i. l^{-1}) in beans (Anon., 1986), aldicarb 2 g $plant^{-1}$ (Natskova and Karadzhova, 1990) and malathion 500x dilution in kidney bean (Chang and Chen, 1993), methamidophos 3 ml a.i. l^{-1} (Chavarria and Vargas, 1993), triazophos 16.71 µg ml^{-1} (Feng *et al.*, 2000), methomyl 0.05 per cent at 20 days interval (Reddy and Kumar, 2001) and carbofuran 1 kg a.i. ha^{-1} in tomato (Choudary and Rosaiah, 2001) were reported against *L. trifolii*. Similarly, effectiveness of chlorpyrifos 500 g a.i. ha^{-1} was reported against *L. trifolii* in snap bean (Omar and Faris, 2000) and tomato (Choudary and Rosaiah, 2001).

Isoxathion and thiocyclam gave high mortality of *L. trifolii* larvae with LC_{50} of 33 and 72 ppm respectively and had high adulticidal activity and reduced number of feeding and oviposition punctures on vegetables and ornamentals (Saito *et al.*, 1992). Oxydemeton-methyl @ 0.05 per cent was effective against *L. trifolii* in vegetables (Viraktamath *et al.*, 1993).

Weekly applications of synthetic pyrethroids were recommended *to control L. trifolii in broad bean (Vercambre, 1980). Six sprays of* deltamethrin 20 g ha^{-1} were effective to reduce *L. trifolii* incidence in cowpea (Price and Dunstan, 1983). Spraying deltamethrin 0.028 per cent + honge oil 0.1 per cent gave good control of *L. trifolii* in tomato (0.13 mines per leaf) followed by deltamethrin 0.028 per cent (0.23 mines per leaf) (Reddy and Kumar, 2001).

Seed treatment of cotton with imidacloprid 5 g kg^{-1} enhanced plant growth and consequently enhanced population of *L. trifolii* (Sharma *et al.*, 1997). Spraying acetamiprid 50 g a.i. ha^{-1} at 10 days interval was found effective to reduce *L. trifolii* infestation on tomato while imidacloprid 20 g ai ha^{-1} was ineffective (Choudary and Rosaiah, 2001).

An insect growth regulator, fenoxycarb 96 g a.i. per 100 l of water affected adult emergence of *L. trifolii* and gave more than 80 per cent control of the pest in chrysanthemum and was safe to *C. parksi* (Parrella *et al.*, 1983). Cyromazine, a systemic growth regulator caused larval mortality of *L. trifolii* on tomato with LC_{50} of 4.8 ppm (Schuster and Everett, 1983) and *P. vulgaris* with LC_{50} of 3 ppm after 3 days (Saito *et al.*, 1992). Cyromazine (0.025 per cent) was compatible with the endoparasitoid of *L. trifolii*, *C. parksi* in chrysanthemum (Parrella *et al.*, 1983). Foliar application of cyromazine at 0.14 kg a.i. ha^{-1} in bell pepper reduced *L. trifolii* population (Royer *et al.*, 1988) and it had no environmental impact and was non-toxic to birds, fishes and bees. Only low dose was required to contain the pest (Albert, 1992). Cyromazine, 0.039 g a.i. ha^{-1} was less toxic to the parasitoid, *D. isaea* (Chavarria and Vargas, 1993). Application of buprofezin at 0.75 g a.i. per 10 l twice at eight days interval gave effective control of *L. trifolii* on gerbera and tomato and had no adverse effects on the parasitoids, *D. sibirica* and *D. isaea*. It had larvicidal activity for moults from first to second and second to third instar and also ovicidal activity (Viere and Vaconte, 1988). Diflubenzuron (0.1 per cent) was effective against *L. trifolii* larvae in tomato (Natskova and Karadzhova, 1990). Similarly, flufenoxuron could reduce *L. trifolii* incidence in *P. vulgaris* with LC_{50} of 103 ppm, three days after treatment (Saito *et al.*, 1992) and on tomato when sprayed @ 100 g a.i. ha^{-1} at 10 days interval (Choudary and Rosaiah, 2001).

A formulation of *Bacillus thuringiensis* (Dipel) could reduce the population of leaf miners in tomato compared to methomyl (Johnson *et al.*, 1980; Al-Amad *et al.*, 2001). Tomato plants treated with two per cent of Bactoculicide (a Russian preparation based on *B. thuringiensis* H_{14} subsp. *israelensis*) contained less number of punctures and mines compared to control when freshly emerged adults were allowed to feed (Ushchekov, 1994). Abamectin, a biorational pesticide of microbial origin was, reported to be an outstanding chemical for controlling *L. trifolii* (Lasota and Dybas, 1991). The reservoir of abamectin that remains within the mesophyll layer of treated leaves makes the chemical easily accessible for ingestion by mining larvae and it was shown to cause an increase in aberrant puparial forms (Lasota and Dybas, 1991). MK 936 (avermectin B) at 13.5 – 27 g a.i. ha^{-1} gave more than 85 per cent control of larvae of permethrin resistant *L. trifolii* in chrysanthemum (Parrella, 1983). Avermectin induced high mortality in one and three day old larvae of *L. trifolii* with LD_{50} of 0.386 ppm on third instar larvae and weekly application @ 1.2 g a.i. per 100 l of water inhibited oviposition by adults on tomato (Schuster and Everett, 1983; Schuster and Taylor, 1987). Effectiveness of avermectin 20 g a.i. ha^{-1} sprayed at weekly intervals against *L. trifolii* has been reported on ornamentals (Hara, 1986; Parrella *et al.*, 1988), celery (Trumble, 1985a), tomato (Schuster and Taylor, 1987; Longiswaran and Bhuvaneswari, 2000), brinjal (Keun *et al.*, 2000) and snap bean (Omar and Faris, 2000). LD_{50} of abamectin against third instar larvae of *L. trifolii* on chrysanthemum was 0.386 ppm by leaf dip bioassay and 0.404 ppm by topical application to susceptible females (Parrella *et al.*, 1988). Abamectin reduced the parasitoid population in the field but the population recovered soon (Weintraub, 2001). Spinosad, another insecticide of microbial origin, showed significant effect on *L. trifolii* larvae and pupae and persisted for 15 days in bell pepper (Gahbiche and Aoun, 1999).

Cartap, an insecticide of animal origin at 75 g per100 l of water was effective in reducing *L. trifolii* on *P. vulgaris* (Saito *et al.*, 1992).

2.4.3 Resistance to Insecticides

It has been observed that *Liriomyza* spp. easily develops resistance to insecticides. Control failures with chlorinated hydrocarbons, organophosphates and pyrethroids between 1947 and 1978 have been reported (Parrella *et al.*, 1984). There was 30 fold resistance to permethrin in

L. trifolii population on protected chrysanthemum in USA (Parrella and Lindquist, 1983) and resistance to insecticides had been responsible for control failures of *L. trifolii* in ornamentals (Parrella and Keil, 1984). The pest had developed resistance to dimethoate and methamidophos (Chandler, 1985; Keil and Parrella, 1990), fenvalerate (Mason *et al.*, 1987), chlorpyrifos (Grafius and Hayden, 1988), monocrotophos, carbaryl, fenthion and phosalone (Lyra-Netto *et al.*, 1989) and methyl parathion, mixture of methyl parathion and permethrin and cross resistance to DDT and cypermethrin (Keil and Parrella, 1990). Resistance level of *L. trifolii* was very high compared to other species (Mason *et al.*, 1987). Resistance mechanism of *L. trifolii* was reported to be oxidative metabolism (Keil and Parrella, 1990).

Overuse of pesticides with resultant decimation of natural enemies in addition to development of resistance was attributed for the failure to control *L. trifolii* (Johnson *et al.*, 1980).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A study was conducted at the College of Agriculture, Vellayani during 2001 – 2002 to determine the extent of damage done by the serpentine leaf miner on cowpea and to identify effective measures to manage the pest.

3.1 DOCUMENTATION OF EXTENT OF DAMAGE

Kalliyoor panchayat, an important vegetable-growing tract in Thiruvananthapuram district was selected for the study. Survey was conducted in two wards of the panchayat viz., Kalliyoor and Palappur where cowpea was cultivated extensively, to assess the extent of damage caused by the pest (Plate 1). Ten farmers were selected at random in each ward and a plot of 200 m^2 was demarcated in each farmer's field. Ten plants were selected at random in each plot and tagged. The damage inflicted by the leaf miner (Plate 2) was scored at two stages of the crop *viz.*, the vegetative and reproductive phases during rainy and summer seasons. The following arbitrary scale (0 – 4) was adopted for cataloguing the damage.

Score	Per cent infestation
0	0
1	1 – 25
2	26 – 50
3	51 – 75
4	> 76

The infestation index was calculated as:

$$\text{Infestation index} = \frac{\text{Sum of all scores}}{\text{Total number of scores x Maximum score}} \times 100$$

Plate 1. Cowpea plants damaged by *Liriomyza trifolii* in a farmer's field in Kalliyoor Panchayat

The data was statistically analyzed using Student's t test. The variety grown, agronomic practices adopted (spacing and manuring) and plant protection measures taken by each farmer were also recorded. Weeds infested by *L. trifolii*, seen in and around the cowpea fields were noted.

3.2 IDENTIFICATION OF PARASITOIDS

Parasitized larvae (Plate 3) seen on leaves of cowpea and susceptible weeds were collected from the farmers' field. The leaves were placed in perforated polythene bags, labelled, sealed and kept in the laboratory for emergence of the parasitoids. On emergence, the parasitoids were preserved in 70 per cent alcohol. The parasitoids were identified by Dr. T. C. Narendran, Professor, Department of Zoology, Calicut University, Malappuram, Kerala.

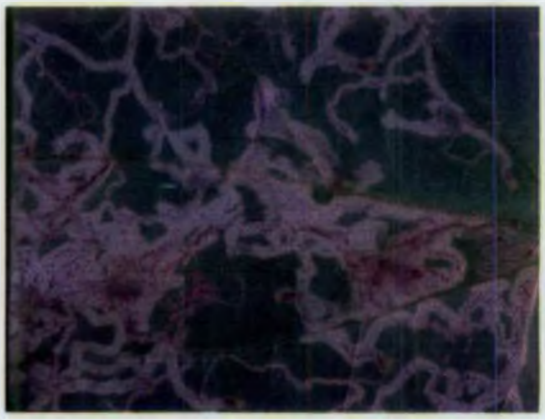
3.3 EVALUATION OF ACCESSIONS FOR RESISTANCE / TOLERANCE

Twenty accessions of cowpea including improved varieties obtained from the germplasm maintained in the Department of Plant Breeding, College of Agriculture, Vellayani and local collections made from farmers' field were screened for their resistance / tolerance to *L. trifolii*. Ten each of trailing and bush type of cowpea were selected for the evaluation.

3.3.1 Rearing of *L. trifolli*

Cowpea leaves with serpentine mines having active larvae, were collected from the Instructional Farm, Vellayani. The leaves with moistened cotton at the base of petiole were kept in polythene covers for pupation. The pupae were transferred to glass vials and observed for adult emergence. Greyish black adults, 1 – 2 mm long with a distinct yellow spot on top of the thorax and a yellow margin behind the compound eyes emerged from the pupae (Plate 4). Based on the identifying characters, the species was confirmed to be *L. trifolii*. The

(A) Feeding /oviposition punctures



(B) Serpentine mines on leaf

Plate 2. Symptoms of damage of *Liriomyza trifolii*

Plate 3. Parasitized larvae of *Liriomyza trifolii*

adults (males and females) (Plate 4) were released on potted cowpea plants (variety: local) confined in polythene cages for mass culturing of the pest (Plate 5).

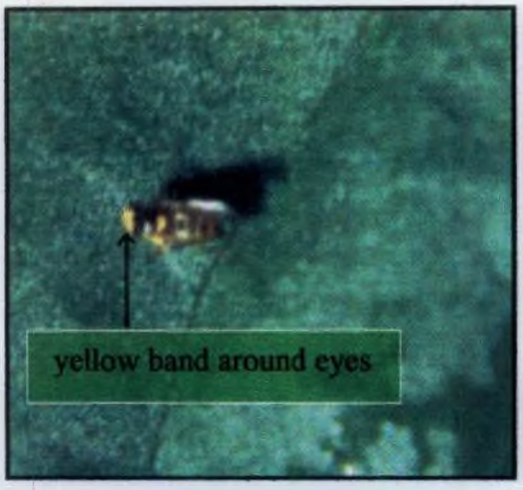
Cotton swabbed in sugar solution (10 per cent) was kept inside the cages for the adults to feed. A day later, the exposed plants were transferred to another cage for development of the larvae. When the larvae attained full growth, the plants were placed horizontally for easy collection of pupae. The pupae were kept in glass vials and the emerging adults were used for further studies on the same day of emergence.

3.3.2 Evaluation of Varieties

Evaluation for resistance / tolerance was done in CRD with 20 accessions and three replications. The accessions screened were as given below.

Trailing type	Bush type
VU-25 (Vellayani local)	Kanakamony
Sharika	Subra
Malika	Bhagyalekshmi
Vyjayanthi	Arka Garima
VU- 27 (Balaramapuram local)	VU-1 (Koliyakode local)
VU- 13 (Kallara local)	VU-2 (Vaikom local)
VU-10 (Manarkad local)	VU-3 (Kumaranellor local)
VU-11 (Alathoor local)	VU-4 (Koliyoor loal)
VU-12 (Valiyathura local)	VU-5 (Thodupuzha local)
Padavalapayar	VU-6 (Koothattukulam local)

Seeds of each variety was sown in plastic cups of 6 cm diameter filled with potting mixture (soil, sand and cowdung 1: 1: 1) @ one seed per cup. The plants were watered daily and at 2 – 3 leaf stage the plants were caged with *L. trifolii* adults @ one pair (one male and one female)



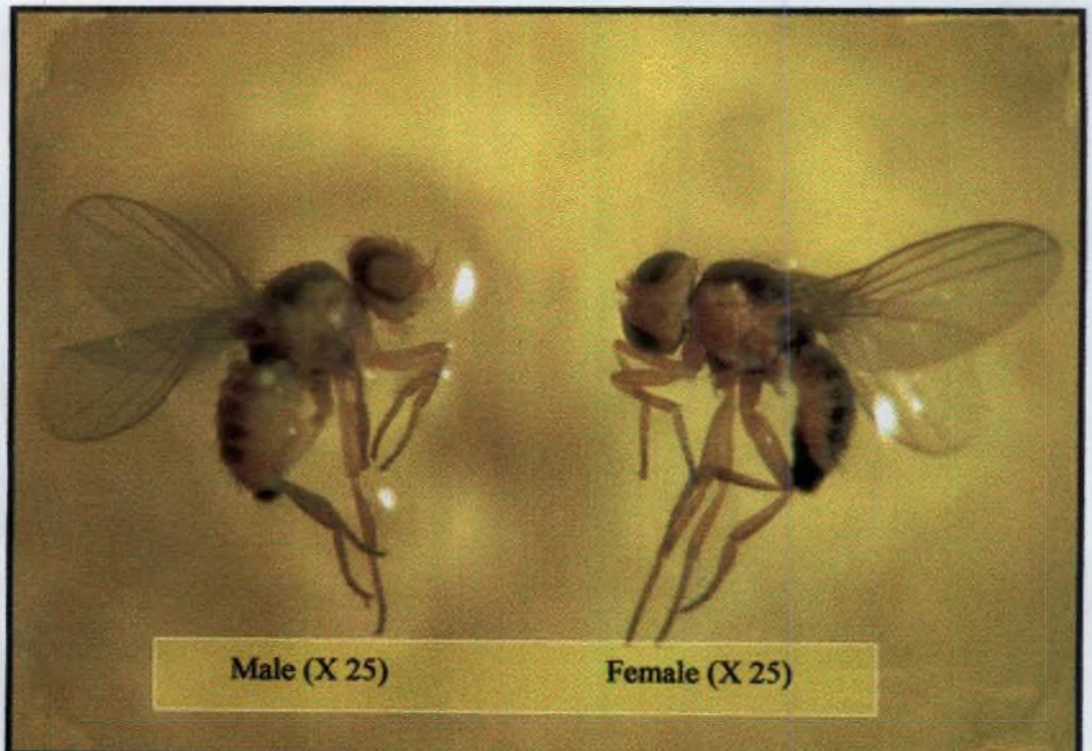
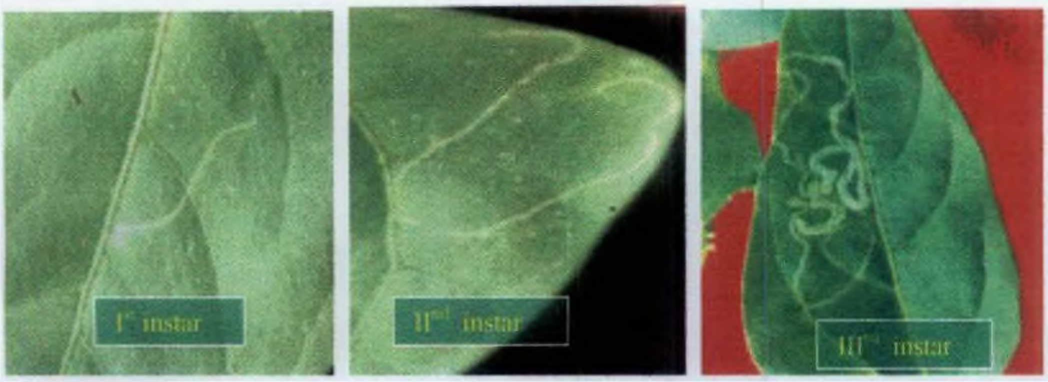


Plate 4. Life stages of *Liriomyza trifolii*, (A) Adult



(B) Larval mines at different instars

(C) Larva

(D) Pupa (x 20)

Plate 4 (continued). Life stages of *Liriomyza trifolii*

Plate 5. Rearing cage

per plant. Twenty four hours after exposure to the pest, the plants were removed and kept in polythene cages.

The leaves were observed for feeding / oviposition punctures and development of larval mines. The number of larvae, pupae and adults emerging from each accession was noted. The time taken to complete the different stages *viz.*, egg, larva and pupa was also recorded. The data was statistically analyzed using non-factorial CRD.

3.4 EVALUATION OF PLANT OILS AND INSECTICIDES

Four plant oils and four newer synthetic insecticides were tested for their efficacy in causing adult and larval mortality in the laboratory. The promising ones were further tested in the field.

3.4.1 Laboratory Screening

Cowpea, variety local (VU-25) obtained from Instructional Farm, College of Agriculture, Vellayani was raised as described in 3.3.2. The experiment was laid out in CRD with 18 treatments and an untreated check, each replicated thrice. The treatments were as detailed below.

Plant oils		Dose
Custard apple	(*Annona squamosa* L.)	: 5 per cent
Custard apple	(*Annona squamosa* L.)	: 2.5 per cent
Castor	(*Ricinus communis* L.)	: 5 per cent
Castor	(*Ricinus communis* L.)	: 2.5 per cent
Marotti	(*Hydnocarpus wightiana* Blume.)	: 5 per cent
Marotti	(*Hydnocarpus wightiana* Blume.)	: 2.5 per cent
Illupai	(*Madhuca longifolia* Koeing)	: 5 per cent
Illupai	(*Madhuca longifolia* Koeing)	: 2.5 per cent
Neem	(*Azadirachta indica A.Juss.*)	: 2.5 per cent

Synthetic insecticides		
Imidacloprid	(Confidor 17.8 SL)	: 0.005 per cent
Imidacloprid	(Confidor 17.8 SL)	: 0.01 per cent

Profenophos	(Curacron 50 EC)	: 0.025 per cent
Profenophos	(Curacron 50 EC)	: 0.05 per cent
Thiamethoxam	(Actara 25 WG)	: 0.02 per cent
Thiamethoxam	(Actara 25 WG)	: 0.04 per cent
Abamectin	(Vertimec 1.8 EC)	: 0.003 per cent
Abamectin	(Vertimec 1.8 EC)	: 0.006 per cent
Dimethoate	(Rogor 30 EC)	: 0.05 per cent

3.4.1.1 Preparation of Spray Solution

3.4.1.1.1 Oil emulsion

Soap (0.6 g) was cut into small pieces and mixed with 5 ml of water to get soap solution. Oil (10 ml) was added to the soap solution with continuous stirring. The solution was made up to 100 ml to prepare 10 per cent oil emulsion. The different concentrations (5 and 2.5 per cent) of oil emulsions were prepared by diluting the 10 per cent emulsion.

3.4.1.1.2 Synthetic Insecticides

The required quantity of chemical insecticides was weighed or pipetted and mixed with a small quantity of water and made up to 100 ml.

3.4.1.2 Testing for Bioactivities

3.4.1.2.1 Adult mortality

Cowpea plants at three- leaf stage were sprayed with the respective pesticides with a hand sprayer and allowed to evaporate till the leaves dried completely. Five such plants were confined in a cage and five pairs of adults of *L. trifolii* were released to the plants. This served as one replication and three replications were maintained for each treatment. Adult mortality at 12 and 24 hours after release, number of feeding / oviposition punctures, number of larvae, pupae and adults emerging from the treated plants were observed. Adult mortality was corrected using Abbot's formula (Abbot, 1925). The data were statistically analysed using non-factorial CRD.

3.4.1.4 Larval Mortality

Cowpea plants (variety: VU-25) raised in plastic cups of 6 cm diameter at three- leaf stage were caged with adults of *L. trifolii* @ one pair per plant. The plants were removed 24 hours after oviposition and kept for larval development. When majority of the larvae in the leaf were in the second instar (next day of hatching of eggs), the plants were sprayed with the respective insecticides after counting the number of live larvae present. The treated plants were kept in separate cages for observations and three replications were maintained for each treatment. The number of dead larvae at 24 and 48 hours after treatment, number of pupae and adults emerging from the treated leaves were recorded.

3.4.2 Field Trial

A field trial was conducted to evaluate the effective plant oils and insecticides identified in the laboratory in comparison with neem oil and dimethoate. The experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani.

3.4.2.1 Preparation of the Field

Seeds of vegetable cowpea (variety: VU-25) obtained from the Instructional Farm, College of Agriculture, Vellayani was used for the trial. The details of the trial were as follows:

Design : RBD
Plot size : 2 x 2 m
Spacing : 45 x 15 cm
Replications : 4
Treatments : 8

T_1 – Thiamethoxam : 0.02 per cent

T_2 – Abamectin : 0.003 per cent

T_3 – Profenophos : 0.05 per cent

T_4 – Marotti oil : 2.5 per cent

T_5 – Illupai oil : 2.5 per cent

T_6 – Neem oil : 2.5 per cent

T_7 – Dimethoate : 0.05 per cent

T_8 – Untreated check

The crop was raised and maintained as per the Package of Practices Recommendations (KAU, 1996) except for the plant protection measures, which were given according to the treatments fixed.

3.4.2.2 Preparation of Spray Solution

Spray solutions of the respective pesticides were prepared as described in 3.4.1.1. The first application of pesticides was done when leaf miner infestation was noted, four weeks after sowing. Subsequently, the pesticides were sprayed at weekly intervals upto eight weeks after sowing.

3.4.2.3 Assessment of Pest Incidence

Observations on the incidence of pests were recorded at weekly intervals. Ten observational plants were selected at random from each plot and the total number of leaves, number of leaves infested and number of mines in each leaf were counted. Harvest was done once in two days when the pods were ready for picking. The number and weight of pods were recorded from each plot.

RESULTS

4. RESULTS

4.1 EXTENT OF DAMAGE

The extent of damage caused by *L. trifolii* in cowpea during different seasons and phases of growth of the plants in Kalliyoor panchayat of Thiruvananthapuram district is presented in Table 2. Significant difference was observed in the damage caused during summer and rainy seasons and at vegetative and reproductive phases of the plants. Maximum infestation was noted in summer and at the reproductive phase, the mean infestation index being 67.63 per cent with the extent of infestation ranging from 50.00 – 80.00 per cent. At the vegetative phase during summer, the mean infestation index was 31.75 per cent with a range of 22.50 – 42.50 per cent. Occurrence of the pest was low during the rainy season as indicated by the mean infestation index, being 16.75 per cent at the vegetative phase with a range of 10.00 – 42.50 per cent and 38.63 per cent at the reproductive phase with a range of 15.00 – 62.50 per cent.

4.1.1 Influence of Cultivation Practices on the Extent of Damage

Certain cultivation practices (Table 3) adopted by the farmers were seen to influence the extent of damage caused by *L. trifolii* in cowpea.

4.1.1.1 Method of Planting

Of the selected farmers, 85 per cent (Fig. 1a) adopted the pit system of planting for raising cowpea. Four plants were raised in a single pit taken at a distance of 1 m each. Only 15 per cent of the farmers grew cowpea in trenches. Two plants were grown in a small hole dug out in the trench, 30 cm apart.

Between the two methods of planting, more damage was seen in the plants raised in pits than plants raised in trenches during the two

Table 2. Extent of damage caused by *Liriomyza trifolii* during different seasons and phases of growth of cowpea.

Damage	Summer season		Rainy season	
	Vegetative phase	Reproductive phase	Vegetative phase	Reproductive phase
Mean infestation index, %	31.75 (34.23)	67.63 (55.49)	16.75 (23.87)	38.63 (38.13)
SE_M	(0.70)	(1.19)	(1.07)	(1.81)
CV, %	(9.11)	(9.56)	(20.0)	(21.22)
Range of infestation index, %	22.50– 42.50	50.00 – 80.00	10.00 – 42.50	15.00 – 62.50

(Figures in parentheses are angular transformed values)

t value – between phases : Summer : 15.06**
: Rainy : 6.62**

between seasons : Vegetative : 7.92**
: Reproductive : 7.82**

**-Significant at 5 % and 1 %

Table 3. Influence of cultivation practices adopted by farmers on the extent of damage caused by *Liriomyza trifolii* in cowpea. %

Cultivation practices	Particulars	Mean infestation index			
		Summer season		Rainy season	
		Vegetative phase	Reproductive phase	Vegetative phase	Reproductive phase
Method of planting	Pit	32.90 (25.00 – 42.50)	70.20 (57.50 – 80.00)	17.80 (10.00 – 42.50)	42.25 (22.50 – 62.50)
	Trench	25.00 (22.50 – 27.50)	52.50 (50.00 – 57.50)	10.30 (10.00 – 12.50)	18.30 (15.00 – 20.00)
Accessions cultivations	Local	28.45 (25.00 – 42.50)	66.75 (50.00 – 80.00)	14.85 (10.00 – 42.50)	35.95 (22.50 – 47.50)
	Improved	33.75 (30.00 – 37.50)	61.25 (57.50 – 65.00)	15.00 (10.00 – 20.00)	55.00 (47.50 – 62.50)
Fertilizer dose	N=POP P=POP K=POP	25.00 (22.50 – 27.50)	53.75 (50.00 – 57.50)	10.60 (10.00– 12.50)	23.10 (15.00 – 32.50)
	N>POP P=POP K>POP	32.50 (32.50)	70.00 (70.00)	12.50 (12.50)	42.50 (42.50)
	N>POP P=POP K=0	35.00 (32.75 – 37.50)	75.00 (75.00)	21.70 (17.50 – 22.50)	57.50 (57.50)
	N>POP P>POP K=0	30.00 (27.50 –32.50)	75.00 (75.00)	13.75 (10.00 – 17.50)	33.75 (35.00 – 37.50)
	N>POP P<POP K=0	33.75 (32.75 – 35.00)	75.00 (75.00)	12.50 (12.50)	37.50 (37.50)
	N>POP P=0 K>POP	25.80 (22.50 – 30.00)	64.60 (60.00 – 65.00)	16.25 (15.00 – 17.50)	34.60 (30.00 – 37.50)
	N>POP P=0 K=0	42.50 (42.50)	77.50 (75.00 – 80.00)	32.50 (22.50 – 42.50)	60.00 (57.50 – 62.50)
Pesticide used	Methyl parathion	32.50 (30.00 – 37.50)	72.50 (67.50 – 75.00)	16.00 (10.00 – 20.00)	39.00 (35.00 – 47.50)
	Monocrotophos	38.30 (35.00 – 42.50)	75.00 (75.00)	20.80 (17.50 – 22.50)	55.00 (50.00 – 57.50)
	Dimethoate + Quinalphos	27.50 (27.50)	57.50 (57.50)	12.50 (12.50)	20.00 (20.00)
	Monocrotophos+ Malathion	42.50 (42.50)	80.00 (80.00)	42.50 (42.50)	62.50 (62.50)
	Fenvalerate	30.00 (25.00 – 32.50)	65.80 (62.50 – 67.50)	14.20 (10.00 – 15.00)	26.70 (22.50 – 35.00)
	Lambdacyhalothrin	22.50 (22.50)	50.00 (50.00)	10.00 (10.00)	15.00 (15.00)
	Fenvalerate+ Lambdacyhalothrin	25.00 (25.00)	50.00 (50.00)	10.00 (10.00)	15.00 (15.00)
	Methylparathion+ Fenvalerate	28.75 (27.50 – 30.00)	61.25 (57.50 – 65.00)	12.50 (10.00 – 15.00)	21.25 (20.00 – 22.50)
	Monocrotophos+ Fenvalerate	33.75 (30.00 – 37.5)	75.00 (75.00)	17.50 (15.00 – 20.00)	45.00 (42.50 47.50)
	Quinalphos + Fenvalerate	25.00 (25.00)	57.50 (57.50)	10.00 (10.00)	15.00 (15.00)

Figures in parentheses are ranges. N-Nitrogen, P- Phosphorus, K- Potassium POP-Package of practices recommendations of Kerala Agricultural University, POP recommendation of NPK – 20: 30: 10 kg ha^{-1}

1. Method of planting

2. Variety

Fig. 1a. Extent of adoption of different cultivation practices for raising cowpea in Kalliyoor panchayat

seasons and stages of growth as indicated by the infestation index computed. While the mean infestation index was 70.26 per cent during the reproductive stage and 32.90 per cent during the vegetative stage in the pit method of planting, it was 52.50 per cent and 25.00 per cent in the trench method of planting during summer. Similarly, the mean infestation index in the reproductive and vegetative stages was 42.25 and 17.80 per cent in the pit method of planting and 18.30 and 10.30 per cent in the trench method of planting, respectively during the rainy season.

4.1.1.2 Accessions Cultivated

Ninety per cent of the farmers in the selected panchayat cultivated local accessions of vegetable cowpea (Fig. 1b). Only ten per cent cultivated improved high yielding varieties. The extent of damage caused by *L. trifolii* in the local accessions was higher ranging from 50.00 – 80.00 and 25.00 – 42 50 per cent, the mean infestation index being 66.75 and 28.45 per cent in the reproductive and vegetative stages of the crop, respectively during summer season. The infestation index ranged from 22.50 – 47.50 and 10.00 – 42.50 per cent at the reproductive and vegetative stages, respectively during rainy season in the local accessions. The mean infestation indices during these stages were 35.95 and 14.85 per cent, respectively. Compared to the local accessions, an appreciably higher damage (55.00 per cent) was observed in the high yielding varieties in the reproductive stage during rainy season with a range of 47.50 – 62.50 per cent. At the vegetative phase, the mean infestation index was 15.00 per cent during the rainy season. During summer, the mean infestation index in the improved varieties ranged from 30.00 – 37.50 and 57.50 to 65.00 per cent in the vegetative and reproductive stages respectively, the mean infestation indices being 33.75 (vegetative stage) and 61.25 per cent (reproductive stage).

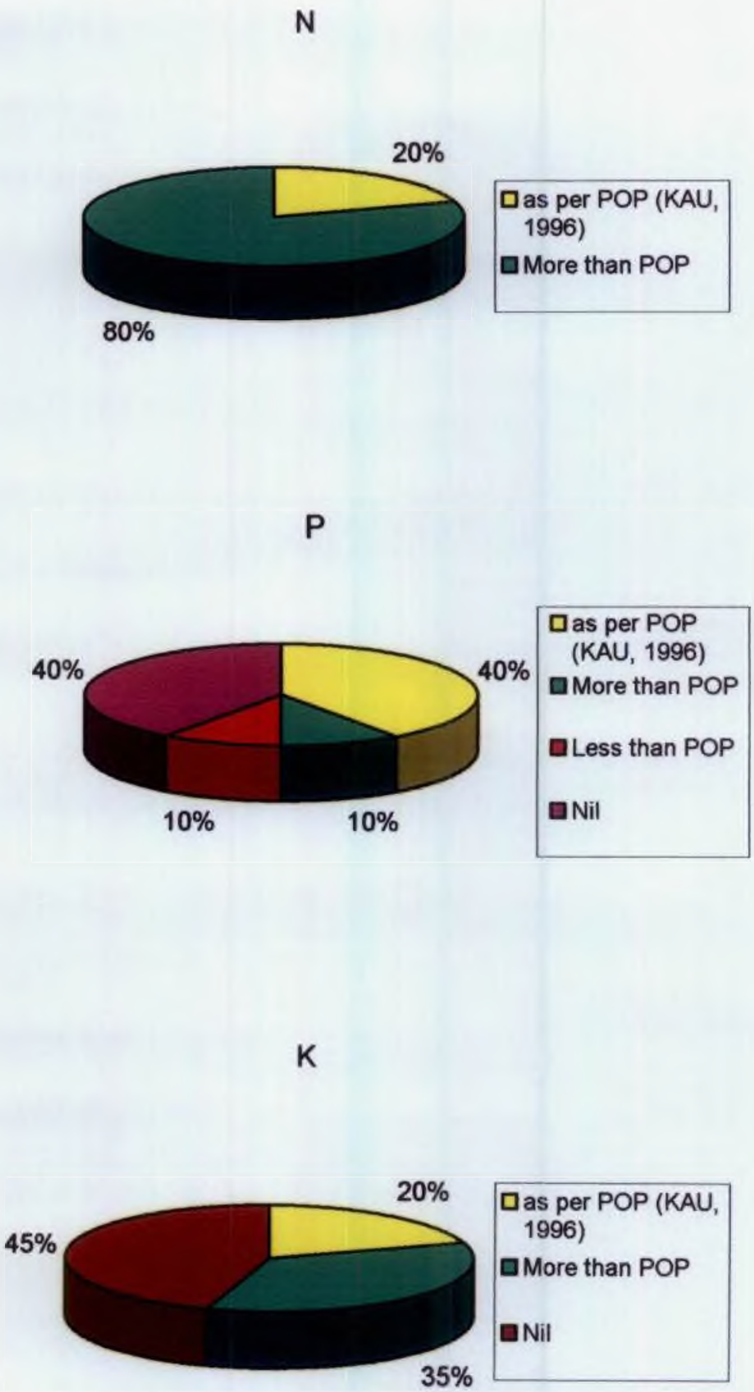


Fig. 1b. Extent of adoption of cultivation practices for raising cowpea in Kalliyoor panchayat - Fertilizer application

4.1.1.3 Dose of Fertilizers Applied

Among the farmers, only 20 per cent followed the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1996) in applying the primary nutrients (NPK). Eighty per cent applied higher doses of N. While 10 per cent applied higher doses of P, 40 per cent applied the same dose of P recommended in Package of Practices Recommendations of Kerala Agricultural University, 10 per cent applied lower dose and 40 per cent did not apply P at all. Forty five per cent of the farmers did not use K and 35 per cent used higher dose of K (Fig. 1b).

The extent of damage caused by *L. trifolii* was observed to be lower in plots where the nutrients were applied according to the Package of Practices Recommendations of Kerala Agricultural University. The mean infestation index in these plots were 53.75 per cent and 23.10 per cent in the reproductive phase, 25.00 per cent and 10.60 per cent in the vegetative phase during summer and rainy seasons, respectively. When N was applied at a higher dose, a higher intensity of infestation was seen in both seasons and phases of growth of the plant. While the mean infestation index ranged from 25.80 – 42.50 per cent and 12.50 – 32.50 per cent during the vegetative phase in summer and rainy seasons, respectively, it ranged from 64.60 – 77.50 and 33.75 – 60.00 per cent during the reproductive phase in summer and rainy seasons, respectively.

Maximum infestation was seen when N was applied alone without P and K, being 77.50 and 60.00 per cent in the reproductive phase during summer and rainy seasons, respectively and 42.50 and 32.50 per cent in the vegetative phase in the respective seasons. Apparently, P and K had little influence on the extent of infestation. The extent of infestation ranged from 22.50 – 42.50 per cent and 60.00 – 80.00 per cent at vegetative and reproductive phases, respectively during summer and 15.00 – 42.50 per cent and 30.00 – 62.50 per cent at the respective stages during rainy season when P was not applied. When P was applied, the range of infestation was 22.50 - 37.50 per cent and 50.00 – 75.00 per cent in the vegetative and reproductive phases during summer and 10.00 – 22.50 per cent and 15.00 – 57.50 per cent at the respective stages during rainy season.

Similarly, when K was given, the infestation index ranged from 50.00 – 70.00 per cent and 15.00 – 42.50 per cent at reproductive phase and 22.50 – 32.50 and 12.50 – 17.50 at vegetative phase during summer and rainy seasons, respectively. In the absence of K, the mean infestation index ranged from 75.00 – 80.00 per cent and 35.00 – 62.50 per cent at reproductive and 27.50 – 42.50 per cent and 10.00 – 42.50 per cent at vegetative phases during summer and rainy seasons, respectively.

4.1.1.4 Use of Insecticides

All the farmers used insecticides for controlling the leaf miner and other pests of cowpea. Six to eight rounds of spray were given by each of the farmers. Fifty per cent of the farmers used organophosphorus insecticides for controlling the pests while 25 per cent used synthetic pyrethroids and 25 per cent both organophosphates and synthetic pyrethroids (Fig. 1c).

Not much difference was observed in the damage caused by the pest when the different groups of pesticides were applied. The infestation index ranged from 57.50 – 80.00 per cent and 20.00 – 62.50 per cent in the reproductive phase during summer and rainy seasons, respectively. During the vegetative phase the infestation index ranged from 27.50 to 42.50 and 12.50 to 42.50 per cent in summer and rainy seasons, respectively, when organophosphates were sprayed. When synthetic pyrethroids were used the mean infestation index ranged from 50.00 – 67.50 per cent and 15.00 – 35.00 per cent in the reproductive phase

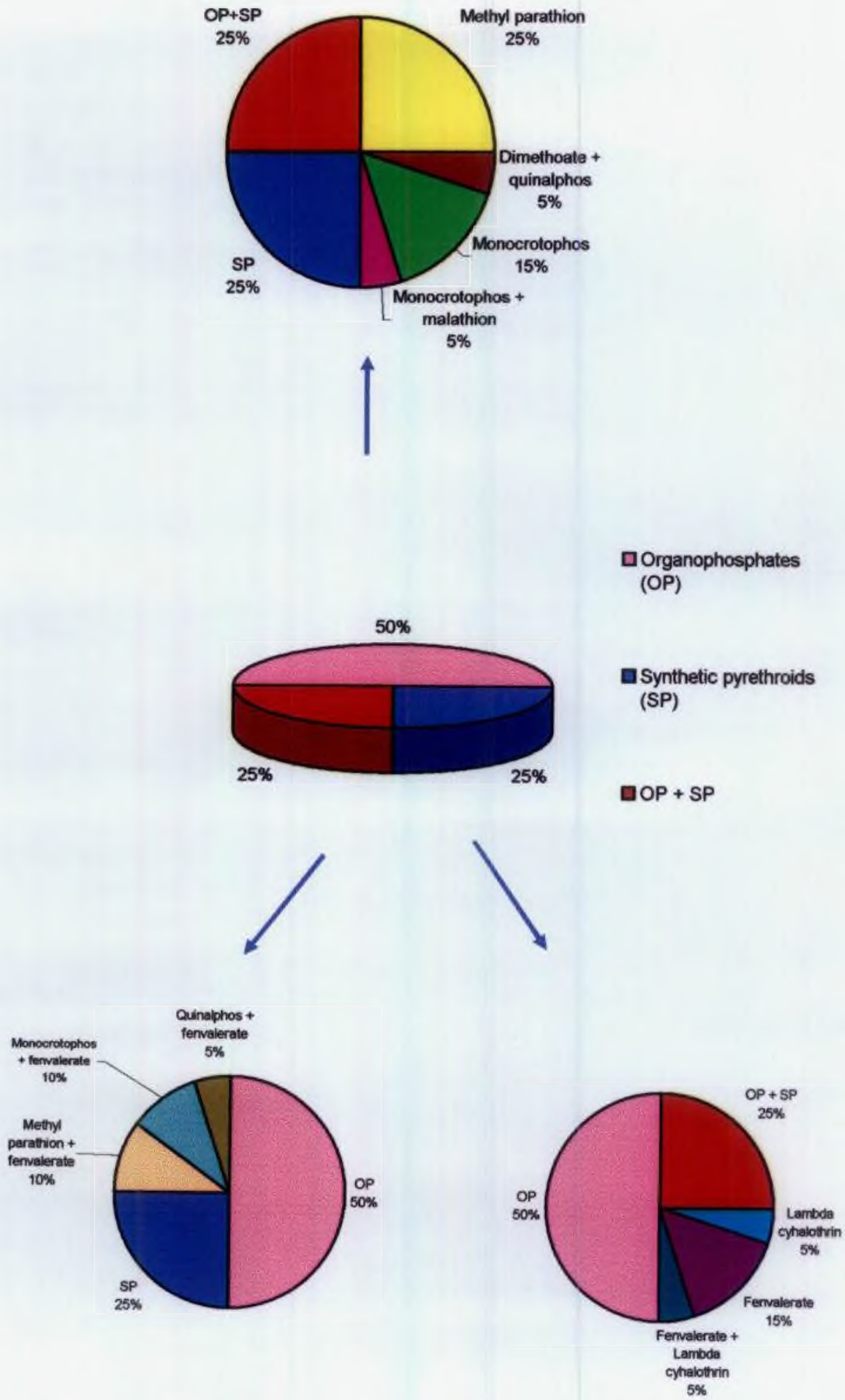


Fig. 1c. Insecticides used for the control of pests in Kalliyoor Panchayat

during summer and rainy seasons, respectively and from 22.50 – 32.50 per cent and 10.00 – 14.20 per cent in the vegetative phase during the two seasons. When both organophosphates and synthetic pyrethroids were used, the infestation index ranged from 57.50 – 75.00 per cent and 15.00 – 47.50 per cent in the reproductive phase and 25.00 to 37.50 per cent and 10.00 to 20.00 per cent in the vegetative phase during summer and rainy seasons, respectively.

Considering the individual insecticides applied by the farmers, higher damage was seen in plots sprayed with six rounds of monocrotophos either alone or with malathion or fenvalerate and the mean infestation ranged from 75.00 – 80.00 per cent and 15.00 – 62.50 per cent in the reproductive phase and 35.00 – 42.50 per cent and 17.50 – 42.50 per cent in the vegetative phase during summer and rainy seasons, respectively. The damage done by the pest was also high in the plots where methyl parathion (72.50 and 39.00 per cent in the reproductive phase and 32.50 and 16.00 per cent in the vegetative phases during the two seasons) and fenvalerate (65.80 and 26.70 per cent in the reproductive phase and 30.00 and 14.20 per cent in the vegetative phase during the two seasons) were applied. Compared to the above insecticides, a lower percentage of damage was seen in farmers fields where the synthetic pyrethroid lambda cyhalothrin (50.00 per cent and 15.00 per cent in reproductive and 22.50 per cent and 10.00 per cent in vegetative phases during the two seasons), lambda cyhalothrin + fenvalerate (50.00 per cent and 15.00 per cent at reproductive and 25.00 per cent and 10.00 per cent at vegetative phases during the two seasons), fenvalerate + quinalphos (57.50 per cent and 15.00 per cent in reproductive and 25.00 per cent and 10.00 per cent at vegetative phases during the two seasons), and dimethoate + quinalphos (57.50 per cent and 20.00 per cent in reproductive and 27.50 per cent and 12.50 per cent in vegetative phases during the two seasons) were applied.

4.1.1.5 Occurrence of L. trifolii Infested Weeds

Among the weeds commonly seen in cowpea plots, *Amaranthus viridis* L., *Heliotropium indicum* L., *Cleome viscosa* L., *Cleome monophylla* Mutohotoho, *Achyranthus aspera* L., *Physalis minima* L. and *Desmodium gyrans* L. were found to be infested by *L. trifolii* (Table 4 and Plate 6).

The frequency of occurrence of weeds susceptible to the leaf miner varied with the season and phase of growth of the crop (Table 5). During summer, 75.00 per cent of the plots had leaf miner infested weeds which increased to 80.00 per cent during the reproductive phase of the crop. In the rainy season, 50.00 per cent of the fields had leaf miner infested weeds in the vegetative phase which increased to 75.00 per cent during the reproductive phase of the crop.

The extent of damage on cowpea was more in fields with leaf miner infested weeds. While the mean infestation index was 33.76 per cent and 71.10 per cent during summer during vegetative and reproductive phases respectively in fields with leaf miner infested weeds, the mean infestation index was only 25.50 per cent and 53.75 per cent in the fields without leaf miner infested weeds. Similarly, during rainy season, the mean infestation index was 21.00 and 45.76 per cent at the vegetative and reproductive phases in the fields with leaf miner infested weeds and a lower infestation (12.50 and 20.00 per cent) in the fields with leaf miner infested weeds.

4.2 PARASITOIDS OF *L. trifolii*

The parasitoids of *L. trifolii* obtained during the survey are listed in Table 6.

All the parasitoids were obtained from the larvae of *L. trifolii* and belonged to the order Hymenoptera. They included *Chrysonotomyia rexia* Narendran, *Asecodes* sp., *Herbertia indica* Burks, *Agathidini* sp, *Closterocerus agromyzae* Narayan, Subba Rao and Ramachandra Rao,

Table 4. Weeds susceptible to *Liriomyza trifolii*

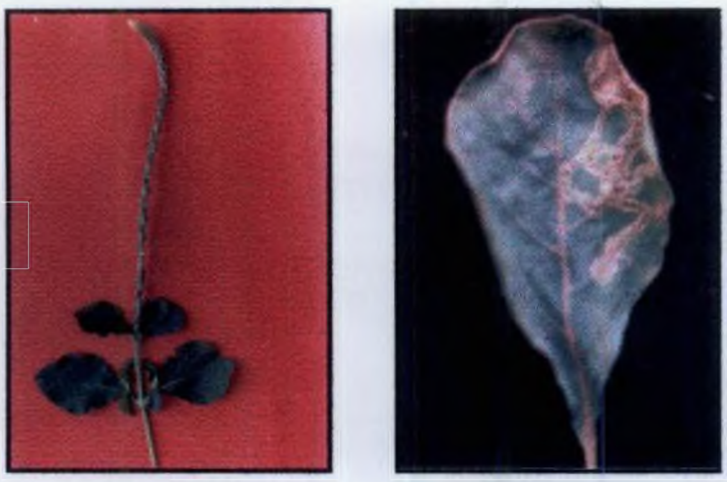
Scientific name	Common name	Family
Achyranthus aspera L.	Prickly chaff flower (Kadaladi *)	Acanthaceae
Amaranthus viridis L.	Slender amaranthus (Kuppacheera *)	Amaranthaceae
Cleome viscose L.	Sticky cleome (Kattukaduku *)	Capparadaceae
Cleome monophylla Mutohotoho	Wild cleome (Kattukaduku *)	Capparadaceae
Heliotropium indicum L.	Indian Heliotrope (Venpacha *)	Boraginaceae
Physalis minima L.	Sunberry (Njotta *)	Solanaceae
Desmodium gyrans L.	Indian Telegraph plant (Kala payar *)	Papilionaceae

* Malayalam name

Table 5. Occurrence of weeds susceptible to *Liriomyza trifolii* and their influence on the extent of damage caused by the pest to cowpea, %

Season	Stage of crop	Fields without *L. trifolii* infested weeds		Fields with *L. trifolii* infested weeds	
		Frequency	Mean infestation index	Frequency	Mean infestation index
Summer	Vegetative	25	25.50 (22.50 – 27.50)	75	33.76 (30.00 – 42.50)
	Reproductive	20	53.75 (50.00 – 57.50)	80	71.10 (60.00 – 42.50)
Rainy	Vegetative	50	12.50 (10.00 – 17.50)	50	21.00 (17.50 – 42.50)
	Reproductive	25	20.00 (15.00 – 27.50)	75	44.76 (32.50 – 62.50)

Figures in parentheses are ranges



(A) *Achyranthus aspera*

(B) Amaranthus viridis

(C) *Cleome monophylla*

Plate 6. Weeds infested by *Liriomyza trifolii*

(D) *Physalis minima*

(E) *Desmodium gyrans*

(F) Heliotropium indicum

Plate 6 (continued). Weeds infested by *Liriomyza trifolii*

Table 6. Larval Parasitoids of *Liriomyza trifolii* infesting cowpea recorded from Kalliyoor panchayat

Scientific name	Family
Chrysonotomyia rexia Narendran	Eulophidae
Asecodes sp.	Eulophidae
Herbertia indica Burks	Pteromalidae
Agathidini sp.	Braconidae
Closterocerus agromyzae Narayan, Subba Rao and Ramachandra Rao	Eulophidae
Entomacis sp.	Diapriidae
Hemiptarsenus brevipedicellus Shafee and Rizvi	Eulophidae

Entomacis sp. and *Hemiptarsenus brevipedicellus* Shafee and Rizvi (Plate 7). Of these the most commonly observed parasitoids were *C. rexia* and *Asecodes* sp. which constituted more than 80.00 per cent of the parasitoids collected.

4.3 VARIETAL PREFERENCE

The relative resistance / tolerance for different accessions of cowpea (trailing and bush type) to *L.trifolii* as indicated by the development of the pest on the plants are presented in Table 7.

4.3.1. Feeding / Oviposition Punctures

Significant difference was observed in the number of feeding / oviposition punctures made by *L. trifolii* on the leaves of different accessions of both trailing and bush type of cowpea. The lowest number of feeding / oviposition punctures (41.00 per plant) was seen in the trailing variety, Padavalapayar. Six trailing accessions *viz.*, VU-12 (44.67 per plant), Malika (96.33 per plant), VU-13 (106.00 per plant), VU-11 (110.33 per plant), VU-10 (114.33 per plant) and seven bush type of cowpea *viz.*, Bhagyalekshmi (62.67), Arka Garima (93.33 per plant), VU-2 (83.33 per plant), VU-3 (83.33 per plant), VU-4 (44.67 per plant), VU-5 (99.67 per plant) and VU-6 (83.33 per plant) were on par with Padavalapayar. The trailing accession Vyjayanthi with 184.33 feeding / oviposition punctures per plant was on par with the bush type of cowpea Subra (126.67 per plant) and VU-1 (224.67 per plant). Maximum puncture was seen on the trailing cowpea, VU-25 (390.00 per plant) and it was on par with high yielding variety Sharika (287.67 per plant) and it was on par with VU-27 (260.00 per plant), Kanakamony (188.33 per plant) and VU-1 (224.67 per plant).

Among the trailing cowpea, the least number of feeding/oviposition punctures was seen in Padavalapayar (41.00 per plant). This accession was on par with VU-12, Malika, VU-13, VU-11 and VU-10. The local, VU-25 had the highest number of

A. *Chrysonotomyia rexia*

B. *Asecodes* sp.

C. *Hemiptarsenus brevipedicellus*

D. *Agathidini* sp.

E. *Herbertia indica*

F. *Entomacis* sp.

G. *Closterocerus agromyzae*

Plate 7. Parasitoids of *Liriomyza trifolii* (X 100)

Table7.Differential preference of *Liriomyza trifolii* to accessions of cowpea

Accessions	No. of feeding punctures /plant	No. of larvae /plant	No. of pupae/ plant	No. of adult / plant	Biology, days		
					Egg period	Larval period	Pupal period
Trailing type							
VU25	390.00	42.67	42.67	40.67	2.67	5.00	8.67
Sharika	287.67	35.67	35.67	29.67	2.00	5.00	8.33
Malika	96.33	10.00	10.00	9.00	2.33	4.67	7.67
Vyjayanthi	184.33	25.33	25.33	22.33	2.00	4.67	8.00
VU 27	260.00	11.67	11.67	11.00	2.33	4.33	8.33
VU 13	106.00	10.33	10.33	10.00	2.00	4.00	8.00
VU 10	114.33	21.33	21.33	17.67	3.00	4.67	8.33
VU 11	110.33	15.00	15.00	12.67	2.33	4.30	8.00
VU 12	44.67	3.67	3.67	3.33	4.67	5.67	8.67
Padavalapayar	41.00	17.67	17.67	15.67	3.00	5.67	8.00
Mean value	163.47	19.33	19.33	17.20	2.63	4.80	8.20
Bush type							
Kanakamony	188.33	12.67	12.67	8.00	3.00	5.67	8.33
Subra	126.67	19.33	19.33	15.33	2.33	4.30	8.00
Bhagyalekshmi	62.67	10.33	10.33	8.67	2.67	4.67	9.00
Arka Garima	93.33	6.67	6.67	6.67	3.00	4.00	8.00
VU 1	224.67	28.33	28.33	23.33	3.00	4.30	8.67
VU 2	83.33	17.33	17.33	15.00	2.67	4.67	8.33
VU 3	83.33	11.33	11.33	6.67	2.00	5.00	8.33
VU 4	44.67	7.67	7.67	7.33	2.67	4.67	9.33
VU 5	99.67	14.67	14.67	13.33	2.33	4.30	8.33
VU 6	83.33	7.67	7.67	7.67	2.33	4.67	9.33
Mean value	109.00	13.60	13.60	11.20	2.60	4.63	8.53
CD (0.05) Treatment	113.86	17.12	17.12	12.52	0.74	0.86	8.33
CD (0.05) Trailing vs Bush	36.01	5.41	5.41	3.96	NS	NS	NS
CD (0.05) Trailing	80.51	12.10	12.10	8.85	0.52	0.61	NS
CD(0.05) Bush	80.51	NS	NS	NS	NS	0.61	0.67

NS- not significant

feeding/oviposition punctures and it was on par with Sharika. The variety Vyjayanthi was on par with VU-27 and Sharika.

The accessions VU-4 had the lowest number of feeding/oviposition punctures per plant (44.67), among the bush type of cowpea and the accessions was on par with VU-2, VU-3, VU-6, Arka Garima, VU-5 and Bhagyalekshmi. VU-1 had the maximum number of feeding/oviposition punctures and was on par with the high yielding dual purpose variety Kanakamony, which was on par with Subra.

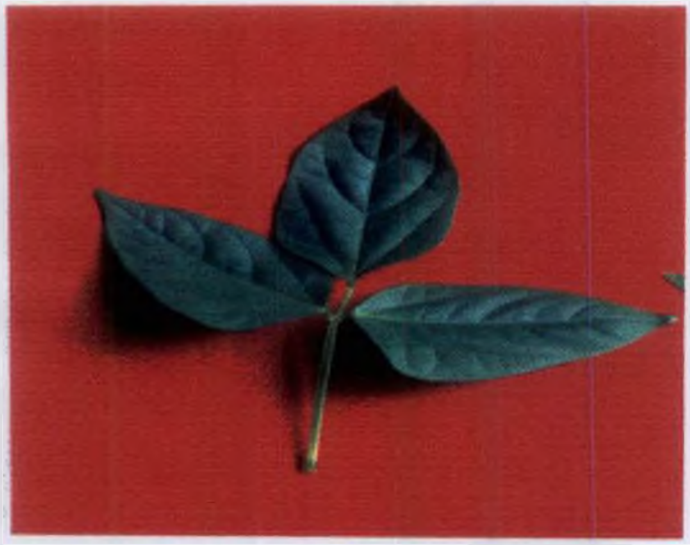
Between the trailing and bush type of cowpea, the trailing type of cowpea accessions were more susceptible to *L. trifolii* the mean number of feeding / oviposition punctures being 163.47 per plant. The bush type of cowpea had only 109.00 oviposition puncture per plant. The number of feeding / oviposition puncture per plant ranged from 41.00 – 390.00 per plant in trailing type of cowpea while it ranged from 44.67 – 224.67 in the bush type.

4.3.2. Number of Larvae per Plant

Though a large number of punctures are made on the leaves of a host plant, eggs are laid only in a few punctures. So the number of larvae developing on a variety can be taken as an indication of the preference of the pest for the variety.

Among the accessions screened, the least preferred was the trailing accession, VU-12 (Plate 8) with only 3.67 larvae per plant. It was on par with Malika (10.00 larvae per plant), VU-13 (10.30 per plant), VU-27 (11.67 larvae per plant), VU-11 (15.00 per plant), Padavalapayar (17.67 per plant) and VU-10 (21.33 per plant) among the trailing type of cowpea. With the exception of VU-1 having 28.33 larvae per plant, all other bush type of cowpea accessions were on par with VU-12; the number of larvae per plant in the accessions ranging from 6.67 – 19.33. Maximum number of larvae per plant was seen in VU-25 (42.67)

VU 25



VU 12

Plate 8. Susceptible and resistant cowpea accessions

and it was on par with Sharika (35.67) which was on par with Vyjayanthi (25.33), VU-10 and VU-1.

There was a significant difference in the number of larvae developing on the different accessions of trailing type of cowpea. The least preferred accession was VU-12 with 3.67 larvae per plant and it was on par with Malika, VU-27, VU-13, VU-11, Padavalapayar and VU-10. The most preferred accession was VU-25 which was on par with Sharika. Sharika was also on par with Vyjayanthi and VU-10.

No significant difference was observed in the number of larvae developing on different varieties of bush type of cowpea. The number of larvae per plant ranged from 6.67 – 28.33 in the different accessions.

Between the two types of cowpea screened, the trailing accessions with a mean number of 19.33 larvae per plant were significantly more susceptible to infestation by *L. trifolii* than the bush types (13.60 larvae per plant).

4.3.3 Number of Pupae per Plant

All the larvae observed in the accessions pupated and so the number of pupae obtained per plant was the same as the number of larvae per plant as explained in 4.3.2.

4.3.4 Adult Emergence

The number of adults emerging from each accession of cowpea (trailing and bush type) differed significantly. A trend similar to the development of larvae was noticed in the case of adult emergence also. Again, the emergence was least in VU-12 (3.33 adults per plant) and it was on par with Malika (9.00 adults per plant) VU-13 (10.00 adults per plant), VU-27 (11.00 adults per plant), VU-11 (12.67 adults per plant), Padavalapayar (15.67 adults per plant) and VU-10 (17.67 adults per plant) belonging to the category of trailing type of cowpea. Excepting VU-1 (23.33 adults per plant), all other accessions of bush type of cowpea *viz*., Kanakamony (8.00 adults per plant), Subra (15.33 adults per plant), Bhagyalekshmi (8.67 adults per plant), Arka Garima, (6.67 adults per plant), VU-2 (15.00 adults per plant), VU-32 (6.67 adults per plant), VU-4 (7.33 adults per plant, VU-5 (13.33 adults per plant) and VU-6 (7.67 adults per plant) were on par with VU-12, the number of adults emerging ranging from 6.67 – 15.33 per plant. VU-25 and Sharika were on par, registering the maximum number of adult emergence being 40.67 and 29.67 per plant respectively.

A significant variation was seen in the number of adults emerging from the different accessions of trailing type of cowpea. Adult emergence was least in VU-12 which was on par with Malika, VU-27, VU-10, VU-13, VU-11 and Padavalapayar. Higher number of adults emerged from VU-25 and Sharika followed by Vyjayanthi (22.33 adults per plant) and VU-10.

The different accessions of the bush type of cowpea did not show any significant difference among them in the number of adults emerging per plant.

Between the two types of cowpea screened, the trailing accessions with a mean of 17.20 adults per plant significantly differed from the bush accessions with a mean of 11.20 adults per plant.

4.3.5 Biology

4.3.5.1 Egg Period

The incubation period of *L. trifolii* was longest in VU-12 (4.67 days). Statistically, there was no significant difference in the incubation period in VU-25, Malika, VU-27, VU-10, VU-11, Padavalapayar, Kanakamony, Subra, Bhagyalekshmi, Arka Garima, VU-1, VU-2, VU-4, VU-5 and VU-6 with the egg period being completed in 2.33 – 3.00 days.

A significant difference was seen in the time taken for hatching of eggs when laid on different accessions of trailing type of cowpea. Maximum time was taken when eggs were laid on VU-12 followed by

Padavalapayar, VU-10 and VU-25. The egg period was completed in a short period of 2.33 days in Malika, VU-27 and VU-11.

No significant difference was noticed in the incubation period in the different varieties of bush type of cowpea. Similarly, between the two types of cowpea *viz.*, trailing and bush type, there was no significant difference.

4.3.5.2 Larval Period

The time taken to complete the larval stage of *L. trifolii* varied significantly in the different accessions. The longest larval period of 5.67 days was observed in VU-12, Padavalapayar and Kanakamony closely followed by the VU-25, Sharika and VU-3 with larval period of 5.00 days. The shortest period of 4.00 days was seen in VU-13, which was on par with Malika (4.67 days), Vyjayanthi (4.67 days), VU-27 (4.33 days), VU-10 (4.67 days), VU-11 (4.30 days), Subra (4.30 days), Bhagyalekshmi (4.67 days), Arka Garima (4.00 days), VU-1 (4.30 days), VU-2 (4.67 days), VU-4 (4.67 days), VU-5 (4.30 days) and VU-6 (4.67 days) where the larval period was completed in 4.33 – 4.67 days.

Among the trailing accessions, there was a significant difference in the larval period. VU-12 and Padavalapayar with the longest larval period were on par. VU-25 and Sharika with 5.00 days and Malika, Vyjayanthi and VU-10 with 4.67 days were on par.

Among the bush type of cowpea accessions, the miner took the longest period of 5.67 days to complete its larval period in Kanakamony and was on par with VU-3, while Bhagyalekshmi, VU-2, VU-4, and VU-6 took 4.67 days. The larval period was completed in 4.33 days in Subra, VU-1 and VU-5 The least period of 4.00 days was seen in Arka Garima.

Between the trailing and bush type of cowpea, there was no significant difference in the larval period.

4.3.5.3 Pupal Period

No significant difference was observed in the pupal period among the 20 accessions screened, the stage being completed in 7.67 to 9.33 days. Among the trailing accessions, there was no significant difference in the pupal period (7.67 – 8.67 days). However, statistically the bush type of cowpea accessions differed significantly. Maximum period was seen in VU-4 and VU-6 (9.33 days) and it was on par with Bhagyalekshmi (9.00 days). These accessions were followed by Kanakamony, VU-2, VU-3 and VU-5 with 8.33 days. The least period was seen in Arka Garima (8.00 days).

4.4 EFFECT OF PLANT OILS AND NEWER SYNTHETIC INSECTICIDES

4.4.1 Laboratory Screening

4.4.1.1 Application of Plant oils and Insecticides Before Infestation

Significant difference was noticed in the percentage of adults killed, number of feeding / oviposition punctures and larvae and percentage of pupae and adult emerging when plant oils and synthetic insecticides were sprayed on cowpea plants and the results are presented in Table 8.

4.4.1.1.1 Adult Mortality

Among the plant oils tested, neem oil 2.5 per cent resulted in maximum mortality of adults of *L. trifolii* (72.31 per cent) when observed 12 hours after spraying. It was closely followed by marotti oil 5 per cent (68.19 per cent) and illupai oil 2.5 per cent (56.53 per cent). All the above treatments were on par. Excepting custard apple seed oil, no significant difference was observed between the lower and higher doses of oils tested. Castor oil 2.5 per cent, marotti oil 2.5 per cent and illupai oil 5 per cent resulted in only less than 50.00 per cent mortality, the mortality ranging from 44.34 per cent to 47.63 per cent. The mortality of adults was least in custard apple seed oil at 2.5 per cent and 5 per cent with 5.36 and 22.99 per cent mortality respectively. Twenty

Table 8. Effect of prophylactic application of plant oils and synthetic insecticides on infestation of *Liriomyza trifolii* in cowpea

Treatments	Adult mortality		Reduction over control			
	12 h	24 h	Feeding/ oviposition punctures	No. of larvae	Percentage of pupa emerging	Percentage of adult emerging
Plant oils						
Custard apple oil 2.5%	5.36 (13.39)	41.95 (40.35)	21.82	4.08	0.00 (0.00)	0.00 (0.00)
Custard apple oil 5 %	22.99 (28.64)	51.69 (45.95)	42.58	20.27	9.34 (7.79)	12.57 (20.76)
Castor oil 2.5 %	44.34 (41.73)	58.02 (49.59)	63.48	74.64	9.34 (7.79)	12.57 (20.76)
Castor oil 5 %	51.84 (46.03)	73.62 (59.07)	80.27	76.79	18.27 (25.29)	15.96 (23.54)
Marotti oil 2.5 %	48.13 (43.91)	85.34 (67.46)	89.73	82.80	29.25 (32.73)	31.12 (33.89)
Marotti oil 5 %	68.19 (55.64)	89.61 (71.16)	93.92	89.19	36.16 (36.95)	37.15 (37.54)
Illupai oil 2.5 %	56.53 (48.73)	89.61 (71.16)	91.29	91.68	38.77 (38.49)	30.10 (3.26)
Illupai oil 5 %	47.63 (43.62)	79.76 (63.23)	91.63	91.53	48.60 (44.18)	36.21 (36.98)
Neem oil 2.5 %	72.31 (58.23)	100.00 (90.00)	100.00	100.00	100.00 (90.00)	100.00 (90.00)
Synthetic insecticides						
Imidacloprid, 0.005%	47.32 (43.45)	85.34 (67.46)	74.25	88.23	0.00 (0.00)	11.76 (20.05)
Imidacloprid, 0.01 %	61.25 (51.48)	81.63 (64.59)	82.57	93.52	0.00 (0.00)	20.80 (27.12)
Profenophos 0.025 %	56.34 (48.62)	67.72 (55.35)	82.00	57.18	6.00 (14.18)	8.14 (16.57)
Profenophos 0.05 %	72.31 (58.23)	85.34 (67.40)	89.19	87.53	25.53 (30.34)	15.58 (23.24)
Thiamethoxam 0.02%	63.85 (53.02)	98.06 (81.95)	86.63	87.67	46.76 (43.13)	55.54 (48.16)
Thiamethoxam 0.04%	73.70 (9.13)	98.35 (82.55)	91.73	94.08	79.66 (63.17)	95.75 (78.07)
Abamectin 0.003%	73.71 (59.13)	100.00 (90.00)	95.80	100.00	100.00 (90.00)	100.00 (90.00)
Abamectin 0.006 %	84.51 (66.79)	100.00 (90.00)	100.00	100.00	100.00 (90.00)	100.00 (90.00)
Dimethoate 0.05%	32.08 (34.46)	61.70 (51.75)	86.44	86.04	28.71 (32.38)	70.00 (56.77)
CD (0.05) (treatments)	(12.18)	(25.62)	(9.43)	(7.74)	(9.73)	(9.91)
CD (oils vs insecticides)(0.05)	(4.06)	(8.54)	(3.14)	(2.58)	(6.88)	(7.01)
CD within oils (0.05)	(8.61)	(18.12)	(6.67)	(5.48)	(6.88)	(7.01)
CD within insecticides(0.05)	(8.61)	(18.12)	(6.67)	(5.48)	(6.88)	(7.01)

Figures in parentheses are angular transformed values.

four hours after treatment castor oil 5 per cent (73.62 per cent) marotti oil 2.5 per cent (85.34 per cent) and 5 per cent (89.61 per cent), illuppai oil 2.5 per cent (89.61 per cent)) and 5 per cent (79.76 per cent) and neem oil 2.5 per cent (100.00 per cent) resulted in high mortality of adults. Neem oil 2.5 per cent with 100.00 per cent mortality was the best treatment followed by marotti oil and illupai oil, with the mortality percentage ranging from 83.34 to 89.61 and were on par. Castor oil 2.5 per cent (58.02 per cent), custard apple seed oil 5 per cent (51.69 per cent) and 2.5 per cent (41.95 per cent) were comparatively less effective. Between the two doses of plant oils there was no significant difference in the mortality of adults.

Twelve hours after application of the insecticides, more than 70.00 per cent mortality of the adults was seen in abamectin 0.006 per cent (84.51 per cent), abamectin 0.003 per cent (73.71 per cent), thiamethoxam 0.04 per cent (73.70 per cent) and profenophos 0.05 per cent (72.31 per cent) and the treatments were on par. Imidacloprid 0.01 per cent and profenophos 0.025 per cent with 61.25 per cent and 56.34 per cent mortality respectively were statistically on par with the above treatments with the exception of abamectin 0.006 per cent. Dimethoate 0.05 per cent (32.08 per cent) and imidacloprid 0.005 per cent (47.32 per cent) did not result in any appreciable mortality of the adults. There was no significant difference between the lower and higher doses of the different synthetic insecticides. Twenty four hours after spraying, with the exception of the profenophos 0.025 per cent and dimethoate 0.005 per cent with 67.72 and 61.70 per cent mortality respectively, all other treatments killed more than 80.00 per cent of the adults released, the percentage mortality being 100 00 per cent in abamectin 0.003 per cent and 0.006 per cent, 98.35 per cent in thiamethoxam 0.04 per cent, 98.06 per cent in thiamethoxam 0.02 per cent, 85.34 per cent in imidacloprid 0.005 per cent and profenophos 0.05 per cent and 81.63 per cent in imidacloprid 0.01 per cent.

Considering the botanicals and synthetic pesticides together, the two doses of marotti oil, illupai oil 2.5 per cent neem oil 2.5 per cent and all the synthetic pesticides at two doses excepting the lower dose of profenophos (0.025 per cent) and dimethoate gave significantly good kill of the pest, the mortality percentage ranging from 81.63 to 100.00 per cent. Custard apple seed oil was least effective (41.95 – 51.69 per cent).

4.4.1.1.2 Feeding / Oviposition Punctures

Only few feeding / oviposition punctures were seen on the leaves of cowpea plants sprayed with neem oil 2.5 per cent, marotti oil 5 per cent and illupai oil at two doses and the treatments were on par. While the maximum reduction of 100.00 per cent was seen in neem oil, the percentage reduction was 93.92 per cent, 91.29 and 91.63 in marotti oil 5 per cent, illupai oil 2.5 per cent and illupai oil 5 per cent, respectively. This was closely followed by marotti oil 2.5 per cent (89.73 per cent) and castor oil 5 per cent (80.27 per cent). Higher number of punctures was seen in both the doses of custard apple seed oil, the percentage reduction when compared to control being 21.82 and 42.58 per cent in 2.5 per cent and 5 per cent respectively. Significant difference in the reduction in punctures was seen between two doses of castor oil, being 80.27 per cent at higher dose and 63.48 per cent at lower dose. Generally, the number of feeding / oviposition punctures in the insecticide treatment was low, the percentage reduction ranging from 100.00 to 74.25 per cent.

Among the chemical treatments, maximum reduction was seen in abamectin 0.006 per cent (100.00 per cent) which was on par with abamectin 0.003 per cent (95.80 per cent) and thiamethoxam 0.04 per cent (91.73 per cent). Both these treatments were on par with profenophos 0.05 per cent (89.19 per cent) thiamethoxam 0.02 per cent (86.63 per cent) and dimethoate 0.05 per cent (86.44 per cent). Comparatively lower reduction in the feeding / oviposition puncture was seen in the lower doses of imidacloprid (74.25 per cent), profenophos (82 per cent) and dimethoate (86.44 per cent).

When the botanicals and chemical pesticides were considered together two doses of marotti oil, illupai oil and abamectin, neem oil 2.5 per cent and thiamethoxam 0.04 per cent were on par in their effect.

4.4.1.1.3 Number of Larvae

No larvae developed in plants treated with neem oil 2.5 per cent. Similarly, a significant per cent reduction in the number of larvae was observed in plants treated with the higher (91.53 per cent) and lower (91.68 per cent) doses of illupai oil and marotti oil 5 per cent (89.19 per cent) closely followed by marotti oil 2.5 per cent (82.8 per cent). A fairly appreciable reduction in the emergence of larvae was observed in castor oil 5 per cent (76.79 per cent) and castor oil 2.5 per cent (74.64 per cent). Custard apple seed oil with only 20.27 per cent and 4.08 per cent reduction in number of larvae at 5 and 2.5 per cent respectively was ineffective.

Among the insecticides, abamectin 0.006 per cent (100.00 per cent) and 0.003 per cent (100.00 per cent) resulted in a remarkable reduction in number of larvae being 99.21 and 98.35 per cent respectively and was on par with thiamethoxam 0.04 per cent (94.08 per cent). Imidacloprid 0.01 per cent which gave 93.52 per cent reduction in number of larvae was on par with thiamethoxam 0.04 per cent and abamectin 0.003 per cent. Both the doses of imidacloprid were statistically on par in reducing the number of larvae being 93.52 per cent and 88.23 per cent respectively in 0.01 per cent and 0.005 per cent. Thiamethoxam 0.02 per cent, profenophos 0.05 per cent and dimethoate 0.05 per cent with 87.67 per cent and 87.53 per cent and 86.04 per cent reduction in number of larvae, respectively were on par. With the exception of profenophos 0.025 per cent (57.18 per cent), all the insecticides resulted in more than 80.00 per cent reduction in the number of larvae.

Considering the botanicals and insecticides, neem oil 2.5 per cent was on par with abamectin 0.006 per cent and 0.003 per cent, thiamethoxam 0.04 per cent and imidacloprid 0.01 per cent in reducing the number of larvae. More than 80.00 per cent reduction in the number of larvae was observed in marotti oil, illupai oil, imidacloprid 0.005 per cent, profenophos 0.05 per cent and thiamethoxam 0.02 per cent. Among the pesticides the least effective was custard apple seed oil.

4.4.1.1.4 Percentage of pupa emerging

Consequent to the total suppression in larval development no pupae was observed in neem oil 2.5 per cent. Only 48.60 per cent reduction in pupation was observed in illupai oil 5 per cent. It was closely followed by illupai oil 2.5 per cent (38.77 per cent reduction) and marotti oil 5 per cent (36.16 per cent). Spraying of custard apple seed oil did not affect the formation of pupae as only 0 - 9.34 per cent reduction was seen in the emergence of pupae was seen in the treatment. While the percentage reduction pupal formation was 9.34 per cent in castor oil 2.5 per cent, it was 18.27 per cent in castor oil 5 per cent, 38.77 per cent in marotti oil 2.5 per cent.

No pupae were developed in the plants treated with abamectin. The percentage reduction in pupation was 79.66 per cent in thiamethoxam 0.04 per cent. Similarly, 46.76 per cent reduction in pupation was observed in thiamethoxam 0.02 per cent treated plants. The per cent reduction in pupal formation was low in all the other insecticide treatments, being zero per cent in imidacloprid, 6.00 per cent in profenophos 0.025 per cent, 25.53 per cent profenophos 0.05 per cent and 28.71 per cent dimethoate 0.05 per cent.

While abamectin (both doses) and neem oil 2.5 per cent were on par in preventing the formation of pupae of *L. trifolii*, custard apple seed oil (both doses), castor oil 2.5 per cent, imidacloprid (both doses) and profenophos 0.025 per cent did adversely affect the formation of pupae.

in all other oils was low and the percentage reduction in pupal formation ranging from 0 – 22.22 per cent.

Abamectin and thiamethoxam showed equally significant inhibition of formation of pupae, the percentage ranging from 90.17 – 93.24 per cent. Spraying of dimethoate also gave good reduction of pupae (82.42 per cent). The higher dose of profenophos resulted in 71.65 per cent reduction in pupal emergence. The lower dose of profenophos and thiamethoxam gave only 57.86 per cent and 52.37 per cent reduction in pupal emergence. Reduction in pupal formation was significantly low in imidacloprid (7.67 and 4.12 per cent).

4.4.1.2.3. Adult Emergence

Since neem oil 2.5 per cent resulted in 100.00 per cent mortality of the larvae, no adults were observed in the treatment. A reduction of 51.72 per cent and 34.68 per cent was observed in the number of adults emerging in the plants treated with illupai oil at 5 and 2.5 per cent respectively. No significant difference was observed between the two doses of marotti oil. The percentage reduction in adult emergence was negligible in castor oil and custard apple seed oil treatments.

No adults emerged in abamectin and thiamethoxan 0.04 per cent treated plants and the treatments were significantly superior to all the other treatments. A significant reduction in the adult emergence was also seen in dimethoate (3.71 per cent). The percentage reduction in adult emergence was comparatively low in all the other treatments ranging from 4.21 to 19.78 per cent.

Between the plant oils and synthetic insecticides, neem oil 2.5 per cent was equally good as the two doses of abamectin and thiamethoxam 0.04 per cent in reducing adult emergence. Similarly, illupai oil 5 per cent was on par with dimethoate in its effect closely followed by the lower dose. All other plant oils and insecticides did not show any remarkable effect on adult emergence.

4.4.1.2 Plant oils and Synthetic Insecticides Applied After Infestation

A significant difference was noted in larval and pupal mortality and adult emergence when plant oils and insecticides were applied on live larvae and the results are presented in Table 9.

4.4.1.2.1 Larval Mortality

Excepting neem oil 2.5 per cent which resulted in 48.00 per cent and 93.93 per cent mortality of larvae when observed 24 and 48 hours after spraying, none of the other plant oils caused any larval mortality.

The chemical insecticides killed the larvae of *L. trifolii* to varying extent when sprayed on plants infested by the pest. When observed 24 hours after treatment, abamectin 0.006 per cent resulted in maximum kill of the larvae (89.99 per cent) followed by thiamethoxam 0.04 per cent (78.92 per cent) and dimethoate (72.69 per cent) which were on par. Abamectin 0.003 per cent resulted in 69.21 per cent larval mortality and was on par with dimethoate. Larval mortality was significantly low in both doses of imidacloprid being 5.40 per cent and 6.10 per cent in 0.01 per cent and 0.005 per cent respectively. After 48 hours of spraying both doses of abamectin resulted in more than 90 per cent mortality of the larvae (96.89 per cent at 0.006 per cent and 90.20 per cent at 0.003 per cent) and was on par with thiamethoxam 0.04 per cent (88.81 per cent) (Plate 9). Dimethoate gave 82.39 per cent mortality of the larvae, while thiamethoxam 0.02 per cent and the higher dose of profenophos gave 76.49 per cent and 71.64 per cent mortality respectively and the lower dose of profenophos resulted in only 55.92 per cent mortality. Imidacloprid was ineffective giving only 7.64 and 10.30 per cent mortality of the larvae.

4.4.1.2.2 Percentage of pupa emerging

Consequent to the high larval mortality in neem oil 2.5 per cent treated plants no pupae were seen in this treatment. The pupal mortality

Table 9. Effect of applying plant oils and synthetic insecticides on cowpea infested with *Liriomyza trifolii*, %

Treatment	Larval mortality		Reduction over control in percentage of emerging	
	24 h	48 h	Pupa	Adults
Plant oils				
Custard apple oil 2.5 %	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Custard apple oil 5 %	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	3.80 (11.31)
Castor oil 2.5 %	0.00 (0.00)	0.00 (0.00)	10.42 (18.83)	1.87 (7.87)
Castor oil 5 %	0.00 (0.00)	0.00 (0.00)	13.21 (21.31)	0.06 (1.44)
Marotti oil 2.5 %	0.00 (0.00)	0.00 (0.00)	22.20 (28.10)	23.50 (29.03)
Marotti oil 5 %	0.00 (0.00)	0.00 (0.00)	12.13 (20.37)	23.43 (28.95)
Illupai oil 2.5 %	0.00 (0.00)	0.00 (0.00)	15.86 (23.46)	34.68 (36.08)
Illupai oil 5 %	0.00 (0.00)	0.00 (0.00)	16.35 (23.84)	51.72 (45.99)
Neem oil 2.5 %	48.00 (43.85)	93.93 (75.74)	99.98 (89.18)	100.00 (90.00)
Synthetic insecticides				
Imidacloprid 0.005 %	6.10 (14.30)	7.64 (16.04)	7.67 (16.07)	4.21 (11.84)
Imidacloprid 0.01 %	5.40 (13.40)	10.30 (18.72)	4.12 (11.71)	5.45 (13.50)
Profenophos 0.025 %	45.99 (42.68)	55.92 (48.5)	57.86 (49.50)	8.17 (16.61)
Profenophos 0.05 %	62.95 (52.46)	71.64 (57.8)	71.65 (57.81)	12.62 (20.81)
Thiamethoxam 0.02 %	63.34 (52.71)	76.49 (66.79)	52.37 (46.34)	19.78 (26.41)
Thiamethoxam 0.04 %	78.92 (62.64)	88.81 (70.43)	90.17 (71.70)	100.00 (90.00)
Abamectin 0.003 %	69.21 (56.27)	90.20 (71.72)	92.13 (73.66)	100.00 (90.00)
Abamectin 0.006 %	89.99 (71.52)	96.89 (79.81)	93.24 (74.89)	100.00 (90.00)
Dimethoate 0.05 %	72.69 (58.47)	82.39 (69.16)	82.42 (65.19)	3.71 (52.96)
CD (0.05) treatments	(7.85)	(10.20)	(7.06)	(13.79)
CD (0.05) oils vs insecticides	-	-	(2.35)	(4.86)
CD (0.05) within oils	-	-	(4.99)	(10.30)
CD (0.05) within insecticides	-	-	(4.99)	(10.30)

Figures in parentheses are angular transformed values.

in all other oils was low and the percentage reduction in pupal formation ranging from 0 – 22.22 per cent.

Abamectin and thiamethoxam showed equally significant inhibition of formation of pupae, the percentage ranging from 90.17 – 93.24 per cent. Spraying of dimethoate also gave good reduction of pupae (82.42 per cent). The higher dose of profenophos resulted in 71.65 per cent reduction in pupal emergence. The lower dose of profenophos and thiamethoxam gave only 57.86 per cent and 52.37 per cent reduction in pupal emergence. Reduction in pupal formation was significantly low in imidacloprid (7.67 and 4.12 per cent).

4.4.1.2.3. Adult Emergence

Since neem oil 2.5 per cent resulted in 100.00 per cent mortality of the larvae, no adults were observed in the treatment. A reduction of 51.72 per cent and 34.68 per cent was observed in the number of adults emerging in the plants treated with illupai oil at 5 and 2.5 per cent respectively. No significant difference was observed between the two doses of marotti oil. The percentage reduction in adult emergence was negligible in castor oil and custard apple seed oil treatments.

No adults emerged in abamectin and thiamethoxan 0.04 per cent treated plants and the treatments were significantly superior to all the other treatments. A significant reduction in the adult emergence was also seen in dimethoate (63.71 per cent). The percentage reduction in adult emergence was comparatively low in all the other treatments ranging from 4.21 to 19.78 per cent.

Between the plant oils and synthetic insecticides, neem oil 2.5 per cent was equally good as the two doses of abamectin and thiamethoxam 0.04 per cent in reducing adult emergence. Similarly, illupai oil 5 per cent was on par with dimethoate in its effect closely followed by the lower dose. All other plant oils and insecticides did not show any remarkable effect on adult emergence.

4.5 FIELD TRIAL

4.5.1 Percentage of Infested Leaves

The percentage of infested leaves seen one week after each spray is presented in the Table 10.

A significant difference was observed in the percentage of leaves damaged by *L. trifolii* when observed one week after the first spray. All the treatments were significantly superior to control having 68.84 per cent infested leaves. Maximum reduction in the number of infested leaves was observed in plots treated with abamectin (35.87 per cent) which was significantly superior to other treatments (Plate 10). Neem oil with 40.76 per cent infested leaves was on par with illupai oil (43.16 per cent) which was on par with thiamethoxam (44.44 per cent). A higher incidence of *L. trifolii* was seen in plots treated with dimethoate as evidenced by the per cent of leaves infested (52.48 per cent) and it was on par with profenophos (49.93 per cent). In plots treated with marotti oil, the percentage of infested leaves was 48.14 per cent.

Compared to control (66.5 per cent) all the treatments reduced the damage of *L. trifolii* significantly when observed a week after the second spray. A lesser infestation was noted in abamectin treated plots, the per cent of infested leaves being 22.90. The treatment was on par with illupai oil (27.83 per cent) and thiamethoxam (29.28 per cent). Neem oil with 33.05 per cent infested leaves was on par with marotti oil (37.25 per cent). Again higher infestation was seen in dimethoate treated plots (42.83 per cent) and the treatment was on par with profenophos (41.45 per cent).

Observations recorded a week after the third spray indicated that all the treatments were significantly superior to control (66.33 per cent). Lower infestation was observed in abamectin treated plots with 24.38 per cent infested leaves which was significantly different from all other treatments. It was followed by illupai oil (30.00 per cent), thiamethoxam (30.98 per cent) and neem oil (33.50 per cent). Neem oil was also on par

.Table 10. Effect of plant oils and synthetic insecticides on the incidence of *Liriomyza trifolii* in cowpea, %

Treatment	Damaged leaves per plant observed at different intervals (weeks) after sowing				
	5	6	7	8	9
Thiamethoxam 0.02 %	44.44	29.28	30.98	25.08	30.58
Abamectin 0.003 %	35.87	22.90	24.38	19.88	27.50
Profenophos 0.025 %	49.93	41.45	42.38	34.83	39.78
Marotti oil 2.5 %	48.14	37.25	36.63	31.93	40.93
Illupai oil 2.5 %	43.16	27.83	30.00	26.00	35.60
Neem oil 2.5 %	40.76	33.05	33.50	26.25	36.43
Dimethoate 0.05 %	52.48	42.83	42.68	39.30	49.00
Control (untreated)	68.84	66.50	66.33	68.95	77.75
CD (0.05)	3.40	6.80	5.46	5.93	6.29

Note : Plant oil and insecticides were sprayed at weekly intervals commencing from the 4th week after sowing

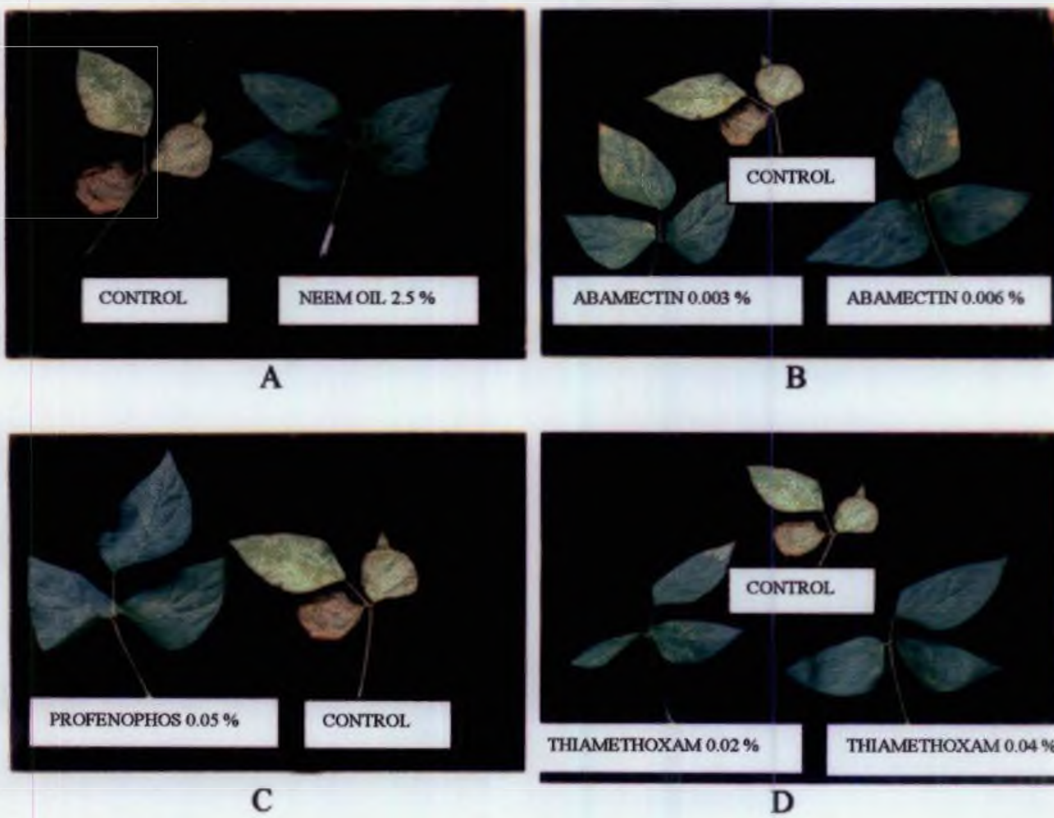


Plate 9. Damage of *Liriomyza trifolii* in neem oil and insecticide treatments

(A) Plants treated with abamectin 0.003 %

(B) Untreated plants

Plate 10. Effect of applying abamectin in the field

with marotti oil (36.63 per cent). Dimethoate with nore infestation (42.68 per cent) was on par with profenophos (42.38 per cent). A similar trend was seen after the fourth spray too, the lowest percentage of infested leaves was observed in abamectin treated plots (19.88 per cent) and the treatment was on par with thiamethoxam (25.08 per cent). Thiamethoxam was also on par with illupai oil (26.00 per cent) and neem oil (26.25 per cent) which was on par with marotti oil also. Though a significantly lower number of infested leaves was seen in dimethoate (39.30 per cent) when compared to control (68.95 per cent), it was inferior to other treatments. Profenophos (34.83 per cent) was on par with dimethoate.

When observed two weeks after the fourth spray abamectin was the most effective treatment (27.50 per cent) which was on par with thiamethoxam (30.58 per cent). Illupai oil (35.60) which was on par with neem oil (36.43 per cent), marotti oil (40.93 per cent) and profenophos (39.78 per cent). Dimethoate (49.00 per cent) though superior to untreated control (77.75 per cent) was inferior to the other treatments.

4.5.2 Average Number of Mines per Leaf

The effect of plant oils and synthetic insecticides on the incidence of *L. trifolii* is presented in Table 11. Considering the rumber of mines, seen on the leaves one week after the first spray, plants treated with abamectin (3.88 mines per leaf) and thiamethoxam (4.46 mines per leaf) differ significantly from other treatments. With the exception of profenophos (7.50 mines per leaf) all other treatments *viz*., marotti oil (6.29 mines per leaf), illupai oil (6.34 mines per leaf), neem oil (6.51 mines per leaf) and dimethoate (6.77 mines per leaf) were on par with control (5.97 mines per leaf).

After the second spray too, abamectin had the least number of mines per leaf (4.29 mines per leaf) and was on par with thiamethoxam

(5.10 mines per leaf) and illupai oil (5.29 mines per leaf). Thiamethoxam and illupai oil were on par with neem oil (5.98 mines per leaf) was on par with marotti oil, and untreated control (6.68 mines per leaf). Dimethoate had the highest number of active mines per leaf bearing 9.33 per leaf was on par with profenophos (8.26 mines per leaf). Except in illupai oil and neem oil, there was an increase in the number of mines per leaf during sixth week compared to the fifth week after sowing.

After the second spray, again abamectin had the least number of mines per leaf (3.53 mines per leaf) and was on par with thiamethoxam (4.50 mines per leaf). Neem oil (5.30 mines per leaf) and illupai oil (5.40 mines per leaf) were on par with thiamethoxam (4.50 mines per leaf) and marotti oil (6.18 mines per leaf). Profenophos (7.63 mines per leaf) and marotti oil (6.18 mines per leaf) were on par with control (7.08). Dimethoate had the highest number of mines per leaf (8.83) which was on par with profenophos (7.63).

One week after the third spray, the number of mines per leaf was equally low in abamectin (2.58 mines per leaf) and thiamethoxam (3.65 mines per leaf). Again illupai oil (4.75 mines per leaf) and neem oil (4.20 mines per leaf) were on par with thiamethoxam and marotti oil (5.35 mines per leaf). Dimethoate had the maximum number of mines per leaf (7.85 mines per leaf) followed by profenophos (6.45 mines per leaf).

A similar trend was seen after the fourth spray also. Least number of mines / leaf was in abamectin treated plots (3.18 mines per leaf) which was on par with thiamethoxam (4.90 mines per leaf), followed by neem oil (5.63 mines per leaf) which was on par with illupai oil (5.95 mines per leaf) and marotti oil (6.30 mines per leaf). Illupai oil and marotti oil were also on par witn profenophos (7.10 mines per leaf). The intensity of mines in dimethoate was high, the number of mines per leaf being 8.90 mines per leaf which was on par with untreated check having 8.35 mines per leaf.

4.5.3 Yield

The effect of different treatments on yield are presented in Table 11.

The number of pods per plot obtained from different treatments did not differ significantly. However, there was a significant difference in the weight of pods. Maximum yield was recorded in plots treated with marotti oil (1370.00 g) which was on par with illupai oil (1032.50 g) and abamectin (975.00 g) and the treatments significantly differed from all other treatments. Excepting marotti oil, the yield in all other treatments ranging from 565.00 g to 1032.50 g per plot was on par with the yield in untreated control (807.50 g per plot).

Table 11. Effect of plant oils and synthetic insecticides on the intensity of mining by *Liriomyza trifolii* and yield of cowpea

Treatment	Average number of mines per leaf per plant at different intervals (weeks) after sowing					Mean yield, g/plot	Mean number of pods/plot
	5	6	7	8	9		
Thiamethoxam 0.02 %	4.46	5.10	4.50	3.65	4.90	892.50	143.25
Abamectin 0.003 %	3.88	4.29	3.53	2.58	3.18	975.00	171.00
Profenophos 0.025 %	7.50	8.26	7.63	6.45	7.10	760.00	143.00
Marotti oil 2.5 %	6.29	6.28	6.18	5.35	6.30	1370.00	183.00
Illupai oil 2.5 %	6.34	5.29	5.40	4.75	5.95	1032.50	165.00
Neem oil 2.5 %	6.51	5.98	5.30	4.20	5.63	857.50	138.25
Dimethoate 0.05 %	6.77	9.33	8.83	7.85	8.90	565.00	129.00
Control (untreated)	5.97	6.68	7.08	7.03	8.35	807.50	167.00
CD (0.05)	1.19	1.69	1.58	1.22	1.23	422.59	NS

NS not significant

DISCUSSION

5. DISCUSSION

The american serpentine leaf miner, *L. trifolii* is one of the highly polyphagous pests that has invaded India recently. It is known to attack more than 70 plants including fibre crops, pulses, vegetables, ornamentals, fodder crops, narcotics and weeds (Srinivasan *et al.*, 1995). The ability to disperse rapidly and adapt to different habitats and the capability to develop resistance to any insecticides within 6 – 8 generations have magnified the pest status of *L. trifolii*. Of late, the incidence of the pest whose mining activity reduces the photosynthetic capacity of plants drastically has become wide spread in cowpea in Kerala. Frequent application of insecticides against other pests of cowpea like the aphid, pod borers and pod bugs probably created an environment free of the natural enemies of the pest, favouring its multiplication. Information on the factors influencing the occurrence of the pest, the damage caused and natural enemy complex is a necessary requisite for developing effective management strategies.

5.1 EXTENT OF DAMAGE

Season and stage of the growth greatly influence the extent of damage caused by *L. trifolii* (Chandler and Gilstrap, 1987). In the survey conducted in Kalliyoor panchayat, significant difference was observed in the occurrence of the pest during summer and rainy seasons and in the vegetative and reproductive stages of cowpea as indicated by the mean infestation index presented in para 4.1. Greater incidence was observed during the summer season when the daily mean temperature ranged from 25 – 33^{0}C. This temperature regime has been reported to be favourable for the rapid development of the larvae of *L. trifolii* (Minkenberg and Lenteren, 1986). Moreover, at high temperature there is an increase in the number of eggs laid by the female per day (Zoebisch *et al.*, 1992). Both these factors may have contributed to the increased incidence of the pest in summer. Such high incidence of the pest in summer has been reported in bell pepper (Chandler and Gilstrap, 1987), lettuce (Palumbo *et al.*, 1994), french bean, cucumber and tomato (IIHR, 1998) and cotton (Jeyakumar and Uthamasamy, 2000). The adverse effect of precipitation on adult abundance (Heyer *et al.*, 1989) reduced the build up of *L. trifolii* during rainy season and consequently resulted in the lower incidence of the pest on cowpea. Thus, the results indicated that occurrence of *L. trifolii* on cowpea in summer is definitely a concern in Kerala.

Primarily, the larvae of *L. trifolii* damage the cotyledons and the first few leaves on a number of crops (IIHR, 1988). The infestation continues through the vegetative (Lakshminarayana *et al.*, 1992) and reproductive stages (Chandler and Gilstrap, 1987) and is even seen at the fag end of the several crops (Chandler and Thomas, 1983; Musgrave *et al.*, 1975), the severity of the damage depending on the host plants. In cowpea, the incidence of the pest was noted from the 2 – 3 leaf stage of the crop in the areas surveyed. The infestation continued through the vegetative phase but reached to a destructive level in the reproductive phase. This severe damage to the leaves in the reproductive phase in cowpea is critical since yield is produced largely from photosynthesis after flowering (Adipala *et al.*, 2000). Fifteen mines per leaf at this stage were observed to reduce the yield significantly (Schreiner *et al.*, 1986). More than 20 mines per leaf was observed in several plots in the reproductive stage during the survey, suggesting that *L. trifolii* can be considered as an important pest of the later stages of cowpea.

The extent of infestation during the reproductive phase in summer was more than 50 per cent in all the plots surveyed, indicating the heavy damage caused to cowpea in the panchayat (Fig. 2) during this period, the mean infestation index being 67.63 per cent. Infestation ranging from one per cent (Patnaik, 2000) to 50 per cent (Price and Dunstan, 1983) had been reported in cowpea earlier. This varying intensity of infestation has been attributed to the cultivation practices and cropping

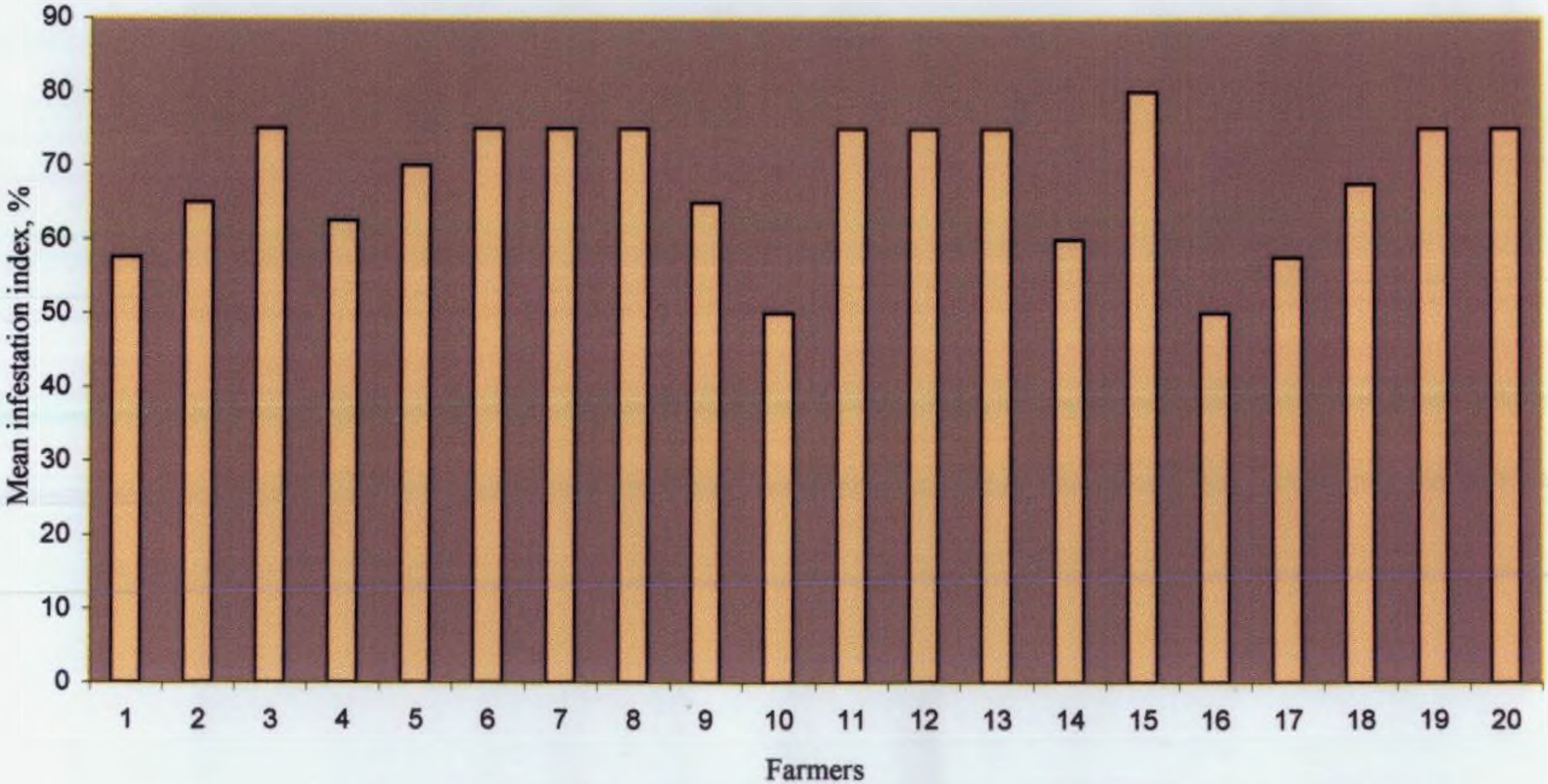


Fig. 2. Extent of damage caused by *Liriomyza trifolii* in cowpea in twenty farmers' field during the reproductive phase in summer

pattern adopted (Jeyakumar and Uthamasamy, 2000). The incidence of the pest in the present study too was found to be influenced by several cultivation practices followed by the farmers.

5.1.1 Influence of Cultivation Practices

Eighty five per cent of the farmers in the vegetable growing areas of Kalliyoor panchayat adopted the pit system of planting, raising four plants together in pits spaced on meter apart. In the trench method of planting two plants were raised together the distance between two trenches being 45 cm. Comparatively, higher infestation was seen in plants raised in the pits. The mean infestation index in the pit method of planting ranged from 57.50 to 80.00 per cent and 22.50 to 62.50 per cent in the summer and rainy season respectively during the reproductive stage. The lower plant density per unit area in the pit method of planting might have created a microclimate with high temperature and more sunlight which is favourable for the multiplication of the leaf miner as opined by Minkenberg and Lenteren (1986).

Not much difference was observed in the extent of damage caused to the different accessions raised by the farmers. Both the local and improved accssions had an appreciable level of damage indicating the susceptibility of the accession to the pest. Host suitability is a key factor contributing to the status of a pest in any ecosystem. Cultivation of varieties lacking resistance tends to aggravate pest problems. This might have been one of the major reasons for the high incidence of the pest in the panchayat. This result agrees with the report of (CIP, 1995) wherein, severe incidence of *L. huidobensis* was observed in areas where susceptible cultivars of potato were cultivated

Among the fertilizers applied, nitrogen was found to exert a profound influence on the extent of damage caused by *L. trifolii*. Eighty per cent of the farmers applied 40 – 100 kg N ha^{-1}, which was 2 – 5 times higher than the optimum dose (20 kg ha^{-1}) recommended by the

Kerala Agricultural University for cowpea (KAU, 1996). With increase in the level of nitrogen,there was a corresponding increase in the extent of damage caused by *L. trifolii* (Fig. 3). Wherever such high doses were applied the extent of damage was also high (Zambon et *al.*, 1991). The other nutrients *viz.*, P and K did not have much influence on the extent of damage caused. The influence of nitrogen level on host plant selection by *L. trifolii* has been documented. The leaf miner fly has a feeding and oviposition preference for plants with high nitrogen (Harbaugh *et al.*, 1983; Minkenberg and Lenteren, 1986). Moreover, application of nitrogenous fertilizers increased the preference of *L. trifolii* to less preferred varieties (Bethke *et al.*, 1987). The increased succulence of plants consequent to the application of higher levels of nitrogen may have attracted the pest resulting in the high damage observed. In this context, the tendency of farmers to apply high doses of nitrogen to crops for increasing yield should be viewed seriously especially in areas endemic to *L. trifolii*.

Though insecticides were applied by all the farmers to control the pests attacking cowpea including the leaf miner, the mean infestation index was high in all the plants, irrespective of the type of insecticide used. More than 50 per cent infestation was observed during the reproductive stage in summer indicating the ineffectiveness of the insecticides used in protecting the plants from the ravages of the pest. Information gathered from the farmers revealed that insecticides belonging to organophosphorus group like methyl parathion, monocrotophos, dimethoate, quinalphos and malathion had been in use in the locality for many years while the synthetic pyrethroids *viz.*, fenvalerate and lambdacyhalothrin were of recent introduction. However, no remarkable difference could be observed in the leaf miner infestation when the different groups of insecticides were used (Fig. 4). Compared to other species,the capability of *L. trifolii* to become rapidly resistant to insecticides is high (Mason and Johnson, 1987), the average

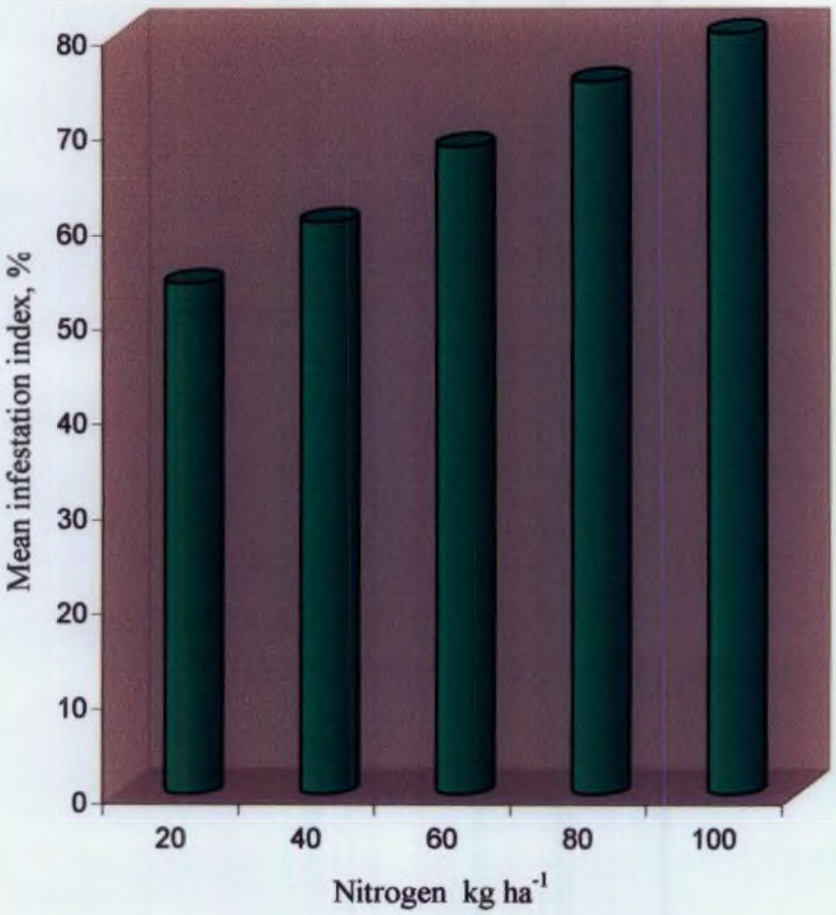


Fig. 3. Influence of different levels of nitrogen on the extent of damage caused by *Liriomyza trifolii* in cowpea

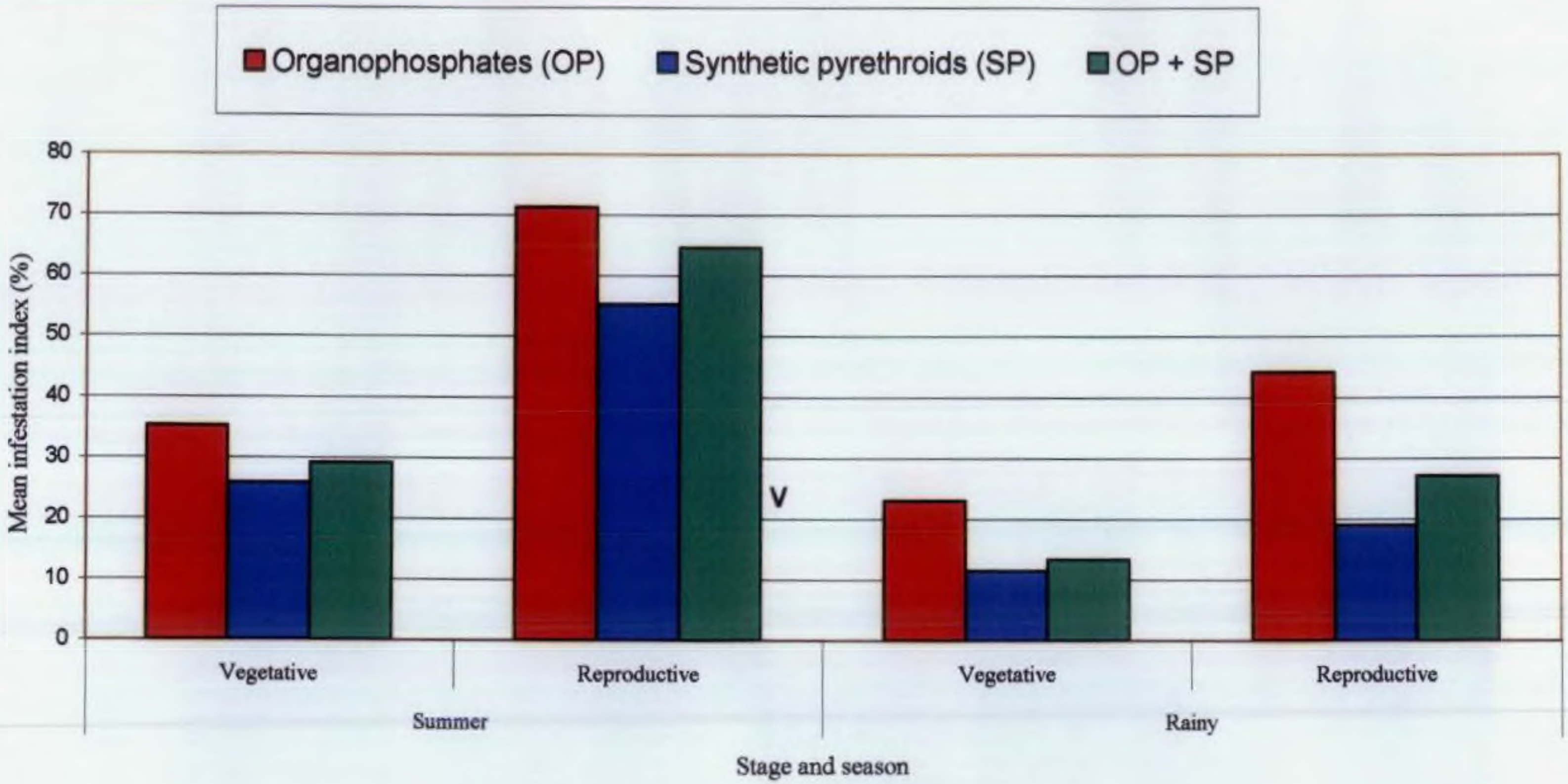


Fig. 4. Extent of damage caused by Liriomyza trifolii in cowpea when different groups of insecticides were used

effective field life of an insecticide used against the species being less than three years (Parrella and Keil, 1984). The farmers were seen to give six to eight sprays of insecticides to the crop in a season to control a complex of pests besides *L. trifolii*. Still, the extent of damage caused by the miner was high suggesting that the pest might have developed resistance to the insecticides. While occassional application of monocrotophos, dimethoate (Gloria and Salas, 1977), malathion (Chang and Chen, 1993) and fenvalerate (Waddil, 1980) and other synthetic pyrethroids (Chang and Chen, 1993; Reddy and Ashokkumar, 2001) gave good control of *L. trifolii*, the pest developed resistance to the same *viz.*, monocrotophos (Lyra-Netto *et al.*, 1989); dimethoate (Keil and Parrella, 1990), methyl parathion (Keil and Parella, 1990), malathion (Lorini and Foerster, 1985) and fenvalerate (Mason *et al.*, 1989) when used consistently.

Several weeds seen in the cowpea fields were observed to be susceptible to *L. trifolii*. The common weeds included *A. viridis*, *H. indicum*, *C. monophylla*, *C. viscosa*, *A. aspera* and *D. gyrans*. A higher infestation index ranging from 21 – 70 per cent during the two seasons and phases of growth of the plant was noted in the plots where the leaf miner infested weeds were seen. Presumably, these alternate hosts contributed significantly to the damage on the host plant. The result is in conformity with the observations made by Schuster *et al.* (1991) on the important role played by weed hosts and volunteer plants in the build up of population of *L. trifolii*.

Since cowpea is a direct seeded crop, population of *L.trifolii* attacking the plant must originate from surrounding crops or weed hosts. Thus, initial colonization starts with the movement of adults from this adjacent vegetation. Application of insecticides on cowpea plants might destroy the pest in the early stage. At the reproductive stage, the plant would have trailed and spread to form a sufficiently thick canopy. Any insecticide applied to the crop at this stage will not reach the weeds beneath. Thus, the pest surviving on the susceptible weeds will not be affected, resulting in migration of the pest to cowpea plants growing in close proximity. Hence, the usual practice of farmers in retaining weeds in the field in the later stages of the crop, especially in the reproductive stage should be viewed seriously.

5.2 PARASITOIDS OF *L. trifolii*

The parasitoid complex has a good role in maintaining population of *Liriomyza* below damaging levels (Palumbo *et al.*, 1994). In the present study, a number of hymenopterans were seen to parasitize *L. trifolii*. The parasitoid complex consisted predominantly of species in the family Eulophidae. This fact is in agreement with the findings of Prieto and Olloa (1982) who indicated that about 92 per cent of the parasitoids found attacking the larvae of *L. trifolii* were Eulophids. *C. rexia* and *Asecodes* sp. were the most abundantly observed species in the present study. *Diglyphus* spp. (Johnson, 1987 ; Godinho and Mexia, 2000), *Hemiptarsenus* sp. (IIHR, 1998; Fu *et al.*, 1999) and *Chrysonotomyia* sp. (Johnson, 1987; Kapadia, 1995) were the frequently encountered parasitoids of *L. trifolii*. The predominance of *C. rexia* and *Asecodes* sp. in the area surveyed reflect the views of Johnson and Hara (1987) that the variation in the composition of leaf miner parasitoid complex is often dependent on the *Liriomyza* spp., crop host and locality of crop.

The extent of parasitization was low in the cowpea field signifying the deleterious effect of the chemical management practices adopted by the farmers. Most of the parasitoids were obtained from the larvae collected from stray cowpea plants and susceptible weeds seen near the field. Obviously, the insecticides applied destroyed this biological wealth leading to the high infestation observed. The seven parasitoids *viz.*, *C. rexia*, *Asecodes* sp., *H. indica*, *Agathidini* sp., *C. agromyzae*, *H. brevipedicelius* and *Entomacis* sp. were recorded for the first time in Kerala.

5.3 HOST PLANT RESISTANCE

Exploitation of insect resistance in agricultural crops has provided an effective tool for the management of several noxious pests. It is the most practical and economical control measure of pests. Even moderately resistant varieties prove extremely useful in enhancing the effects of predators, parasitoids and pathogens on insect pests. Identification of genotypes resistant / tolerant to *L. trifolii* is extremely important for tackling the pest which develops resistance to insecticides rapidly. With this objective 20 accessions including local and high yielding ones of cowpea were screened for their relative resistance / tolerance to the leaf miner. Both trailing and bush types of cowpea accessions were included in the trial to compare the preference of the pest if any for the architecture of the cowpea plant.

Comparatively, accessions of trailing type of cowpea were more susceptible to *L. trifolii* than the bush types. The trailing type of cowpea VU-12, a local collection with 44.7 punctures per plant, 3.7 larvae and pupae per plant, 3.3 adult per plant was identified as least preferred by *L. trifolii* among the accessions screened. While the high yielding trailing type of cowpea, Malika showed appreciable tolerance to the pest, Sharika and Vyjayanthi were found to be susceptible to the pest. Among the bush type of cowpea accessions, the pest showed lower preference to the local collections, VU-4 and VU-6 and the high yielding variety, Arka Garima. Though a lower percentage of adult emergence was observed in bush type accessions *viz.*, VU-3 and Kanakamony, more than 80 per cent emergence was seen in the other bush and trailing type accessions of cowpea(Fig. 5a). No remarkable difference was seen in the life cycle of the insect in the different accessions (Fig. 5b). Futhermore, no adverse effect was observed on the survival, development or reproduction of the insect confirming that the mechanism of resistance seen was not antibiosis. Comparatively, lower number of feeding / oviposition punctures observed in the tolerant varieties indicated a non-preference

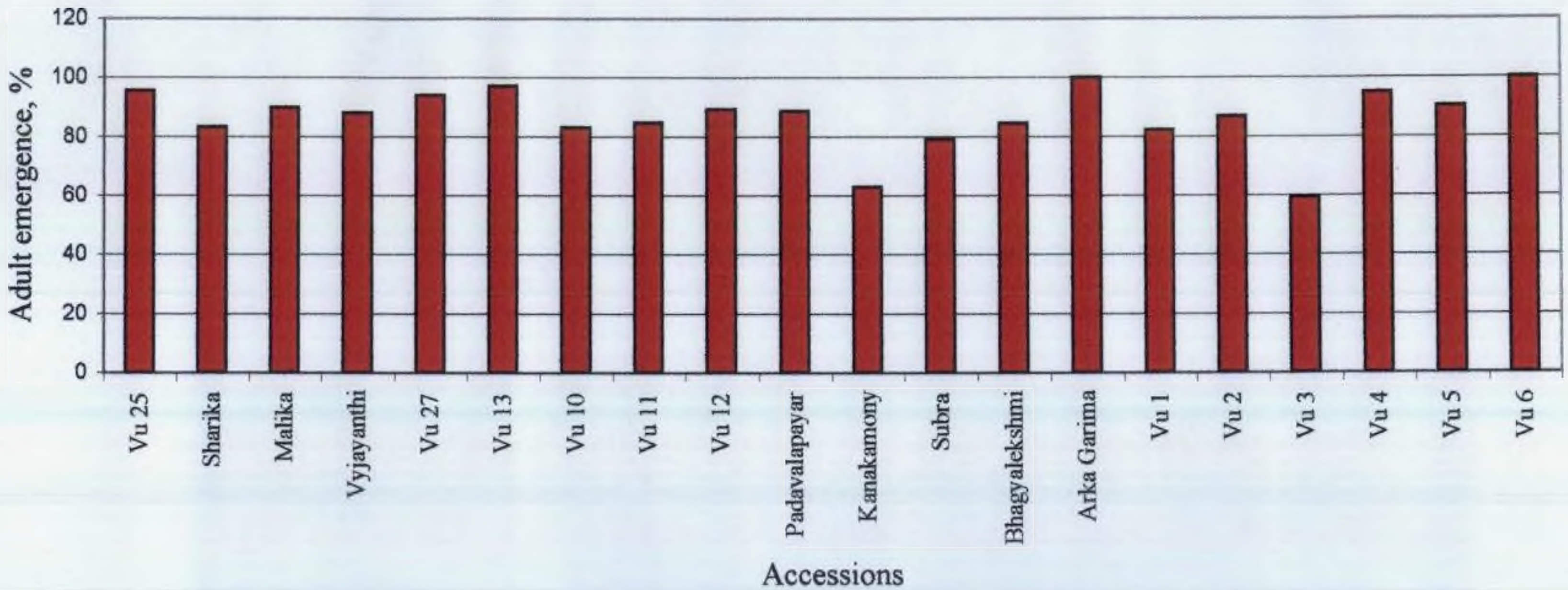


Fig. 5a. Development of *Liriomyza trifolii* on different accessions of cowpea- adult emergence

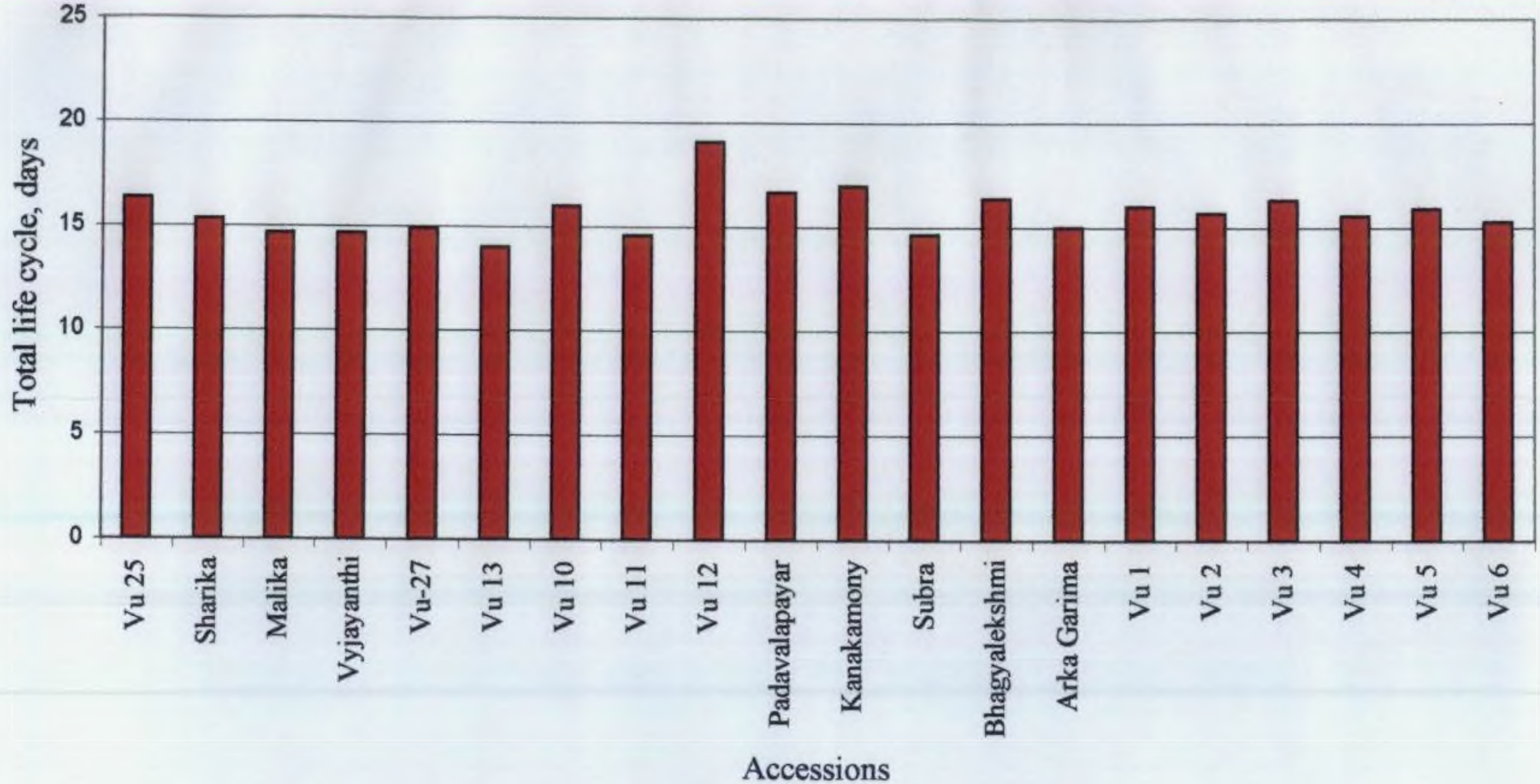


Fig. 5b. Development of *Liriomyza trifolii* on different accessions of cowpea - Total life cycle

for the variety by the pest implying the mechanism operating to be antixenosis. Since the larvae of *L. trifolii* are unable to leave one leaf and enter another, the ultimate choice of host selection rests with the ovipositing adult female. They exhibit distinct preference for host plants. The distribution and density of plant trichomes, the phenolic content and nutritional value of hosts were found to influence host plant selection of *L. trifolii* (Parrella, 1987). The difference in the infestation of the pest observed in the different accessions in the study might have been due to varying biochemical and leaf morphological factors which restricted the feeding / oviposition of *L. trifolii* and needs to be further investigated. Though sources of resistance to *Liriomyza* spp. have been reported in vegetables like tomato (Wolfenbarger, 1966; Eigenbrode *et al.*, 1993; Choudhary *et al.*, 2000), Indian bean (Kapadia *et al.*, 1995), ridge gourd (Nandihalii *et al.*, 1995), *Vicia faba* (El-Khouly *et al.*, 1997) and cucumber (Xi *et al.*, 1999), literature on host plant resistance in cowpea is limited. Cowpea variety TK –1 compared to 4R-026-IR (Price and Dunstan, 1983) and the variety Vita - 3 had lowest infestation of the leaf miner (Moraes *et al.*, 1981).

5.4 EVALUATION OF PLANT OILS AND INSECTICIDES

Result presented in para 4.4 showed that among the plant oils and newer synthetic insecticides evaluated in the laboratory, neem oil 2.5 per cent and abamectin 0.003 and 0.006 per cent effectively controlled the pest in the laboratory. Exposure of adults of *L. trifolii* to plants treated with abamectin and neem oil resulted in 100 per cent mortality. The higher and lower doses of illupai oil, marotti oil, thiamethoxam and imidacloprid resulted in more than 80 per cent mortality of the adults. Reduced number of feeding / oviposition punctures and larvae and emergence of pupae and adults were seen in these treatments suggesting the efficacy of the products in protecting the plants when applied prior to the incidence of the pest. No significant difference was noticed between the two doses indicating that the lower dose of the pesticides was sufficient to check the pest. Castor oil, profenophos and dimethoate gave comparatively lower protection to the plants. Custard apple seed oil was ineffective.

With the exception of neem oil 2.5 per cent which gave 93.93 per cent mortality of larvae, none of the other plant oils caused mortality to the larvae when applied on cowpea plants infested with *L. trifolii*. The synthetic insecticides, abamectin, thiamethoxam and profenophos gave more than 70.00 per cent mortality of larvae. No adults emerged in thiamethoxam (0.04 per cent) and both doses of abamectin. Imidacloprid was ineffective when applied on pest infested plants. Treating plants with the plant oils before infestation had a greater suppressive effect on the pests than treatment after infestation. The oil deposits on the surface of the sprayed leaves might have probably interfered with the feeding and / or probing behaviour of the ovipositing females. Possibly, the repellent action and / or toxicity to adults may have reduced the egg laying capacity of the pest. Consequently the fly might have died of starvation. The repellent / oviposition deterrent action of the plant oil might have prevented the pest from infesting the plant. The mode of action of the oils on the pest need to be investigated further. On the other hand synthetic insecticides were equally effective when applied both before and after infestation.

Neem oil 2.5 per cent was definitely superior to other botanicals and ranked with abamectin in its effectiveness. The efficacy of various extracts of neem like neem seed kernel extract (Meisner, *et al.*, 1986; Schmutterer, 1990), oil emulsion (Reghunath and Gokulapalan, 1996; Azam, 1991) and commercial products (Weintraub and Horowitz, 1977; Omar and Faris, 2000; Choudhary and Rosaiah, 2001) in controlling *L. trifolii* is well documented. Similarly Jeyakumar and Uthamasamy (2000) had reported the efficacy of neem oil and illupai oil 3 per cent in controlling the pest. No information is available on the efficacy of marotti oil against the pest. The effectiveness of these oils observed in the study provides wider options of plant oils for controlling the pest. The excellent control obtained with abamectin, a biorational pesticide of microbial origin conforms to earlier reports on its effectiveness (Schuster and Everett, 1983; Hara, 1986; Parrella *et al.*, 1988; Lasota and Dybas, 1991; Hurni, 1992; Longiswaran and Bhuvaneswari, 2000). Adult leaf miners are killed when they come in contact with fresh spray deposits. Moreover, the reservoir of abamectin that remains within the mesophyll layer of treated leaves makes the chemical easily accessible for ingestion by the mining larvae. Similarly, the neonicotinoid insecticide, thiamethoxam too gave good control of the pest. The study indicated that both abamectin and thiamethoxam could be used as alternatives for insecticides to which the pest has developed resistance. The ineffectiveness of imidacloprid to control the pest, especially when applied after infestation observed in the study is in consonance with the observations made by Choudary and Rosaiah (2001) on its ineffectiveness.

The plant oils and insecticides found effective in the laboratory were evaluated in the field for determining their efficacy under field conditions. Abamectin 0.003 per cent was the best in controlling the pest when assessed in terms of the percentage of leaves damaged and average number of mines per leaf agreeing with the findings of Green *et al.* (1985) that weekly application of abamectin at 0.5 ppm gave excellent control of *L. trifolii*. The extent of infestation was also low in neem oil 2.5 per cent, thiamethoxam 0.02 per cent, illupai oil 2.5 per cent and marotti oil 2.5 per cent. Dimethoate failed to control the pest. Probably, the population of the pest in the field might have been a resistant population, since this insecticide is frequently used for the control of pests of cowpea in the Instructional Farm, College of Agriculture, Vellayani where the trial was laid out. Such inefficacy of dimethoate in controlling the field population of leaf miner has been reported by Chandler (1985) in pepper though efficacy in beans has also been reported (Anon., 1986). On the contrary, significantly higher yield was obtained from plots treated with marotti oil (1370.00 g $4m^{-2}$ plot). The yield of a crop is dependent on the total protection it gets from several pests under field conditions. In the field trial laid out incidence of aphid, pod bugs and pod borers was also seen besides the leaf miner. Though abamectin gave excellent control of *L. trifolii* it might not have been effective against the other pests. Similarly, a higher dose of neem oil (10 per cent) only checks aphids adequately under field conditions as reported by Reghunath and Gokulapalan (1996). Thus the lower dose used in the trial, though reduced infestation of *L. trifolii*, may not have been effective against the other pests. A lower incidence of these pests was noted in marotti oil treatment. Probably, the oil might have been effective against these pests too thus accounting for the significantly higher yield in the treatment. Hence the efficacy of these insecticides need to be evaluated before recommending their application in situations where a complex of pests cause damage.

Thus, the study clearly indicated that *L. trifolii* is a serious pest of cowpea especially in the summer season in Kerala, the status of which is unknowingly magnified through several practices adopted by the farmers like growing susceptible varieties, applying higher doses of N, retaining of susceptible weeds in and around the field and unnecessarily applying insecticides. Evidently, avoidance of these practices could reduce infestation of the pest substantially. Normally, when incidence of *L. trifolii* alone is noted, this package of practices would be sufficient to check the pest infestation. When protection is required over and above these, application of botanical pesticides like neem oil, marotti oil and illupai oil at 2.5 per cent can be resorted to. Insecticides should be applied only when absolutely needed since continuous use of the insecticides induces resistance in the pest and also destroys the natural enemies abundantly seen in the cropping system. Though abamectin was undoubtedly the best treatment for the pest, the high cost of the pesticide dissuades its use in the field. Hence in an emergency, thiomethoxam, a new insecticide molecule can be utilized for controlling the pest.

Based on the findings of the study cultivation of the tolerant accession VU-12 in endemic areas, destruction of weed host plants, judicious application of nitrogen and need based application of neem oil / marotti oil / illupai oil at 2.5 per cent can be recommended for inclusion in IPM strategies of *L. trifolii*. The future line of work should include the evaluation of the indigenous natural enemies for their potential in controlling the pest.

SUMMARY

6. SUMMARY

Consequent to its introduction, the American serpentine leaf miner, *Liriomyza trifolii* became a major threat to the cultivation of several crops in many countries within a short span of time. Widespread occurrence of the pest on vegetables was noted in Kerala too. The extent of damage caused by *L. trifolii* to cowpea was assessed through a survey conducted in two wards of Kalliyoor panchayat in Thiruvananthapuram district, where the crop was cultivated extensively. Detailed information on the practices adopted by the farmers for raising the crop was also gathered to determine their influence on the pest incidence. The natural enemies of the pest were documented. High yielding varieties and local collections of cowpea were screened for their relative resistance / tolerance to the pest. The efficacy of plant oils and newer synthetic insecticides in controlling the leaf miner was studied in the laboratory and under field conditions.

The major findings of the study are summarized below.

1. Higher incidence of the pest was observed in the summer season. Based on the infestation index, the pest was seen to inflict significantly greater damage to cowpea during the reproductive stage of the crop.
2. Several practices adopted by the farmers for cultivating cowpea played a decisive role in the incidence of the pest. Lack of resistance in the varieties raised pre-disposed the plants to the ravages of the pest.
3. Between the two methods of planting, more damage was seen in plants raised in pits than plants raised in trenches. The lesser number of plants per unit area in the pit method of planting created a microclimate favourable for the multiplication of the pest.

4. Application of increased doses of nitrogen resulted in a higher intensity of infestation in both the seasons and phases of growth of the plant. Phosphorus and potash did not influence the damage caused by the pest.
5. Though organophosphorus and synthetic pyrethroid insecticides were used for controlling the leaf miner and a complex of other pests, the mean infestation index was high in all the plots surveyed indicating that the pest may have developed resistance to the insecticides which had been used continuously in the locality.
6. The weeds *viz., Achyranthus aspera, Amaranthus viridis, Cleome viscosa, Cleome monophylla, Heliotropium indicum, Physalis minima* and *Desmodium gyrans* were identified as host plants of *L. trifolii*. Presence of these weeds in and around the plots increased the damage on the plants.
7. Seven parasitoids *viz., C. rexia, Asecodes* sp., *H. indica, Agathidini* sp., *C. agromyzae, H. brevipedicellus* and *Entomacis* sp were recorded from the larvae of the miner. These parasitoids were recorded for the first time in Kerala. Among these, *C. rexia* and *Asecodes* sp. were seen abundantly in the ecosystem. The possibility of utilizing these parasitoids for *L. trifolii*, which develops resistance to insecticides easily, is to be explored.
8. Among the accessions of trailing and bush types of cowpea screened, significantly higher damage was observed in the trailing type of cowpea. Based on the feeding / oviposition punctures and development of the pest on the different accessions, VU-12 was least susceptible among the trailing type while the high yielding varieties Sharika and Vyjayanthi were susceptible. Among the bush types VU-4, VU-6, VU-3 and Arka Garima were less susceptible.
9. Prophylactic application of neem oil (2.5 per cent) resulted in significantly higher mortality of *L. trifolii* followed by marotti oil

(2.5 per cent) and illupai oil (2.5 per cent). However, excepting neem oil, none of the plant oils caused larval mortality when applied after infestation. No significant difference was seen between the higher and lower doses of the plant oils. Among the synthetic insecticides evaluated, application of abamectin, thiamethoxam and profenophos both before and after infestation gave significantly higher mortality of the pest. Again, there was no significant difference between the two doses tested.

10. Based on the percentage of leaves damaged and intensity of mining, abamectin 0.003 per cent was significantly superior in controlling the leaf miner when evaluated in the field. Neem oil, marotti oil and illupai oil at 2.5 per cent also reduced pest infestation. Significantly higher yield was obtained from plots treated with marotti oil.

L. trifolii is a potential pest of cowpea especially in the summer season. Avoidance of practices that aid in the multiplication of the pest would reduce the damage remarkably. Based on the results, cultivation of the tolerant accession VU-12 in endemic areas, destruction of weed host plants, judicious application of nitrogen and need based application of neem oil / marotti oil / illupai oil at 2.5 per cent can be recommended for inclusion in IPM strategies of *L. trifolii*.

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* Originals not seen

MANAGEMENT OF THE AMERICAN SERPENTINE LEAF MINER, *Liriomyza trifolii* (Burgess) Dictars ON COWPEA, *Vigna unguiculata* (L.) Walp.

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ABSTRACT

Survey conducted in Kalliyoor panchayat of Thiruvananthapuram district revealed that *Liriomyza trifolii* caused maximum damage to cowpea at the reproductive phase of the crop in summer. Raising susceptible varieties, applying high doses of nitrogen and frequent use of insecticides were noted to intensify the pest incidence. The weeds, *Achyranthus aspera, Amaranthus viridis, Cleome viscosa, Cleome monophylla, Heliotropium indicum, Physalis minima* and *Desmodium gyrans* were identified as host plants of the pest. Seven larval parasitoids were recorded of which *Chrysonotomyia rexia* and *Asecodes* sp. were predominant.

Twenty accessions of cowpea including trailing and bush types were screened in the laboratory for resistance to *L. trifolii*. Accessions of trailing type were more susceptible to the pest. VU-12 was least susceptible among the trailing type while Sharika and Vyjayanthi were highly susceptible. Among the bush type, VU-4, VU-6, VU-3 and Arka Garima were less susceptible.

Four plant oils and four synthetic insecticides when evaluated in the laboratory at two doses along with neem oil (2.5 per cent) and dimethoate (0.05 per cent) showed no significant diffe.ence in efficacy between the doses. Neem oil, marotti oil and illupai oil at 2.5 per cent and abamectin, 0.003 per cent, thiamethoxam, 0.02 per cent and profenophos, 0.025 per cent were found to be effective in controlling the pest.

All the treatments reduced the pest infestation significantly in the field. Abamectin, 0.003 per cent was significantly superior. Neem oil, marotti oil and illupai oil 2.5 per cent also reduced pest infestation. Considering the cost and safety to the natural enemies, the oils were found more advantageous to the farmers.

Based on the results, cultivation of the tolerant accession VU-12 in endemic areas, destruction of weed host plants, judicious application of nitrogen and need based application of neem oil / marotti oil / illupai oil at 2.5 per cent can be recommended for inclusion in IPM strategies of *L. trifolii*.

APPENDIX

APPENDIX – I

Weather parameters during 2001 – 2002

Month	Average maximum temperature, ^0C	Average minimum temperature, ^0C	Total rainfall, mm	Total sunshine hours, h	Average relatively humidity, %
June	30.42	31.15	182.50	150.20	79.98
July	30.34	30.30	297.30	140.30	82.70
August	29.60	21.20	189.50	191.80	84.20
September	30.10	23.80	558.20	207.30	80.90
October	30.00	24.00	256.90	203.90	83.19
November	30.39	23.48	238.10	185.00	77.00
December	30.85	23.10	20.60	227.30	79.90
January	31.05	22.19	-	248.50	78.69
February	30.50	22.26	15.00	237.60	75.80
March	32.95	23.50	16.70	264.10	74.95
April	33.10	24.80	50.60	236.90	76.97
May	31.50	25.00	200.10	177.40	80.08