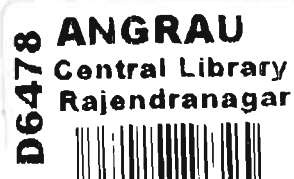


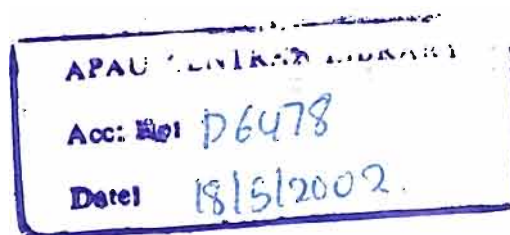
**“STUDIES ON BIOLOGY AND MANAGEMENT
OF SERPENTINE LEAFMINER
Liriomyza trifolii Burgess ON TOMATO”**

By

B. HEMALATHA, B.Sc., (Ag.)



THESIS SUBMITTED TO THE
ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(ENTOMOLOGY)



DEPARTMENT OF ENTOMOLOGY
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OCTOBER, 2001

CERTIFICATE

Ms. B. HEMALATHA has satisfactorily prosecuted the course of research and that the thesis entitled "**STUDIES ON BIOLOGY AND MANAGEMENT OF SERPENTINE LEAFMINER *Liriomyza trifolii* Burgess ON TOMATO**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by her for a degree of any University.

Date : 28.11.01
Place : Tirupati



(Dr. T. UMAMAHESWARI)
(Major Advisor)
Assistant Professor
Department of Entomology
S.V.Agricultural College
Tirupati

CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON BIOLOGY AND MANAGEMENT OF SERPENTINE LEAFMINER, *Liriomyza trifolii* Burgess ON TOMATO" submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE IN AGRICULTURE of the Acharya N.G.Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by Ms. B. HEMALATHA under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.



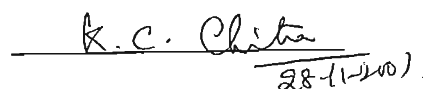
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LIST OF ABBREVIATIONS

@	:	At the rate of
a.i	:	Active ingredient
°C	:	Degree Centigrade
Cm	:	Centimetre
Fig	:	Figure
g	:	Gram
i.e.,	:	That is
Ha	:	Hectare
Kgs	:	Kilograms
m	:	Meter
m ²	:	Square meter
mm	:	millimetre
Max	:	Maximum
Min	:	Minimum
RF	:	Rainfall
RH	:	Relative humidity
S.No.	:	Serial Number
SLM	:	Serpentine Leafminer
Sp.	:	Species
%	:	Percentage
Viz.,	:	Namely
Lit	:	Litre
ml	:	Milli litre

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(B. HEMALATHA)

DECLARATION

I Ms. B. HEMALATHA do here by declare that thesis entitled "STUDIES ON BIOLOGY AND MANAGEMENT OF SERPENTINE LEAFMINER *Liriomyza trifolii* Burgess ON TOMATO" submitted to Acharya N.G. Ranga Agricultural University for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that the material contained in this thesis has not been published earlier in any manner.

Date :

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ABSTRACT

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Title of the thesis	:	"STUDIES ON BIOLOGY AND MANAGEMENT OF SERPENTINE LEAFMINER, <i>Liriomyza trifolii</i> Burgess ON TOMATO"
Submitted for the award of degree	:	Master of Science in Agriculture
Faculty	:	Agriculture
Department	:	Entomology
Major Advisor	:	Dr. T. Umamaheswari
University	:	Acharya N.G. Ranga Agricultural University
Year of Submission	:	2001

Studies on biology, seasonal incidence, influence of tomato varieties and different management strategies on the infestation of leafminer, *Liriomyza trifolii* Burgess were carried out at insectary, S.V.Agricultural College, Tirupati, Chittoor District, Andhra Pradesh during July 2000 to June 2001.

Observations on the biology, morphometrics and developmental durations of serpentine leafminer, *L. trifolii* were documented under laboratory conditions at a mean temperature of 25.9°C. Results indicated that the incubation period lasted for 2.9 ± 0.83 days while the mean duration of larval, prepupal and pupal stages lasted for 4 ± 0.77 days, 3.25 ± 0.24 hours and 9 ± 0.83 days respectively. Adult longevity lasted for 11 ± 0.77 days when two per cent sugar solution provided as source of food material. The total developmental period from egg to adult was completed in 13-20 days with an average of 16.6 ± 2.73 days. Sex ratio was found to be 1:1.14.

Studies on seasonal incidence of SLM, *L. trifolii* Burgess were carried out on tomato. Initial incidence of miner was recorded during first week of July (27th Standard Week). The Peak activity of leafminer was observed during first week of October and first week of January (40th and 1st standard weeks). The activity of leafminer was completely absent during April and May months.

Observations on distribution of leafminer during the crop period at different stages revealed that initial egg laying was observed on fourth leaf

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Observations on distribution of leafminer during the crop period at different stages revealed that initial egg laying was observed on fourth leaf

stage on seedlings of 10 days old that gradually increased. By the end of 30th day, miner incidence was found to be to the extent of 1.25 to 9.16 larvae per branch. In transplanted crop, peak incidence of 18.80 larvae per branch was observed at 45 days after sowing. From this stage, miner incidence gradually decreased and minimum miner incidence of 1.75 to 2 maggots per branch was observed from 94 and 101 days after sowing.

Studies on influence of mechanical barrier, 60 mesh net in relation to crop stages at field level for checking the infestation of leafminer, *L. trifolii* revealed that the mechanical barrier was considered as one of the major element in pest management when tomato crop was protected throughout the nursery stage upto 30 days and from 30 to 60 days in transplanted crop with net resulted in minimum miner incidence of 14.26 to 18.37 per cent and yield of 22.65 to 23.58 kgs per 20 sq.m. Protection of crop with net throughout the crop period affected the crop growth and yield (10.66 kgs per 20 sq.m). Protection of the crop during 60 to 90, 90 to 120 days did not show any significant reduction of the pest.

Seven cultivars of tomato were screened under field conditions against serpentine leafminer during peak infestation period. The cultivars Hybrid Cross-08, Hybrid Cross-17 and Tomato Ruchi were found moderately resistant to leafminer *L. trifolii* with an infestation level of 20 to 25 per cent where as Pusa Ruby, S-22 and PKM-1 were highly susceptible with 63.33 to 75 per cent miner infestation and Arka Vikas was found to be susceptible with 50 per cent miner infestation. Experiments oriented to document the biochemical constituents of tomato leaves revealed that the total phenols were comparatively high (2.96 mg/g) in "Hybrid Cross-08" that recorded low pest load whereas "Pusa Ruby" was found to be highly susceptible with a phenol content of 1.76 mg/g of leaf material.

Evaluation of different management strategies including chemical pesticides, botanicals and mechanical barrier to check *L. trifolii* on tomato both in nursery and transplanted crop revealed that among chemicals evaluated in nursery at field level triazophos @ 0.05 per cent and NSKE @ 5 per cent were found effective in reducing the pest to an extent of 76.37 to 94.82 per cent reduction of larval population. In transplanted crop triazophos, NSKE with or without seed treatment with imidacloprid showed reduction of larva to an extent of 63.79 to 77.21 per cent. The efficiency of remaining chemicals viz., seed treatment + profenophos, profenophos, seed treatment + azadirachtin, azadirachtin, seed treatment + annona seed extract, annona seed extract and imidacloprid was in descending order of larval reduction over control from 8.02 to 57.35 per cent. No miner incidence was recorded in nursery when crop was protected with mechanical barrier 60 mesh net. However, miner incidence gradually increased and recorded 11 larvae per branch at 70 days when the barrier was removed and 58.27 per cent larval reduction was recorded compared to untreated control.

Chapter - I

Introduction

CHAPTER - I

INTRODUCTION

The awareness of the importance of nutritive values of vegetables to the rapid increase of their production in several regions of the country. Andhra Pradesh being one of the important vegetable growing states of the country, possesses extensive areas covered with diversified vegetable crops of Solanaceous, Malvaceous, Leguminaceous, Cruciferous and Cucurbitaceous origin.

Tomato (*Lycopersicon esculentum*) is one of the most popular vegetable crops cultivated in India for both fresh market and processing. In terms of per capita consumption tomatoes are the leading processed vegetables. Tomatoes occupy a prominent place in common man's diet - salads, curries, raw fruits etc. and are rich source of Vitamin A, B and C and act as a blood purifier.

In India around 3 lakh hectares of land is with tomato crop giving around 5 million tonnes of production. In Andhra Pradesh the area & production levels are ranging around 42,000 ha and 4.2 lakh tonnes respectively. Chittoor, Kurnool, Rangareddy, Prakasam, Mahaboobnagar, Vizag, Krishna and Guntur are important districts that cultivate tomato. Among these tomato is predominantly grown in Chittoor district.

More than one hundred pest species have been recorded on tomato crop (Hussey, Read and Hesling, 1969 and Talekar *et al.*, 1983). Of these fruit borers, jassids, whiteflies, nematodes and leafminers are major in causing damage frequently. Recently there is a regular attack of serpentine leafminer, *Liriomyza trifolii* (Burgess) on tomato inflicting severe damage from nursery stage onwards.

Serpentine leafminer (SLM), *Liriomyza trifolii* (B) is an important cosmopolitan pest that is distributed throughout the world. It is an introduced insect into India from USA during 1990-91 and is found in almost all the states (Viraktamath *et al.*, 1993). It has become a serious pest on tomato, and cucurbitaceous vegetables as well as various commercial crops of sub-tropical regions. Its damage is characterised by sharply curled and contorted leafmines that has a continuous black trail of frass (Srinivasan *et al.*, 1995). The mines of the maggots and ovipositional punctures of adults reduce the photosynthetic ability of host plant ultimately resulting in reduced yields. Serpentine leafminer *L. trifolii* can become a serious threat to crops in India in future because of its wide host range. Though basic studies on *Liriomyza trifolii* in relation to biology and host range were documented elsewhere, information on its bio-ecology and management is meagre. Hence, there is a need to formulate a package for management of serpentine leafminer with special reference to tomato like important vegetable crop. Keeping this in view the present research work was planned both under laboratory and field conditions

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in the Insectary of Department of Entomology, Sri Venkateswara Agricultural College, Tirupati.

The programme comprises the following objectives :

1. Documentation of the developmental duration of serpentine leafminer including morphometrics of different life stages of SLM, *L. trifolii*.
2. Studying the seasonal incidence and peak period of infestation of serpentine leafminer *L. trifolii* with reference to stage of tomato crop.
3. Screening of varieties against serpentine leafminer, *L. trifolii*.
4. Evaluation of various management strategies of *L. trifolii* both in nursery and transplanted crop.

Chapter - II

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

The American serpentine leafminer, *Liriomyza trifolii* Burgess, an introduced agromyzid pest into India during 1990-91 has attained major status and became one of the serious pests of several ornamental and vegetable crops. A comprehensive review on the biology, seasonal incidence and management of this pest has been presented here under the following headings.

2.1 TAXONOMY AND DISTRIBUTION :

Agromyzids as leaf miners were first recorded in literature towards the end of 17th century by Beckman in 1680. Burgess (1880) described for the first time mining of *L. trifolii* on *Trifolium rapens* (L.), who placed it in the genus *Oscinis*. The detailed taxonomic description of the pest *L. trifolii* was given by Spencer (1973) as it usually was confused with several species of *Liriomyza*. A key to differentiate different species of *Liriomyza* including *L. huidobrensis*, *L. trifolii* and *L. sativae* was also described. Zehnder *et al.*, (1983) were able to distinguish *L. trifolii* from *L. brassicae* and *L. sativae* with the help of electromagnetic and electron microscopic scanning studies and reported that interspecific differences occur in the length and spacing of mesonotal setae. Starch gel electrophoretic techniques were utilised by

Menken and Ulenberg (1983) to distinguish larval, pupal and adult stages of *L. trifolii* and *L. bryoniae*. Spencer and Steyskal (1986) considered two species of genus *Liriomyza* viz., *L. phaseolinata* Front and *L. alliovora* Frick as synonyms of *L. trifolii* and confirmed that the serpentine leafminer, *L. trifolii* belongs to the sub family phytomyzinae, family Agromyzidae in order Diptera.

Spencer (1973) reported serpentine leafminer *Liriomyza trifolii* (Burgess) (Agromyzidae: Diptera) as native to Florida in Southern United States and the Caribbean islands. Parrella (1987) reported wide distribution of the genus *Liriomyza* but was most common in temperate areas and relatively with few species in the tropics.

First report about outbreak of an unknown dipteran leafminer in Hyderabad, Ranga Reddy and Mahaboobnagar districts of Andhra Pradesh was reported by Singh (1991). This pest, believed to be an accidental introduction to India, was observed on many vegetable crops, cotton and castor. Its identity was simultaneously established in 1992 by several researchers on a wide variety of crops. (Lakshminarayana *et al.*, 1992 and Srinivasan, 1992).

Viraktamath *et al.* (1993) reported the wide distribution of leafminer in Andhra Pradesh, Gujarat, Karnataka and Delhi and Srinivasan *et al.*, (1995) documented its occurrence in Andhra Pradesh, Karnataka, Maharastra and Tamilnadu during November 1992 and February 1993.

2.1.2 Nature and Symptoms of damage :

Johnson *et al.* (1983) described the serpentine leafminer, *L. trifolii* as an epidermal feeder by larval feeding in the mesophyll tissue reduced photosynthetic activity and yield of the plant. Its direct damage to tomato plants was visualized as serpentine mines between the epidermal layers (Erb *et al.*, 1993). Srinivasan *et al.* (1995) described the leafminer damage as sharply curled and contorted leafmines which had a continuous black trail of frass.

Chakravarthy *et al.* (1995) estimated the range of infestation in terms of mean number of larvae per leaf ranged from 0.06 to 1.86 depending on the host, maximum being on castor (1.86) followed by tomato (1.42) and garden pea (1.21) and minimum of 0.1 to 0.6 larvae per leaf on lucern, berseem and greengram. Patil *et al.* (1997) reported that plants exposed to the pest on 10 and 20 days after sowing showed significantly higher percentage of infestation and more number of maggots affecting the plant height and biomass compared to the uninfested plant.

2.2 BIOLOGY AND MORPHOMETRICS :

2.2.1 Eggs :

Serpentine leafminer, *Liriomyza trifolii* caused serious damage by puncturing the leaves for oviposition. (Johnson *et al.*, 1983). Beri (1974) reported that as the eggs develop, they become opaque and gradually the

brownish cephalopharyngeal skeleton could be differentiated. In some species, the larvae ate the egg shell before moving into the leaf mesophyll and mortality at this stage was as high as 20 per cent.

Bethke and Parrella (1985) observed that the eggs were laid singly, but often in close proximity to each other. Parrella (1987) observed that the whitish translucent eggs were deposited through the adaxial or abaxial leaf surface and the size of these eggs increased after oviposition possibly through the imbibition of fluids from plant tissue. The period of egg development varied with temperature and ranged from 2-8 days. But incubation period varied with reference to the host also as evidenced by Chandler and Gilstrap (1987b) who have recorded an incubation period of 4.2 days on bell pepper and Chakravarthy (1993) reported that incubation period varied from 2-3 days with an average of 2.31 days on castor and 2.17 days on tomato.

The size of the egg was measured as 0.21 to 0.27 mm length and 0.11 to 0.25 mm width on tomato as recorded by many workers (Chakravarthy, 1993, Sanjeeva Rao, 1995 and Park - Jong Dae and Park, 1996) with a slight variation as on castor, which was measured as 0.25 x 0.13 mm (Chakravarthy, 1993).

2.2.2 Larvae :

The light cream coloured larva caused damage by mining into the epidermal layer of leaf. When the larva was ready to pupate it cuts a

semicircular slit on the upper or lower leaf surface usually at the end of the mine. The larva emerged with characteristic peristaltic locomotion, when it was three fourths out of its mine, the anterior portion waves about high above the leaf surface and the larva literally falls out from the leaf to ground (Oatman and Michelbacher, 1958). The matured larva was yellow with a length and width of 2.03 mm and 0.80 mm, revealed a serpentine gallery under the leaf cuticle (Park Jong Dae and Park, 1996).

Different species of leaf miners vary in their feeding habit / behaviour by feeding on different sections of the leaf mesophyll as reported Spencer (1973) and Parella *et al.* (1985) who have observed *L. brassicae* feeding in the palisade and spongy mesophyll, *L. trifolii* on the palisade mesophyll where as *L. huidobrensis* in the spongy mesophyll.

The total larval duration of many *Liriomyza* sp was as short as 4-6 days at both greenhouse and field conditions. (Fagoonee and Toory, 1984 and Leibee, 1984). As the larva develop, both the diameter of the mine and rate of mine formation increased (Fagoonee and Toory, 1984). Parrella (1987) described the shape of larva as cylindrical and maggot like which moved by peristaltic action of their hydrostatic skeleton.

Larval period varied with host which ranged from 4-6 days with an average of 5.30 days on castor and 4.65 days on tomato Chakravarthy (1993) and 5.8 days on bell pepper (Chandler and Gilstrap, 1987b). It also depends on the temperature showed variation in larval period as evidenced by

Chandler and Gilstrap (1987b) recorded 9.9, 4.4 and 3.7 days on gypsophia and 5.5, 3.7 and 2.4 days on beans at 20, 25 and 30°C.

Zoebisch and Schuster (1987b) reported that the development of larvae that hatched from eggs from tomato leaves was significantly slow than those reared on nightshade. Size of the larva was found to show an increase linearly with increasing temperature (Zoebisch *et al.*, 1992).

2.2.3 Prepupae and Pupae :

The period between larval emergence from the mine and puparium formation was referred to as the prepupae. The prepupal period was about 2-4 hours (Oatman and Michelbacher, 1958 and Leibee, 1984). Oatman and Michelbacher (1959) reported that the prepupae is negatively phototactic and positively thigmotactic.

Parrella (1987) observed that the duration of pupal stage varied inversely with temperature, but at least 50 per cent of the total developmental period of a *Liriomyza* individual was spent in this stage. Total developmental period of pupa ranged from 8 to 11 days both under greenhouse and field temperatures. Elferen and Yathom (1989) reported the pupal period of *L. trifolii* which varied with temperature and was found to be 19.9 days at 17°C, 14.7 days at 20°C, 10.4 days at 25°C and 7.8 days at 30°C.

Chakravarthy (1993) reported that no pupation occurred with in the mine where under laboratory conditions, it was seen on the surface of the

glass tube. At later stage pupa became yellowish brown in colour just before adult emergence and pupal period ranged from 6-8 days with an average of 6.95 days on castor and 6.46 days on tomato. Park Jong Dae and Park (1996) observed light brown pupa with a length and width of 1.75 mm and 0.74 mm which pupated on the soil and or on leaf surface. But (Minkenberg and Helderma, 1990 and Sanjeeva Rao, 1995) were reported that the size of pupa varied with sex of the insect where the male pupae were significantly shorter than those of females. Their length and width ranged from 1.83 and 0.92 mm in male and 1.95 and 0.97 mm in female. Minkenberg and Fredrix (1989) observed that pupal size increased with increasing nitrogen levels in tomato leaf.

2.2.4 Total developmental period :

The developmental period of leafminer differed based on the host. Chandler and Gilstrap (1987b) who have recorded the total developmental period from egg to adult of *L. trifolii* at 24°C was 20.2 days on bell pepper. Chakravarthy (1993) recorded as it was ranged from 12 to 16 days with an average of 14.50 days on castor and 13.20 days on tomato.

2.2.5 Adults :

2.2.5.1 Emergence of the adults :

Males appeared to emerge prior to females and both sexes generally

emerged during morning hours (Oatman and Michelbacher, 1958). According to Parrella (1987) adults emerged through the dorsal end of the puparium with the aid of the ptilinum and it might have taken five minutes to more than one hour with some mortality.

Artherton and Rudich (1986) and Viraktamath *et al.* (1993) were observed that adult females were greyish black with a yellow spot on thorax and red eyes. Chakravarthy (1993) observed that the well developed adult measured 1.94 to 1.69 mm in length and an average of 1.79 mm on castor while it ranged from 1.91 to 1.67 mm in length with an average of 1.77 mm on tomato. Srinivasan *et al.* (1995) described that in general the adults possessed greyish black body with an yellow spot on Scutellum and most of frons and with plum red eyes. Park-Jong Dae and Park (1996) measured length and wingspan of adult, as 1.78 mm and 3.43 mm respectively.

2.2.5.2 Sex ratio :

It was the ratio of males and females emerged from pupae. Beri (1974) recorded a sex ratio of 1:1 or a slight bias in favour of females. But variation was observed when reared on different hosts as given by Chakravarthy (1993) who had reported a sex ratio of 1.24 : 1.00 on castor and 1.13 : 1.00 on tomato.

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2.2.5.3 Premating, mating and preoviposition :

Mating took place soon after adult emergence which was completed within 24 hours (Oatman and Michelbacher, 1958). Oatman and Michelbacher (1958) and Parrella *et al.* (1983) observed that food, temperature and relative humidity influence the preoviposition period which was extended upto 5 days after adult emergence. Under greenhouse and laboratory conditions, oviposition by most females was observed within 24-48 hours after emergence.

Parrella (1987) stressed that mating could be observed at any time of the day by adults which generally occurred during early morning hours.

2.2.5.4 Feeding and Oviposition behaviour :

Beri (1974) observed that single eggs were deposited in tubular leaf punctures. After every leaf puncture, the female backed over the wound and feed from all punctures, regardless of whether or not they were used for oviposition earlier. Hence, all leaf punctures were considered as feeding punctures. Parrella and Bethke (1984) observed 4-8 days after emergence as peak period for feeding and oviposition.

Bethke and Parrella (1985) observed similar behaviour for feeding and oviposition like *L. trifolii* in *L. sativae* and *L. huidobrensis*. When a female initiated a leaf puncturing sequence, the ovipositor contacted the leaf and damage the mesophyll cells in a specific manner, created one or two different

types of leaf punctures. Parrella (1987) reported if the abdomen get twisted from side to side a large fan shaped leaf puncture would be created. A tubular leaf puncture was produced when no abdominal twisting follows the puncture and the eggs were deposited in tubular leaf punctures. Feeding and oviposition by adults appeared to occur primarily during morning hours.

Minkenbergh and Helderman (1990) recorded more than 85 per cent of oviposition occurred within 100 day degrees of eclosion when lower threshold temperature was approximately 11°C. Minkenbergh and Ohenheim (1990) found that females showed a preference to feed and oviposit on the high middle leaves within plants.

Number of oviposition punctures by the *L. trifolii* adult were 26.1 per cent in tomato and 13.3 per cent in Gerbera respectively (Park JongDae and Park, 1996). Feeding preference of *L. trifolii* was studied under laboratory conditions using cucumber, tomato, cotton and okra where the preferred ones were cucumber and tomato (Jagannatha and Viraktamath, 1997). But Jeyakumar and Uthamasamy (1998) recorded tomato was the most preferred host for oviposition among 10 different host plants tested.

2.2.5.5 Fecundity and adult longevity :

Studies on fecundity and longevity of adult of *L. trifolii* were conducted by many researchers [Oatman and Michelbacher, 1958 ; Parrella *et al.*, 1983 ; Parrella and Bethke, 1984 and Parrella, 1987] who revealed that

the egg laying capacity of an adult female varied considerably within the genus *Liriomyza*. Females generally laid majority of eggs between 4 and 10 days of adult life depending on temperature besides food source. Close association with a host plant or carbohydrate food source made females to survive for 15-20 days and males for 10-15 days. Longevity generally decreased at higher temperatures but presence of honey during rearing increased the adult longevity.

Zoebisch and Schuster (1987a) have shown that continuous exposure of adults to aphid honey dew has increased longevity. In general, females lived longer compared to males. Fecundity of *L. trifolii* varied when reared on different hosts. Zoebisch and Schuster (1987b) recorded fecundity on tomato, nightshade and groundcherry as 34.6, 31.8 and 9.1 eggs, respectively and Chakravarthy (1993) reported that the egg laying capacity of females varied from 9 to 18 eggs with an average of 13.50 eggs per female on castor and 11.00 eggs on tomato. But Saito *et al.* (1995) determined both longevity and fecundity of female adult on tomato as 3.8 days and 54.7 eggs, cherry-tomato as 5.4 days and 75.6 eggs, melon as 6.9 days and 108.0 eggs and Gerbera as 12.9 days and 156.4 eggs.

Fecundity and longevity were also correlated with the number of feeding punctures (Minkenberg, 1988). But the size of the females appeared to be independent of fecundity, longevity and development time (Minkenberg and Ohenheim, 1990).

2.3 SEASONAL INCIDENCE IN RELATION TO WEATHER PARAMETERS :

In most instances, population fluctuations were attributed to weather factors and stage of the crop. Damage inflicted by mining activity of larvae was important during cotyledon stage of plant and last stages of crop growth resulted in an increase of the leafminer population (Oatman and Michelbacher, 1958 , Johnson *et al.*, 1980 and Chandler and Thomas 1983). Chandler (1984) and Chandler and Gilstrap (1987a and b) reported that the larval population was more during reproductive period of plant growth but Lakshminarayana *et al.* (1992) observed severe pest incidence during younger stages of the crop.

Leafminers were observed to damage the crop during rainy season and the activity of leafminer started in the month of June and July and reached to its peak number by September (Ramesh, 1993). The highest population of live larva was found in the dry season (October - December 1985) ; where as the highest number of leaf mines were found towards the end of the dry season (March - May 1986) on tomato (Issa and Marcano, 1994). Sanjeeva Rao (1995) recorded the population of *L. trifolii* which varied from 1.34 to 9.4 larvae per 10 tomato leaves in different seasons. September sown tomato had heavy infestation (9.41 larvae per 10 leaves) followed by October (6.71 larvae per 10 leaves) and August (6.40 larvae per 10 leaves) where as November and December sown tomato had average leafminer population (4.73

to 4.25 larvae per 10 leaves) and February sown crop has least infestation (1.34 larvae per 10 leaves).

According to Minkenberg (1988) tomato was a suitable food plant allowing *L. trifolii* populations to increase if temperatures were above 16°C. Parrella (1987) reported that the feeding and oviposition activities were positively correlated with temperature. Minkenberg and Helderma (1990) recorded optimum temperature for development of *L. trifolii* was 25°C. A change in temperature from 20°C resulted in rapid response to the development rate and a slower response to reproduction. Saito *et al.* (1995) estimated the threshold temperatures for egg, larval and pupal development as 8.0, 8.9 and 10.1°C respectively and the upper lethal temperature was about 35°C for the pupal stage. Photoperiod has no effect on the developmental period of the pest at constant temperatures of 15°C and 20°C. Sanjeeva Rao (1995) reported that maximum and minimum temperatures had a negative relation and relative humidity had a positive relation on the occurrence of *L. trifolii*. But Park Jong Dae and Park (1996) observed more feeding activity of the larva at 20°C. Ozawa *et al.* (1999) observed no significant difference in egg hatching with temperatures unlike the pupation and adult emergence rates, where fecundity varied from 3.3 at 15°C to 29.4 at 25°C and female longevity was negatively correlated with temperature.

Singh *et al.* (1991) reported that rain has adverse effect on larval populations. The first instar larvae showed maximum vulnerability to the

rains, the entire population being killed by a single day's heavy rain where as only 50 per cent of the final instars were affected by one day's rain. Four day's continuous heavy rains totally destroyed all the third instars within the leaves.

2.4 VARIETAL REACTION :

Very little information was available on the screening of tomato varieties against serpentine leafminer. Schuster *et al.* (1979) examined *Lycopersicon* species accessions and reported that *Lycopersicon hirsutum* F. *typicum* and *L. hirsutum* F. *glabratum* were highly resistant and almost completely immune to leafminer attack. Bethke and Parrella (1985) reported that based on behavioural studies of *L. trifolii* on tomato, it has been assumed that antibiosis character to adults as well as larvae remained same, as feeding by larvae always preceded egg laying. According to Laterrot *et al.* (1987) the *Lycopersicon cheesmanii* accession was reported to be highly resistant to both *L. sativae* and *L. trifolii*.

Hawthorne *et al.* (1992) observed that oviposition and adult feeding by the agromyzid *L. trifolii* on *Lycopersicon pennellii* and its F₁ hybrid with *L. esculentum* were significantly less compared to cultivated tomato.

When *Lycopersicon* interspecific hybrids and species inbreds were examined for resistance to the leafminer, *L. pennellii* Correll, *L. cheesmanii* Riley interspecific hybrids and one of *L. hirsutum* F. *glabratum* Muller had

the highest levels of resistance. Non-preference persisted for all the interspecific hybrids at maturity stage of the crop (Erb *et al.*, 1993).

The application of purified 2,3,4-tri-o-acylglucoses to *L. esculentum* significantly decreased feeding and oviposition on *L. esculentum* leaf lets by 61-99 per cent (Hawthorne *et al.*, 1992).

2.4.5 BIOCHEMICAL BASIS OF RESISTANCE :

Very little work has been done regarding the role of biochemical constituents of tomato leaves in relation to resistance against the leafminer attack.

Ipe M Ipe and Sadaruddin (1984) reported that the concentration of secondary plant products like tannins (Phenolic derivatives) and phenolic compounds which increased with the age of the host plant has showed repellent activity against the pest. Low phenolic content in leaves of the host plants made them more vulnerable to high rate of attack by *Liriomyza brassicae* Riley.

Hawthorne *et al.* (1992) reported the principal component of type IV glandular trichome exudates from *Lycopersicon pennellii* provided a large reduction (91%) in leaf punctures and mines by leafminer, *L. trifolii*.

2.5 MANAGEMENT OF *Liriomyza trifolii* Burgess :

Control of leafminers with insecticides was usually found complicated due to insects biology and larval habit of remaining within the leaf mines itself. Continuous use of insecticides has been found responsible for outbreaks of *L. trifolii*, as these were more toxic to parasitoid complex, which exercise a check on leafminers. (Oatman and Kennedy, 1976 and Parrella *et al.*, 1984).

Murthy and Prasad (1996) recorded highest reduction of leafminer incidence when seed was treated with chlorpyrifos 1.5 per cent at 3 g per kg followed by foliar application of two per cent NSKE on castor.

Rosaiah (2001) conducted a field experiment to evaluate the efficacy of different plant products along with seed dresser and chemical insecticides against *L. trifolii*. He indicated that the neem seed kernal extract at five per cent was found promising effect followed by Karanj oil and carbosulfan seed treatment, whereas spraying of monocrotophos failed to control the pest.

Chandler (1985) used yellow traps 30 cm above ground level which trapped significantly more number of both the adults of *L. trifolii* than those placed at 60, 90, 120 and 150 cm. Robin and Mitchell (1987) placed yellow sticky-cup traps close to the plant canopy without direct contact with leaf which were found effective in monitoring the pest in watermelon. Aushser (1997) documented that insect proof screens were considered one of the major elements of integrated pest management for protecting tomato from insect pests and reducing chemical pest control on cover crops such as vegetables,

flowers and fresh herbs. Ozawa *et al.* (1998b) reported that the yellow sticky trap was more reliable than the pupal tray for estimating densities of *L. trifolii* larvae and mines on tomato. Antignus (1998) reported bionet 50 mesh screens may serve as improved barrier and is sufficient to interfere with the penetration of wide range of insect pests including leafminers.

Stein and Parrella (1985) reported the efficacy of neem seed kernal extract 0.2 to 0.4 per cent and commercial neem products such as neemazal, Margosan-D in reducing the pest where carbosulfan and imidacloprid were proved to be toxic to prepupae under laboratory conditions but failed to perform well under field conditions. Then Larew *et al.* (1985) recorded 89 per cent mortality of prepupae of *L. trifolii* with NSKE 0.4 per cent when used as soil drench. Knodel *et al.* (1986) observed that when neem seed kernal extract and a registered formulation Margosan - O were sprayed on foliage, the toxin has adversely affected the development of internally feeding leafminers. Parkman and Pienkowski (1990) reported that the neem seed kernal extract was effective in controlling *Liriomyza* on different crops.

According to Patanik (1997) tested six formulations of neem and their effect on *L. trifolii* on tomato. Application of multineem was found to be most effective in reducing the leaf infestation by 82.2 per cent. Jeyakumar and Uthamasamy (1997) reported effect of botanicals viz., neem oil (3%), neem seed kernal extract (5%) and Iluppai oil (3%) which had significantly high mortality effect. But neem oil (2%), neem seed kernal extract (2.5%) and

pungam oil (3%) were found ineffective in causing mortality of *L. trifolii* larvae. Choudary and Rosaiah (2001) reported that plant products NSKE 5 per cent and neemazal 0.5 per cent were effective against the leafminer in tomato.

Insect growth regulators like cyromazine and RO 13-5223 when sprayed, resulted in more than 80 per cent control of *L. trifolii*. Cyromazine acted on larvae within mines and significantly reduced larval emergence and pupation. In contrast RO 13-5223 had no effect on larval emergence and pupation but instead, reduced adult emergence significantly (Parrella *et al.*, 1983). When evaluated the growth regulators MK 936 and cyromazine were reported as effective in controlling the pest under field conditions compared to relatively lower mortality of adults in laboratory. But both compounds induced high mortality in one and three days old larvae (Schuster and Everett, 1983). Robb and Parrella (1984) reported that application of insect growth regulator methoprene resulted in decreased fecundity and complete infertility. Sterility index of 88.8 to 100.0 was observed in case of third stage female larva. When newly enclosed female larvae were exposed to highest dosage of methoprene, resulted in high sterility.

Cox *et al.* (1995) reported toxicity of avermectin, abamectin and MK-0244 on larvae and adult of *L. trifolii*. Larvae were found more sensitive to avermectins than adults. Adult mortality was expressed sooner with abamectin compared to MK-0244 upto 72 hours of exposure later both were

equally toxic. According to Patel *et al.* (1998) application of cyromazine at 225 g a.i per ha was most effective for control of *L. trifolii* on tomato. Soil application of endosulfan at 140 g a.i. per ha and dimethoate at 120 g a.i per ha was found to be as effective compared to two lower doses of cyromazine (150 and 75 g a.i per ha).

When the efficacy of 12 insecticides against first and third stage larvae of *L. trifolii* was tested, with the use of larval emergence and pupation as the criteria for efficacy, most insecticides provided greater mortality of first stage larvae except chlorpyrifos 25 WP which was found more effective against third stage larvae (Parrella *et al.*, 1982). Susceptibility of several populations of *L. sativae* and *L. trifolii* leafminers in Hawaii to pyrethroids, permethrin and fenvalerate was studied where *L. trifolii* was significantly more tolerant to fenvalerate than permethrin (Mason *et al.*, 1987). Richter and Tsegaye (1988) reported that methamidophos, dimethoate and deltamethrin were highly toxic to larvae of *L. trifolii*. Lindquist and Casey (1988) recorded ethion and monocrotophos reduced damage and also the number of pupae and emerging adults and pyrazophos affected the development of new generations. Sanderson *et al.* (1989) used yellow sticky cards coated with thin layer of insecticide-sticker mixtures (permethrin and chlorpyrifos) to determine insecticide resistance in adult *L. trifolii*. The pest mortality has increased with increasing amounts of sticker on the cards and with increasing adult age. Males were slightly more susceptible than females and small flies were slightly more susceptible than large flies. Lyra *et al.* (1989) reported that

application of 12 insecticides against *Liriomyza* from seedling to harvest revealed that deltamethrin, azinphos-ethyl, parathion-methyl + meviphos were found to be the most effective insecticides against leafminer.

Viraktamath *et al.* (1993) found oxydemeton-methyl, acephate and neem seed kernal extract to be effective against the leaf miner on vegetable crops. Jagannatha (1994) used different methods of applications of insecticides where foliar spraying of neem seed kernal extract 4 per cent and triazophos were found effective in controlling larvae whereas chlorpyrifos, deltamethrin and fenvalerate in reducing adult emergence from soil which was drenched. According to Sanjeeva Rao (1995) application of carbofuran @ 1.0 kg a.i per ha to nursery beds provided effective control of the *L. trifolii* whereas in transplanted crop, fenvalerate (0.02%) applied from date of transplanting to 75 days after transplanting with 15 days interval offered effective control. Further application of chlorpyrifos (0.04%) and fenvalerate (0.02%) to soil surface resulted in reduced adult emergence. Jyani *et al.* (1995) reported cyfluthrin (0.005%), dimethoate (0.03%) and endosulfan (0.035%) were found effective in reducing leaf damage. However endosulfan and dimethoate gave the best cost : benefit ratio. According to Pawar *et al.* (1996) seven insecticides including cypermethrin 25 EC, endosulfan 35 EC, dimethoate 30 EC, dichlorvos 76 EC, deltamethrin 2.8 EC, malathion 50 EC and phorate 10 G and neem seed kernal extract have significantly reduced infestation of *L.trifolii*.

Rushtapakornchai and Petchuichit (1996) reported that two applications of bifenthrin, fipronil, fenpropathrin and acephate gave significant control of *L. trifolii*. Jeyakumar and Uthamasamy (1997) reported that among insecticides, phosalone, chlorpyrifos and neem oil 50 EC (0.3%) recorded high larval mortality 24 hours after treatment. Ozawa *et al.* (1998a) tested the efficacy of granular insecticides viz., nitenpyram granules, acephate and acetamiprid granules which were applied that at different timings like in the planting holes and to soil just after planting. Their results revealed that nitenpyram granules when applied in the planting holes were more effective than acephate and acetamiprid granules. Nitenpyram granules was as effective as acephate granules when applied to soil just after planting. Choudary and Rosaiah (2001) reported that all the insecticides including carbofuran, acetamiprid, flufenoxuron and chlorpyrifos were significantly superior and carbosulfan, imidacloprid and B.t formulation were found ineffective in reducing the number of miner population per branch.

Alverson and Gorsuch (1982) reported application mixture of pyrethroids and encapsulated methylparathion showed greater efficacy than chemical alone. Fenvalerate treatments provided moderate control and oxydemeton methyl showed no efficacy against the leaf miner.

Hanna *et al.* (1987) reported nitrogen fertilizer level did not significantly affect leafminer density, whereas frequency of permethrin application has significantly affected leafminer density.

Singh *et al.* (1991) reported proper irrigation and flooding could be used effectively to destroy pupae in soil, 3-4 days flooding at the appropriate time before sowing could destroy almost 95% of pupae in soil. Jeyakumar and Uthamasamy (1996) observed low infestation of miner on cotton which was grown in rice-fallow-cotton cropping system.

Chapter - III

Materials and Methods

CHAPTER - III

MATERIALS AND METHODS

To study biology including morphometrics, seasonal incidence and evaluation of different management strategies for their efficacy on serpentine leafminer (SLM), *Liriomyza trifolii* Burgess as well as screening of tomato varieties for the reaction of SLM were carried out in laboratory and fields at insectary, S.V.Agricultural College, Tirupati during 2000-2001. The materials used and methods followed for the above mentioned objectives are presented in this chapter.

3.1 BIOLOGY OF *Liriomyza trifolii* (B) ON TOMATO :

Biology of the SLM was studied during October - December 2000, under laboratory conditions in the Insectary, S.V.Agricultural College, Tirupati. For this a thin layer of moistened cotton was placed at the bottom of the petridish, over which filter paper was spread. In these petridishes, the mined leaves of tomato variety "Pusa Ruby" were kept so that the dorsal surface remaining upperside (Plate 1). Moist condition within the petridish was maintained continuously by periodical wetting of cotton to prevent the leaves from drying. The prepupae and pupae coming out from the leaf mines were transferred to vials with a fine camel hair brush for adult emergence. Adults that emerge from the pupae were used for biology studies. After the



Plate 1. Technique used for studying biology of SLM, *Liriomyza trifolii* (B)

adult emergence two per cent sugar solution was provided as a source of food material for them to document the longevity of adults.

3.1.1 Developmental biology and fecundity :

Three transparent jars were used for studying the mating behaviour of adults. Immediately after emergence (< 24 hr) 10 pairs of male and female flies were placed inside the jar containing second or fourth leaf stage tomato seedlings for observing oviposition. The turgidity of the leaves was maintained by keeping the plants in small vial containing water which is plugged with cotton. The cotton swabs dipped in two per cent sugar solution were provided inside the jar as a source of food material for adults.

The behaviour of adult with regard to pre-mating, mating, oviposition period and fecundity was observed. Exposed leaves were replaced daily until the death of adults for knowing the average egg laying capacity of females.

3.1.2 Egg :

For locating the eggs the exposed leaves were stained in Lactophenol cotton blue solution. The leaves were dipped in boiled lactophenol cotton blue solution for one to two minutes which were then allowed to cool for three to four hours. Excess stain was removed by keeping them with free lactophenol and then the leaves were transferred to small petridishes containing water. These leaves were examined under dissecting microscope at 200 x magnification.

Egg period was recorded from a day after exposure of plants to the adults to the initiation of mines on leaves. The length and width of 20 eggs were measured with the help of ocular and stage micrometers.

3.1.3 Larvae :

The neonate larvae immediately after hatching from eggs were observed by following the staining technique. The length and width of each stage larvae (sample size '20' larvae) were measured under ocular and stage micrometers with 50 x magnification. Larval period was recorded from the date of initiation of mines on the leaves upto the emergence of final instar larva from the leaf mines for pupation.

3.1.4. Prepupae and Pupae :

Prepupal period was recorded from the date of exit of final instar larvae to the formation of puparia and pupal period was recorded from the date of pupation to adult emergence. The length and width of 20 pupae were measured with ocular and stage micrometers at 50 x magnification.

3.1.5 Sex ratio :

Set of pupae i.e. 30 - 30 - 30 obtained from field infested mined leaves, were kept in three different transparent jars and observed for emergence of males and females. Sex ratio was calculated based on the number of males and females emerged from pupae.

3.1.6 Adult longevity :

Adult longevity was recorded by keeping the flies in three different transparent jars numbering 20 each and provided a cotton swab dipped in two per cent sugar solution as a source of food material for them. Data on number of days during which adults have survived was recorded as adult longevity period.

3.1.7 Sex differentiation :

The female and male sexes were identified by the size of the abdomen and presence of prominent retractile ovipositor in females. For this, flies were placed in 10 per cent cold KOH, overnight for maceration. After that, the flies were transferred to tap water, the abdomen was separated from the body and then pressed gently with the help of a pair of bent needles to remove the dissolved tissues. Two to three washings with water were continued to remove all KOH traces, then kept in glycerol and were observed for the sexual differentiation under microscope at 50 x magnification.

3.2 SEASONAL INCIDENCE :

Seasonal incidence of serpentine leafminer *Liriomyza trifolii* (B) was documented from July 2000 to June 2001 on tomato plants grown or raised at insectary, S.V.Agricultural College, Tirupati. For this tomato was raised in pots of 27 cm diameter and height of 25 cm in which seedlings were

maintained upto 45 days. Observations in terms of stage of the plant at initial mining, larval population and per cent miner infestation were recorded on 10 randomly selected plants daily. The data taken for week days was summed and recorded as average for the standard week of the year.

The weather parameters viz., maximum and minimum temperatures, relative humidity and rainfall were recorded continuously during the period of study. The data were correlated with larval population of tomato leaf miner and per cent miner infestation.

3.3 EFFECT OF CROP PHENOLOGY ON *Liriomyza trifolii* Burgess INFESTATION

The study was conducted under field conditions at insectary, S.V.Agricultural College, Tirupati, during *rabi* season of 2000-2001. For this, tomato variety "Pusa Ruby" was selected and the crop was grown adopting the normal package of practices excluding insecticide application during the studies. Crop was maintained from germination to harvest and data was recorded at weekly intervals. Each week was treated as an individual observation that was replicated on three plots. For nursery each replicated plot size was 2 x 2m and for transplanted crop, 5 x 4 m plot size was maintained. In each plot 10 plants were randomly selected and tagged. The data was recorded in terms of number of leaves infested with mines per branch, number of larvae per branch and number of mines per branch.

The data in relation to number of leaves infested, number of larvae and number of mines per branch thus obtained were transformed into square root values and analysed statistically. Significance of different treatments was tested by F-test at 5 per cent level of probability. The critical difference worked out for the treatments was utilised for comparing the treatmental means.

3.3.1 Influence of mechanical barrier on *L. trifolii* (B) in relation to crop stage at field level

Field experiment was conducted with the use of 60 mesh net in different stages of tomato variety Pusa Ruby against *L. trifolii* in the insectary, S.V.Agricultural College, Tirupati during *rabi* season of 2000 to 2001. Six treatments were laid out in a randomised block design including unprotected control and each treatment was replicated four times with a plot size of 5 x 4 m. In each plot 10 plants were tagged at random and per cent of miner infestation per plant were recorded.

$$\text{Per cent of plants with miner infestation} = \frac{\text{No. of plants infested with leafminer}}{\text{Total no. of plants}} \times 100$$

List of treatments imposed :

- T₁ Nursery protection upto 30 days after sowing
 T₂ Protection in 30 to 60 days after sowing

- T₃ Protection in 60 to 90 days after sowing
- T₄ Protection in 90 to 120 days after sowing
- T₅ Protection in all stages
- T₆ Unprotected check

3.4 VARIETAL REACTION OF TOMATO AGAINST SLM :

Response of seven tomato varieties to *Liriomyza trifolii* (B) was studied under field conditions at insectary, S.V.Agricultural College, Tirupati during *rabi* season of 2000-2001. The material selected for screening included three varieties i.e. S-22, PKM-1, Arka Vikas, and three hybrids i.e. Hybrid cross - 08, Hybrid cross - 17 and Tomato Ruchi. Local cultivar (Pusa Ruby) was involved as check. For these studies tomato crop was raised both in nursery and mainfield in a randomised block design with three replications.

3.4.1 Raising of nursery :

Nursery was raised in November - December, 2000. Seven varieties were taken as treatments and each variety was replicated three times. For sowing of seeds in the nursery, beds of size 2 x 2 m were prepared with clay soil mixed with farm yard manure. Seeds were sown in rows on the bed so that a total of 100 plants remain in each bed and in each bed 10 plants were tagged at random for recording observations on miner infestation. The level of leafminer incidence in terms of number of plants showing mines as well

as leaves infested with miner per plot was recorded. Data on per cent miner infestation and larval preference of miner on different tomato varieties were calculated based on number of larvae per branch.

3.4.2 Main field :

Tomato seedlings of 30 days old from the nursery bed were pulled and transplanted into mainfield during December 2000 and were maintained upto February 2001. Each variety was treated as a treatment and was replicated three times. Individual plots of size 5 x 4 mt were prepared mixed with DAP. In each plot 10 plants were tagged at random for recording data. Three leaves of uniform size were selected at random from each of the tagged plant and number of plants as well as number of leaves infested with miner in each replicated plot were recorded. Per cent miner infestation and larval preference in terms of number of mined leaves and number of larvae per branch in each tagged plant on different tomato varieties were calculated.

The observations were recorded at weekly intervals upto 7 days after transplanting. The data recorded in terms of larval development mining of leaves was taken into consideration for interpreting the pest in relation to crop variety.

3.4.3 Statistical analysis :

The mean per cent leaf miner infestation was calculated for all the treatments in both nursery and mainfield by using the following formula.

$$\text{Per cent of plants with leaf miner infestation} = \frac{\text{No. of plants infested with leafminer}}{\text{Total no. of plants}} \times 100$$

The per cent miner infestation thus obtained were transformed into angular values and analysed statistically. Significance of different treatments was tested by 'F' - test at five per cent level of probability. The critical difference was worked out for significant treatments and was utilised for comparing the treatmental means.

Based on per cent infestation, the varieties were grouped into the following four grades (Reddy, 1988).

Grade	Per cent infestation (%)
Resistant (R)	0-10
Moderately resistant (MR)	10 - 30
Susceptible (S)	30 - 50
Highly susceptible (HS)	50 - 100

3.4.4 Estimation of total phenols on different varieties of tomato :

On the basis of varietal preference by SLM, *L. trifolii* the field tested seven tomato cultivars were analysed under laboratory conditions for their

phenol contents. To assess the total phenols, samples of green leaves of the plant of the age 45 days after sowing were collected when the miner incidence was at peak level showing more than 50 per cent mining in leaves i.e., in January 2001. Leaf samples were collected from each replicated plot and grinded separately with mortar and pestle. The total phenol content in leaves of seven tomato varieties was estimated by using the procedure given by Sadasivan and Manickam (1996).

For each sample exactly 1.0 gm of leaf material was taken and grinded it with a mortar and pestle in 10 ml of 80 per cent ethanol. Centrifuged the homogenate materials at 10,000 rpm for 20 minutes. The supernatant liquid was taken and re-extracted the residue with 5 ml of 80 per cent ethanol. Once again the material was centrifuged and pooled the supernatant. Supernatant was evaporated to dry and dissolved the residue in a known volume of distilled water (5 ml). Around 2.0 ml of aliquot was taken into a test tube and volume was made up in each tube to 3 ml with distilled water to which 0.5 ml of folin ciocaltue reagent was added. Two millilitres of 20 per cent sodium carbonate solution was added to each tube and after three minutes the material was thoroughly mixed and the tubes placed in boiling water for exactly one minute, cooled and measured the absorbance at 650 nm against a reagent blank. The standard curve was prepared using different concentrations of catechol.

Preparation of reagents :

- a. Ethanol (80%) was prepared by adding 80 ml of absolute alcohol in a beaker and made upto 100 ml by using distilled water.
- b. Sodium carbonate (20%) was prepared by adding (20) grams of sodium carbonate in 100 ml of distilled water.

3.5 EVALUATION OF DIFFERENT MANAGEMENT STRATEGIES:

To evaluate the efficacy of different management strategies including chemical pesticides, botanicals and mechanical barrier in controlling SLM, *Liriomyza trifolii* (B) under field conditions a trial was conducted both in nursery stage and transplanted crop stage under field conditions at insectary, S.V.Agricultural College, Tirupati during *rabi* season of 2000-2001. The details of chemicals employed in the present investigations were given in Table 1. The treatments were imposed in a randomized block design.

3.5.1 Nursery stage :

The test insecticides i.e. triazophos, neem seed kernel extract (NSKE) and imidacloprid, mechanical barrier (60 mesh net) and untreated control were evaluated and the experiment was laid out in a randomised block design with five treatments including control, each replicated four times during February - March 2001. The size of nursery bed for each replicated plot was 2 x 2 m.

3.5.1.1 Recording of data :

In the beginning of the experiment five plants were randomly selected in each replicated plot and tagged the branch in each selected plant. Imidacloprid was used as a seed treatment chemical and other chemicals were sprayed after noticing the 50 per cent leaf infestation with the pest in terms of mined leaves. Observations were made on number of larvae per branch one day before and 1, 3, 5 and 10 days after the application of insecticides. Mechanical barrier was kept before the germination of seedlings.

3.5.2 Mainfield :

The experiment was laidout in a randomized block design with 13 treatments including two controls i.e. one is untreated check and another was pre-protected control in nursery each treatment was replicated three times with a plot size of 5 x 4 m. A schedule of two sprays was adopted. The first spray was given in synchrony with the build up of miner infestation showing 50 per cent mining in transplanted crop and another spray was given at an interval of 15-20 days after the first spray. This experiment was laid out during August - September, 2001.

List of treatments imposed in mainfield :

- T₁ - Seed treatment with imidacloprid (Gouche) 5 gm/kg seed.
- T₂ - Use of botanicals like neem seed kernel extract (NSKE) (5%)

- T₃ - Azadirachtin (Aza) (0.15%)
- T₄ - Annona seed extract - 0.031%
- T₅ - Synthetic chemical triazophos (0.05%)
- T₆ - Synthetic chemical profenophos (0.05%)
- T₇ - Seed treatment + NSKE (5%)
- T₈ - Seed treatment + Azadirachtin (0.15%)
- T₉ - Seed treatment + Annona seed extract (0.031%)
- T₁₀ - Seed treatment + triazophos (0.05%)
- T₁₁ - Seed treatment + profenophos (0.05%)
- T₁₂ - 60 mesh net as mechanical barrier in nursery
- T₁₃ - Untreated check

3.5.2.1 Recording of data :

Observations were recorded on five randomly selected and tagged plants in each replication, a day prior to spray and 1, 5, 10 and 20 days after each spray in respect of per cent damaged leaves in a branch per plant and total number of larvae on all leaves of the branch. The twentieth day observation was taken as the precount for the next round of insecticide application.

3.5.3 Statistical Analysis :

The mean per cent reduction or mortality of the larval population over precount was calculated for all the treatments in nursery stage by using the following formula.

$$\text{Per cent larval population reduction (mortality)} = \frac{\text{Larval population before spraying} - \text{Larval population after spraying}}{\text{Larval population before spraying}} \times 100$$

The mean per cent mortality of the population over untreated check was calculated for all the treatments in the two sprayings by using the following formula.

$$\text{Per cent larval population reduction} = \frac{\text{Number of larva in untreated check} - \text{Number of larva in treatment}}{\text{Number of larva in untreated check}} \times 100$$

Cumulative efficacy of all the treatments was also worked out from the two sprayings. The percentage values thus obtained were analysed statistically after converting them into angular transformation values. The data were analysed by Fischer's analysis of variance in a simple randomized block design. Significance of different treatments was tested by F-test at 5 per cent level of probability. The critical difference was worked out for significant treatments and was utilised for comparing the treatments.

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Table 1 : Details of insecticides, botanicals and mechanical barrier used in the experiment

S. No.	Common name	Concentration	Trade name	Formulation	Source of Supply
1.	Profenophos	0.05%	Curacron	50 EC	Novartis India Ltd., Mumbai - 20
2.	Triazophos	0.05%	Hostathion	40 EC	M/s Hoechst Schering Agro - Evo Ltd., Mumbai-93
3.	Imidacloprid	5 gm/kg seed	Gouche	70 WS	Bayer (India) Ltd., Mumbai
4.	Neem seed kernal extract	50 gm / lit of water	—	5%	Extracted in the laboratory using solvent
5.	Azadirachtin	5 ml / lit of water	AZA	0.15% EC	Fortune Bio-Tech Ltd. Raigir Village, Bhongir Mandal, Nalgonda (Dist.) A.P.
6.	Annona seed extract	0.31 gm / lit of water	—	0.031%	Extracted in the laboratory using solvent
7.	Mechanical barrier (60 mesh net)	—	—	—	—
8.	Untreated check	—	—	—	—

Chapter - IV

Results

CHAPTER - IV

RESULTS

The results of the investigation carried out on the biology, seasonal incidence, screening of tomato varieties for the reaction of leafminer infestation and management strategies are presented in this chapter under different headings.

4.1 BIOLOGY OF SERPENTINE LEAFMINER, *Liriomyza trifolii*

Burgess :

Studies on biology were carried out on the leaves of tomato variety Pusa Ruby under laboratory conditions during October - December 2000. During this period the room temperature was recorded as 25.9°C.

Observations were made on external morphological features, duration and morphometrics of different life stages of leafminer viz., egg, larval instars, prepupa, pupa and adult stages of the pest. The studies were extended to sex differentiation, premating and mating period and fecundity of adult flies. The data on morphometrics and duration of different stages of *L. trifolii* were presented in tables 2 and 3 respectively.

4.1.1 Egg :

Initial oviposition was observed at second to fourth leaf stage of the crop. The female moth laid about 10-15 eggs either singly or in close proximity which were pearly whitish and translucent in colour. Mostly eggs were laid on the upper leaf surface (Plate 2). The adult female inserted eggs into the mesophyll tissue of leaf in the tubular leaf punctures made by its ovipositor. Eggs were found oval and tubular in shape but not visible to naked eye and could be observed only through microscope. When the leaves with eggs were stained with lactophenol cotton blue stain, eggs appeared as bluish in colour. Oviposition was completed within 48 hours after adult emergence. Incubation period varied from two to four days with an average of 2.9 ± 0.83 days. The eggs on an average were measured about 0.19 ± 0.02 mm length and 0.11 ± 0.01 mm width.

4.1.2 Larvae :

The larval period varied from three to five days and an average of 4 ± 0.77 days. The larva undergoes three moults before the pupal stage, where the larva was found cylindrical and maggot like. The anterior end of larva was tapering without distinct head capsule, whereas the posterior end was truncated.

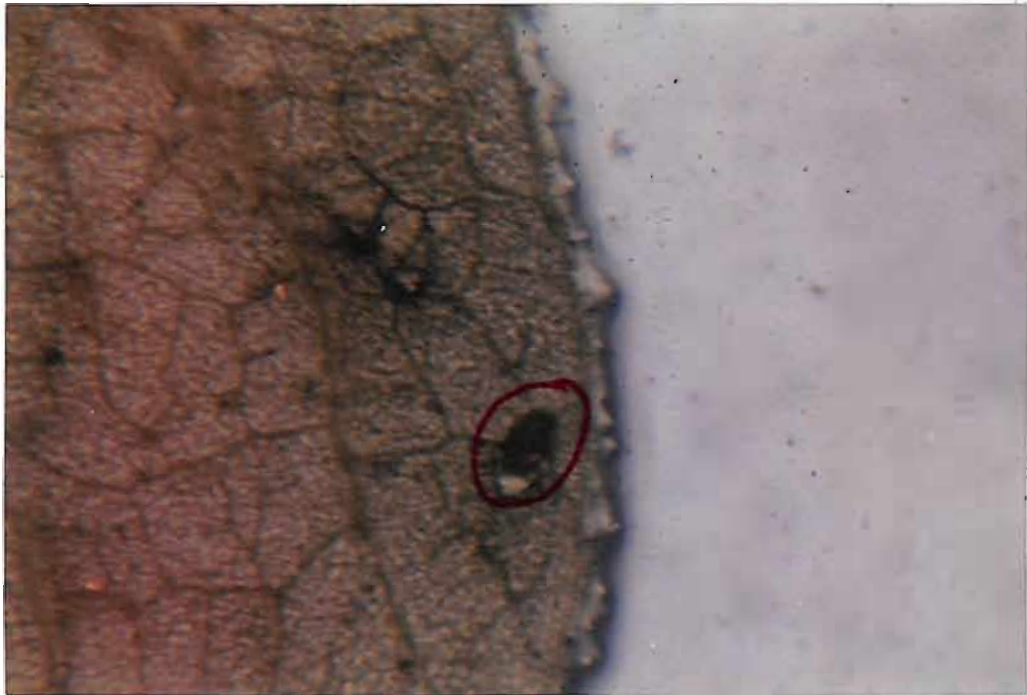


Plate 2. Egg of SLM, *Liriomyza trifolii* (B)

The newly hatched or first instar larva was pale greenish in colour, not visible to naked eye and observed only by staining (Plate 3). It was measured on an average of having 0.57 ± 0.07 mm length and 0.14 ± 0.02 mm width.

The second instar larva was greenish in colour remaining within the leafmine (Plate 4). It was measured on an average of 1.38 ± 0.07 mm length and 0.37 ± 0.04 mm width.

The third instar larva was yellowish in colour (Plate 5) which was measured on an average 2.05 ± 0.16 mm length and 0.53 ± 0.04 mm width. Before pupation, larva comes out of the leafmine and gets pupated in soil.

4.1.3 Prepupae :

The body of full grown larva of leafminer before pupation, remain yellow in colour, greatly contracted and thickened and retained in its last larval skin (Plate 6). During this period larva did not feed and gradually shrunken to the size of future pupa. The mean prepupal period was observed to be 3.25 ± 0.24 hours.

4.1.4 Pupae :

The larvae when reared in the laboratory, pupated on the surface of the glass tubes and on the leaf surface, but never it was observed within the mine. The freshly formed pupa was golden yellow in colour which turned to light yellow (Plate 7). The last stage pupa became yellowish brown in colour



Plate 3. First instar larva of SLM, *Liriomyza trifolii* (B)



Plate 4. Second instar larva of SLM, *Liriomyza trifolii* (B)



Plate 5. Third instar larva of SLM, *Liriomyza trifolii* (B)



Plate 5. Third instar larva of SLM, *Liriomyza trifolii* (B)



Plate 6. Prepupa of SLM, *Liriomyza trifolii* (B)



Plate 7. Pupa of SLM, *Liriomyza trifolii* (B)

just before adult emergence. Pupal period varied from 8-10 days with an average of 9 ± 0.83 days. The pupa on an average was measured about 1.59 ± 0.07 mm length and 0.73 ± 0.03 mm width.

4.1.5 Total developmental period :

Total developmental period from egg to adult varied from 13 to 20 days with an average of 16.6 ± 2.73 days (Table 3).

4.1.6 Adults :

Adult emerged through a slit on the dorsal anterior end of the puparium by breaking along preferred weak lines with the help of its ptilinum and this process of emergence was completed within 12 to 15 minutes. The body of newly emerged adult was fully sclerotized and became coloured within 30-40 minutes after emergence. Most of the adults were found to emerge during morning hours of day between 6 to 9 am and some are in the evening hours between 4 to 6 pm.

The adult was a tiny fly and resemble in appearance with that of housefly having a distinct head, thorax and abdomen. It was a greyish black fly having an yellow to pale yellow spot on the thorax. Eyes were brownish to plum red and abdomen has alternate yellow and black stripes. The forewings were thin, hyaline and transparent with distinct wing venation. The hind wings were modified to form halteres (Plate 8). Females were larger than



Plate 8. Adult fly of SLM, *Liriomyza trifolii* (B)

Table 2 : Morphometrics of the life stages of SLM, *Liriomyza trifolii* (B) on tomato

(Average of 20 individuals)

S. No.	Stage of the insect	Measurements (mm)		Mean	SD	SEM
		Minimum	Maximum			
1. Egg						
	a. Length	0.16	0.22	0.19	0.022	0.007
	b. Width	0.09	0.13	0.11	0.012	0.004
2. I instar larva						
	a. Length	0.44	0.64	0.57	0.072	0.023
	b. Width	0.13	0.19	0.14	0.025	0.008
3. II instar larva						
	a. Length	1.28	1.53	1.38	0.077	0.024
	b. Width	0.32	0.44	0.37	0.045	0.014
4. III instar larva						
	a. Length	1.92	2.27	2.05	0.160	0.050
	b. Width	0.48	0.64	0.53	0.048	0.015
5. Pupa						
	a. Length	1.50	1.73	1.59	0.073	0.023
	b. Width	0.70	0.80	0.73	0.038	0.012
6. Adult female						
	a. Abdomen length	0.73	0.93	0.81	0.061	0.019
	b. Wing span	2.20	2.43	2.33	0.072	0.023
	c. Body length	1.72	1.88	1.80	0.050	0.018
7. Adult male						
	a. Abdomen length	0.64	0.80	0.69	0.049	0.015
	b. Wing span	2.08	2.27	2.14	0.063	0.020
	c. Body length	1.53	1.76	1.61	0.065	0.020

SD = Standard deviation

SEM = Standard error mean

males. Female abdomen was large, stout and was generally recognised by the presence of a prominent retractile ovipositor (Plate 9). The female and male adult flies possessed an average body length of 1.80 ± 0.05 mm and 1.61 ± 0.06 mm, abdomen length of 0.81 ± 0.06 mm and 0.69 ± 0.04 mm and an average wingspan of 2.33 ± 0.07 mm and 2.14 ± 0.06 mm, respectively.

The male to female sex ratio was observed to be 1:1.14.

The pre-mating interval was recorded as 8-10 hours with an average of nine hours and the adults laid eggs within two days after emergence. Mating was observed during day time and mating period varied from 40 to 60 minutes.

4.1.6.1 Feeding, oviposition and adult longevity :

The leaf puncturing, feeding and oviposition behaviour of *L. trifolii* when observed, the leaf punctures were found tubular in shape and eggs were deposited within these tubular leaf punctures. Adult females feed on plant sap from these punctures whereas the males were unable to create their own punctures, but feed from punctures created by females.

The fecundity of female varied from 10-15 eggs with an average of 12.5 eggs per female.

The adult longevity was 10-12 days with an average of 11 ± 0.77 days, when two per cent sugar solution was provided as food source to them.



Plate 9. Male and female abdomen of SLM,
Liriomyza trifolii (B)

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Table 3 : Duration of different developmental stages of SLM, *L. trifolii* (B) on tomato (Average of 10 sample)

S. No.	Stage of the insect	Duration		Mean	SD	SEM
		Min.	Max.			
1	Ovipositional period (days)	2	4	2.9	0.83	0.26
2	Larval period (days)	3	5	4	0.77	0.24
3	Prepupal period (hours)	2.5	4	3.25	0.24	0.07
4	Pupal period (days)	8	10	9	0.83	0.26
5	Total developmental period (days)	13	20	16.6	2.73	0.86
6	Adult longevity (days)	10	12	11	0.77	0.24
7	Premating period (hours)	8	10	9		
8	Mating period (min.)	40	60	50		
9	Fecundity (number) (Eggs / Female)	10	15	12.5		
10	Sex ratio (M:F) (number)	14 (M)	16 (F)	1:1.14		

SD : Standard deviation

SEM : Standard error mean

4.1.7 Nature and Symptoms of Damage :

Initial mining was observed 10-15 days after sowing i.e. from fourth to sixth leaf stage of the crop. The newly hatched larva was found to feed on the mesophyll tissue of the leaf causing serpentine and blotch like mines on the upper surface of the leaf (Plate 10). The mine caused by the larva was initially very narrow and became enlarged gradually as age of the larva increased and subsequently at the end of the mine a hood like mark was formed which has indicated the end of the larval stage. The mines appeared as a transparent lines in which the larva leaves a black trail of frass throughout. The final instar larva wriggled out through the hood portion of the mine and get dropped down to form a pupa.

4.2 SEASONAL INCIDENCE OF SERPENTINE LEAFMINER, *Liriomyza trifolii* Burgess ON TOMATO

Studies on the seasonal abundance of SLM, *L. trifolii* on tomato was carried out from July 2000 to June 2001 with a view to find out the population fluctuation, per cent infestation and also favourable periods for the activity of insect in relation to weather parameters. Observations on larval populations and miner infestation were recorded daily upto 45 days and the data was pooled at weekly and monthly intervals.

The data regarding the larval population, per cent miner infestation with SLM, *L. trifolii* and weather parameters including temperature (both



Plate 10. Infested and healthy tomato plant at sixth leaf stage

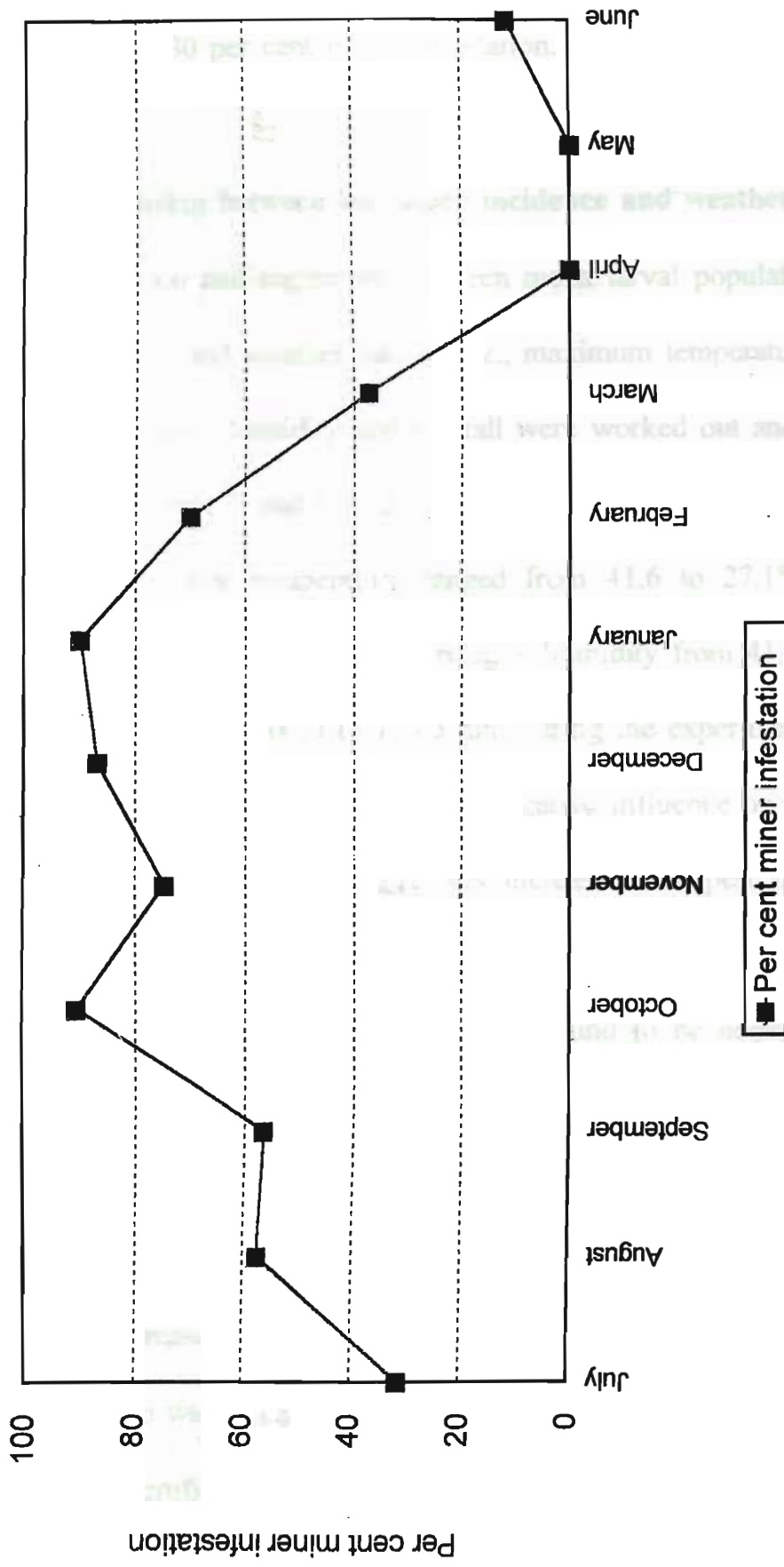
minimum and maximum), relative humidity and rainfall were presented in Table 4 and Figure 1. No miner infestation was observed from the last week of March to first week of June (from 13th to 22nd standard week) and from last two weeks of June (from 25th to 26th standard week). Slight pest incidence of 27 to 30.0 per cent was recorded during second and third weeks of June. Later pest incidence was started appearing from first week of July. Minimum mean larval population of 0.04 to 0.4 larva per leaf and per cent miner infestation of 26.57 to 47.70 per cent was observed from first week of July to fourth week of July (from 27th to 30th standard week), third and fourth weeks of March (11th and 12th standard weeks) and second and third weeks of June (23rd and 24th standard weeks). From August first week onwards pest incidence was gradually increased at moderate level and reached to its peak level (93.3 per cent) during first week of October (40th standard week) and again first week of January (1st standard week). Moderate mean larval population (0.12 to 1.4 larva per leaf) and per cent miner infestation (48.83 to 70.06 per cent) was observed from first week of August to fourth week of September (from 31st to 39th standard week) and from second week of November to fourth week of November (from 45th to 47th standard week) again from first week of February to second week of March (from 5th to 10th standard week). Maximum activity of the pest was observed from first week of October to first week of November (from 40th to 44th standard week) and from last week days of November to fourth week of January (from 48th to

Table 4 : Seasonal incidence of serpentine leafminer *Liriomyza trifolii* (Burgess) on Tomato

Standard week	Date	Max. Temp (°C)	Min. Temp (°C)	Relative humidity (%)	Rainfall (mm)	Mean larval population / leaf	Per cent miner infestation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
July							
27	2-8	30.0	24.2	61.0	014.3 (3)	0.40	38.70
28	9-15	34.3	25.6	52.0	001.0	0.30	30.00
29	16-22	35.8	25.6	48.0	000.0	0.17	26.57
30	23-29	36.9	25.4	41.5	000.0	0.10	30.00
August							
31	30-5	35.7	24.5	58.5	068.3 (2)	1.08	60.26
32	6-12	32.2	23.6	64.5	056.6 (2)	1.25	62.58
33	13-19	33.0	24.01	61.5	015.6 (2)	0.91	50.62
34	20-26	30.2	24.0	65.5	034.6 (4)	1.40	59.20
35	27-2	33.4	25.4	53.0	002.4	1.09	54.79
September							
36	3-9	34.2	24.4	53.0	010.4 (1)	1.08	57.98
37	10-16	34.1	24.5	56.0	000.5	0.66	48.83
38	17-23	32.8	23.4	73.0	099.4 (4)	1.27	68.90
39	23-30	32.4	23.8	69.5	05-1 (3)	0.90	50.62
October							
40	1-7	30.8	22.2	77.5	123.5 (5)	2.20	93.30
41	8-14	31.0	23.2	74.5	049.0 (3)	1.66	92.51
42	15-21	30.5	23.7	69.0	002.2	1.40	90.15
43	22-28	33.9	18.7	56.5	014.8 (1)	1.25	86.59
November							
44	29-4	32.1	19.4	62	006.6 (1)	1.23	82.55
45	5-11	31.2	20.0	66.5	013.2 (1)	0.82	68.90
46	12-18	30.1	19.8	59.0	000.0	0.69	65.60
47	19-25	29.8	20.8	71.0	019.8 (2)	1.17	74.87
48	26-2	28.2	19.5	74.0	070.2 (1)	1.40	82.55
December							
49	3-9	27.5	18.7	75.5	024.7 (3)	1.80	90.00
50	10-16	28.3	14.6	64.5	000.0	1.04	80.70
51	17-23	28.0	15.03	66.0	000.0	1.17	86.82
52	24-31	27.1	19.4	69.5	023.6 (2)	1.20	89.90

Standard week	Date	Max. Temp (°C)	Min. Temp (°C)	Relative humidity (%)	Rainfall (mm)	Mean larval population / leaf	Per cent miner infestation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
January							
1	1-7	28.4	19.0	72.15	000.0	2.40	93.20
2	8-14	28.9	17.3	68.5	000.0	2.01	91.64
3	15-21	28.8	15.7	67.5	000.0	1.71	89.90
4	22-28	29.6	15.8	62	000.0	1.02	85.07
February							
5	29-4	31.2	17.6	62.5	000.0	0.90	79.06
6	5-11	33.9	16.6	55	000.0	0.41	70.00
7	12-18	32.4	17.6	59	000.0	0.61	68.90
8	19-25	36.4	20.9	48.5	000.0	0.12	62.58
March							
9	26-4	35.4	20.1	52	000.0	0.20	50.62
10	5-11	34.9	21.3	52.5	000.0	0.17	48.83
11	12-18	36.1	20.7	44	000.0	0.08	47.70
12	19-25	37.5	24.7	52	000.0	0.10	38.70
13	26-1	38.7	25.8	49	000.0	0.00	0.00
April							
14	2-8	37.3	23.2	46	000.0	0.00	0.00
15	9-15	34.2	24.4	59	027.2 (3)	0.00	0.00
16	16-22	35.8	24.2	58	080.6 (3)	0.00	0.00
17	23-29	37.6	24.8	48	000.0	0.00	0.00
May							
18	30-6	39.5	26.4	46	000.0	0.00	0.00
19	7-13	41.6	28.4	39.5	000.0	0.00	0.00
20	14-20	40.1	28.4	38	000.0	0.00	0.00
21	21-27	39.3	27.3	43.5	012.0 (1)	0.00	0.00
June							
22	28-3	37.3	27.4	48	003.6	0.00	0.00
23	4-10	36.0	26.6	53	7.9 (1)	0.08	30.00
24	11-17	36.0	26.2	48.5	6.0 (1)	0.04	27.52
25	18-24	37.3	27.5	45	7.2 (1)	0.00	0.00
26	25-1	37.6	28.5	43	000.0	0.00	0.00

Fig 1 : Seasonal incidence of serpentine leaf miner, *Liriomyza trifolii* (Burgess) on Tomato



4th standard week) with mean larval population of 1.02 to 2.4 larva per leaf and 80.70 to 93.30 per cent miner infestation.

4.2.1 Relationship between leafminer incidence and weather factors :

Correlation and regression between mean larval population, per cent miner infestation and weather factors viz., maximum temperature, minimum temperature, relative humidity and rainfall were worked out and coefficients were given in Table 5 and Fig. 2.

The maximum temperature ranged from 41.6 to 27.1°C, minimum temperature from 14.6°C to 28.5°C, relative humidity from 41.5 to 77.5 per cent and rainfall from 000.0 to 123.5 mm during the experimental period.

Maximum temperature has exerted negative influence on the incidence of the pest i.e. as the temperature was increased, the pest incidence was reduced. The correlation between mean larval population and per cent miner infestation with maximum temperature was found to be negative and non-significant ($r = -0.83$ and -0.852) respectively.

Leafminer population in general was negatively correlated with the minimum temperature, the pest incidence was increased as the minimum temperature decreased. Correlation between minimum temperature with mean larval population was negative ($r = -0.550$) but non-significant, whereas it was negative and significant with per cent miner infestation ($r = -0.781$).

Table 5 : Relation between weather parameters and leafminer, *L. trifolii* (B) incidence

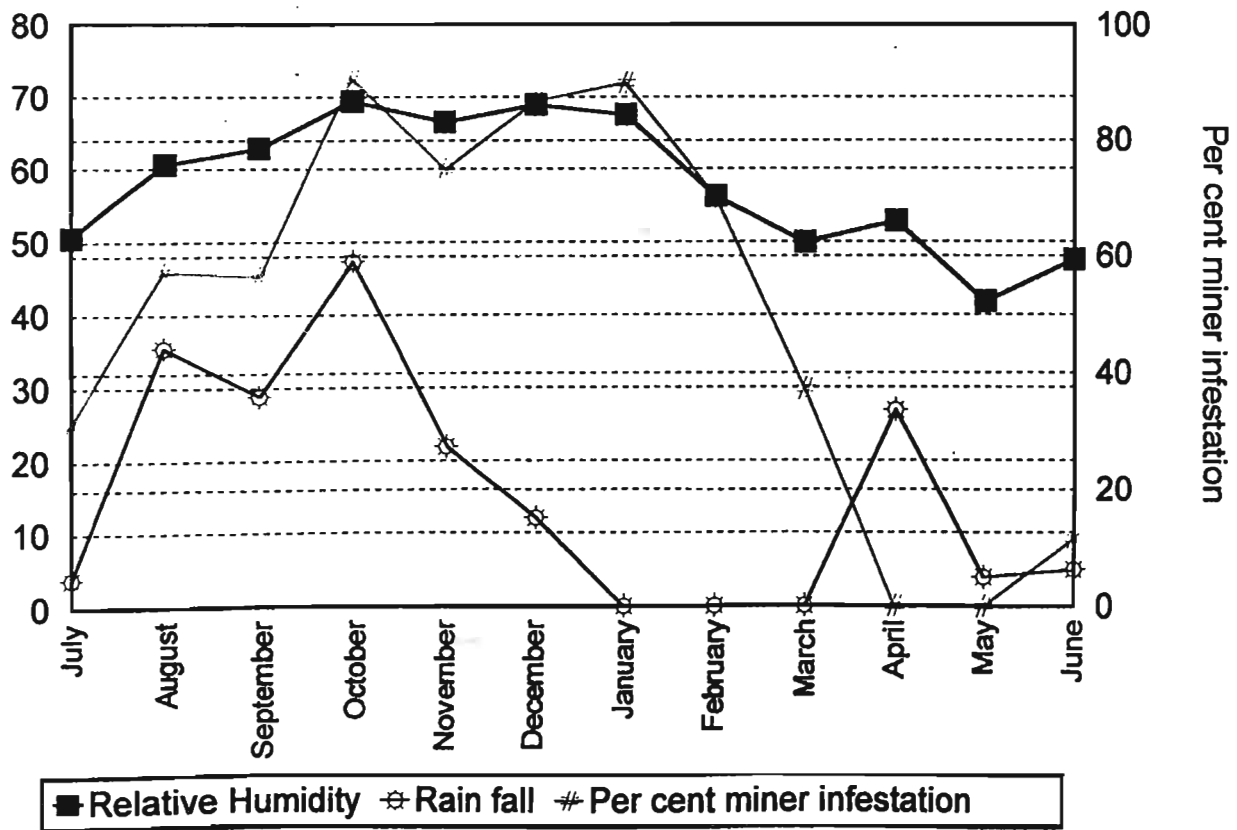
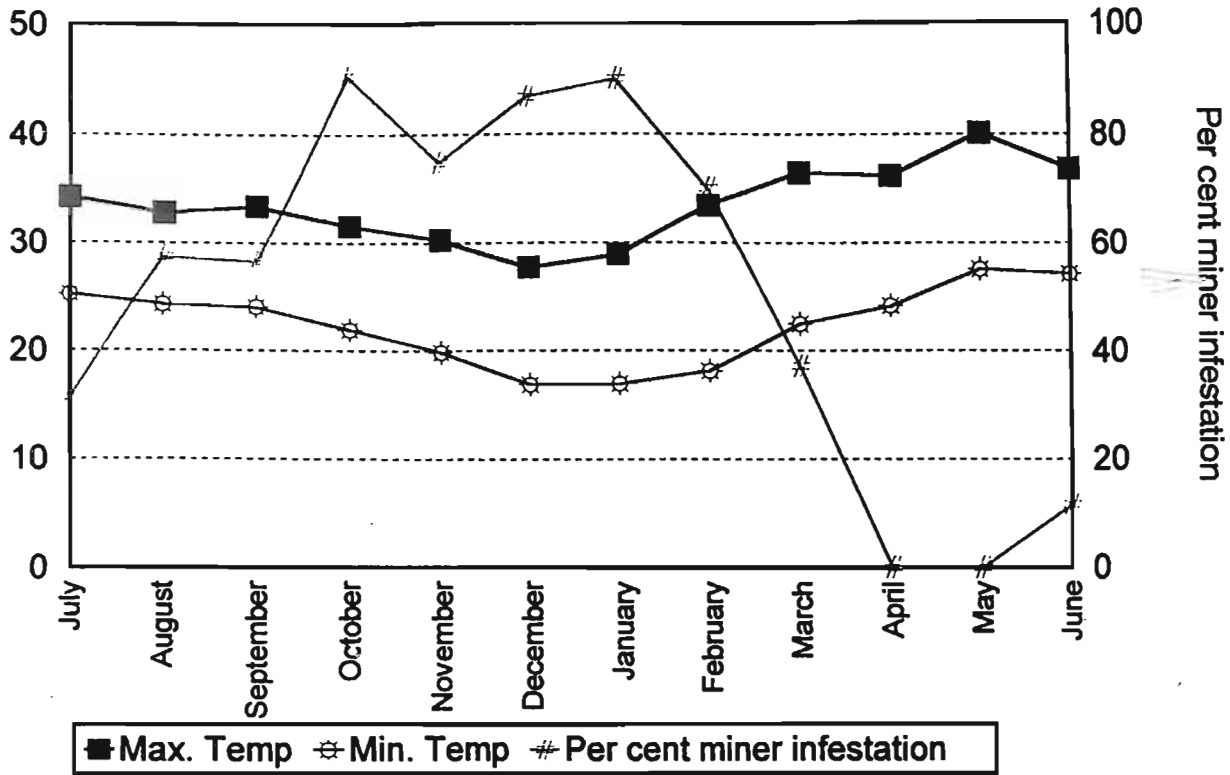
S. No	Particulars	Correlation co-efficient	Partial regression co-efficient	't' values
1	Mean larval population of leaf miner and average maximum temperature	-0.813**	-0.030	0.744 ^{NS}
2	Mean larval population of leaf miner and average of minimum temperature	-0.550**	-0.004	0.246 ^{NS}
3	Mean larval population of leaf miner and average relative humidity	0.861**	0.048	3.168**
4	Mean larval population of leaf miner and rainfall	0.382**	-0.001	0.386 ^{NS}
5	Per cent leaf miner damage and average maximum temperature	-0.852**	-1.030	0.571 ^{NS}
6	Per cent leaf miner damage and average minimum temperature	-0.781**	-3.498	3.875**
7	Per cent leaf miner damage and average relative humidity	0.815**	1.70	2.554*
8	Per cent leaf miner damage and rainfall	0.217 ^{NS}	-0.086	0.713 ^{NS}

NS = Not-significant

* Significant at 5%

** Significant at 1%

Fig 2 : Influence of weather parameters on *L. trifolii* (B) incidence in tomato



Leafminer incidence was positively correlated with relative humidity.

As the relative humidity increase, the leaf miner incidence was increased. Significant positive correlation was observed between relative humidity with mean larval population ($r = 0.861$) and per cent miner infestation ($r = 0.815$).

Rainfall was scattered and ranged in between 000.0 to 123.5 mm during the experimentation period. Correlation of rainfall with mean larval population ($r = 0.382$) and per cent miner infestation ($r = 0.217$) was positive and not-significant.

4.3 EFFECT OF CROP PHENOLOGY ON *Liriomyza trifolii* Burgess INFESTATION :

Studies were carried out during *rabi* season of 2000-2001 with a view to findout the effect of age of the crop on the incidence of serpentine leafminer. Observations revealed that there was a significant effect of age of the crop on the incidence of leafminer. Observations were recorded on ten randomly selected plants in each plot. Results indicated that initial pest incidence was observed on seedlings with four to six leaves in nursery. Further the mean number of mined leaves, larvae and mines per branch were recorded at different stages of the crop. In nursery stage, 10 days old plant has 0.50 mined leaves, 1.25 larvae and one mine per branch where as 2.00 mined leaves, 8.16 larvae and 5.61 mines and 3.00 mined leaves, 9.83 larvae and 11.60 mines per branch, were recorded on 24 and 38 days crop respectively.

After transplanting in the main field at flowering stage, plant at 52 days age old has 5.83 mined leaves, 14.14 larvae and 13.50 mines per branch. Where as 6.16 mined leaves, 8.50 larvae and 10.16 mines per branch were observed at 66 days old crop.

Fruiting was observed from 75 days after sowing of the crop. From that period onwards miner infestation was gradually reduced. 80 days old crop showed only 2.83 mined leaves, 5.16 larvae and 3.50 mines per branch. Lowest record of 1.50 mined leaves, 2.00 larvae and 1.66 mines per branch was observed at 94 days age crop (Table 6, Fig. 3).

Severity of the pest was recorded in terms of presence of live larvae in a single leaf. Maximum miner infestation was recorded at 24 days and 31 days after sowing having 2.00 and 2.83 mined leaves with 8.16 and 9.16 larvae per branch, respectively. At flowering stage about 45 days old crop, maximum of 6.16 mined leaves and 18.80 larvae per branch were observed. Minimum miner incidence was observed at fruiting stage i.e. 94 days and 101 days after sowing, showing 1.50 and 0.42 mined leaves and 2.0 and 1.75 larvae per branch, respectively.

Maximum number of mined leaves and mines per branch were recorded at 31 days and 45 days old crop with 2.83 and 6.16 mined leaves and 11.60 and 15.50 mines per branch, respectively. Though crop showed 6.16 mined leaves at 66 days crop only 10.16 mines per branch were observed. Minimum number of mined leaves and mines were observed from

Table 6 : Effect of crop phenology on SLM, *L. trifolii* (B) infestation

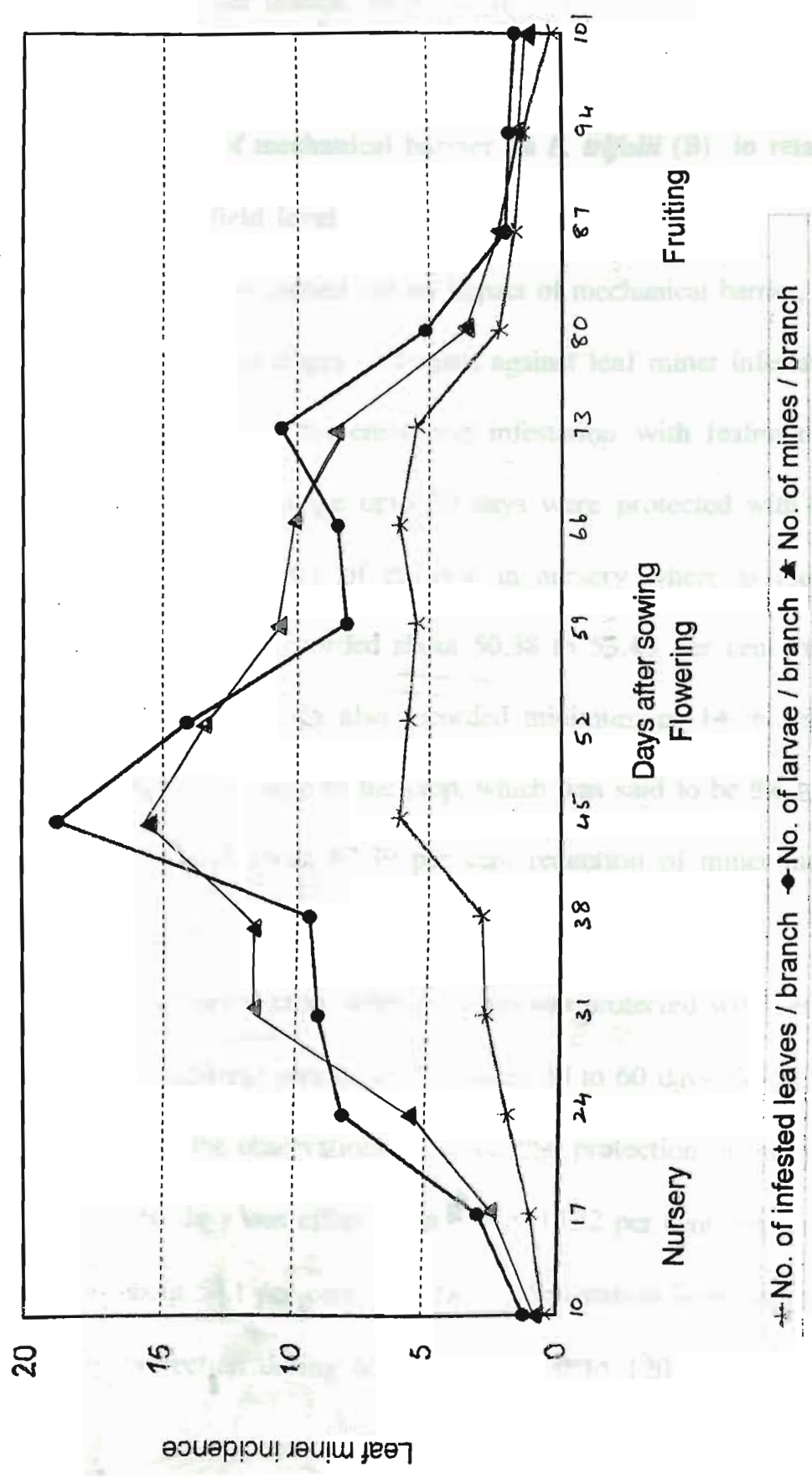
S.No.	Stage of the plant (days)	No. of infested leaves / branch*	No. of larvae/ branch*	No. of mines / branch*
Nursery stage				
1.	10	0.50 (0.8) ^e	1.25 (0.97) ^h	1.00 (0.90) ⁱ
2.	17	1.08 (1.02) ^{de}	3.00 (1.71) ^f	2.50 (1.57) ^{fg}
3.	24	2.00 (1.41) ^c	8.16 (2.84) ^d	5.61 (2.26) ^c
4.	31	2.83 (1.67) ^b	9.16 (3.02) ^c	11.60 (3.40) ^{bc}
Flowering stage				
5.	38	3.0 (1.72) ^b	9.83 (3.13) ^c	11.6 (3.4) ^{bc}
6	45	6.16 (2.47) ^a	18.8 (4.33) ^a	15.50 (3.90) ^a
7	52	5.83 (2.40) ^a	14.14 (3.76) ^b	13.50 (3.66) ^{ab}
8	59	5.50 (2.34) ^a	8.16 (2.85) ^d	10.80 (3.28) ^c
9	66	6.16 (2.47) ^a	8.50 (2.90) ^{cd}	10.16 (3.18) ^{cd}
Fruiting stage				
10	73	5.50 (2.33) ^a	10.6 (3.26) ^c	8.50 (2.9) ^d
11	80	2.83 (1.67) ^b	5.16 (2.26) ^e	3.50 (1.86) ^f
12	87	1.83 (1.35) ^c	2.16 (1.77) ^f	2.33 (1.51) ^g
13	94	1.50 (1.21) ^{cd}	2.00 (1.40) ^{fg}	1.66 (1.27) ^{gh}
14	101	0.42 (0.75) ^e	1.75 (1.11) ^{gh}	1.25 (0.97) ^{hi}
	CD at 5%	0.27	0.32	0.37

Figures in parentheses are square root transformed values

Means with different superscripts differ significantly

* Average of 10 branches

Fig 3 :Effect of crop phenology on *Liriomyza trifolii* (Burgess)



+ No. of infested leaves / branch ● No. of larvae / branch ▲ No. of mines / branch

87 to 101 days old crop with decreasing order. The crop at 87, 94 and 101 days after sowing had only 1.83, 1.50 and 0.42 mined leaves and 2.33, 1.66 and 1.25 mines per branch, respectively.

4.3.1 Influence of mechanical barrier on *L. trifolii* (B) in relation to crop stage at field level :

Investigations carried out on impact of mechanical barrier, 60 mesh net set at different crop stages of tomato against leaf miner infestation revealed that it has prevented the entry and infestation with leafminer. When the seedlings in nursery stage upto 30 days were protected with 60 mesh net resulted in no incidence of the pest in nursery where as the unprotected seedlings in nursery recorded about 50.38 to 53.43 per cent incidence. The same protected seedlings also recorded minimum of 14.26 per cent miner infestation upto last stage of the crop, which was said to be the lowest among all treatments and about 67.39 per cent reduction of miner incidence over unprotected crop.

In transplanted crop, when the crop was protected with net from miner infestation at different periods viz., between 30 to 60 days, 60 to 90 days and 90 to 120 days, the observations revealed that protection in transplanted crop from 30 to 60 days was effective with only 18.32 per cent pest incidence and there was about 58.1 per cent reduction in infestation over unprotected crop. Similarly, protection during 60 to 90 and 90 to 120 days resulted in pest

incidence ranging from 30.2 to 39.4 per cent whereas completely protected crop throughout the nursery as well as in transplanted crop stages, though did not recorded any miner infestation, the crop growth was affected resulting in stunted growth, thick leaf, reduced flowering and fruit formation was observed. The crop which was completely free without any protection in nursery as well as in transplanted crop showed maximum leafminer infestation on an average to an extent of 43.7 per cent.

The observations on yield obtained from all the treatments imposed revealed that maximum yield of 23.58 kgs per 20 sq.m could be obtained when the seedlings in nursery were protected with 60 mesh net. This was almost equivalent to the effect on yield as evidenced by 22.65 kg per 20 sq.m. obtained when the crop was protected with 60 mesh net even during the initial stages of transplantation i.e. from 30 to 60 days. Protection with net during 60 to 90 and 90 to 120 days did not differ much and remain on par with each other getting an yield of 15. to 17.4 kgs per 20 sq.m. Similarly, crop protected with net throughout the growth period has almost equal effect with unprotected crop giving an yield of 10.6 to 13.3 kgs 20 sq.m. which was found to be lowest. (Table 7)

Table 7 : Influence of mechanical barrier on SLM, *L.trifolii* (B) infestation on tomato

S. No.	Treatments	Per cent miner infestation per plant						Mean	Mean per cent reduction over unprotected crop	Yield (kg / 20 m ²)
		Nursery	30-60 DAS	60-90 DAS	90-120 DAS	Mean	Mean per cent reduction over unprotected crop			
1	Nursery protection upto 30 DAS	- (0.00)	29.15 (32.67)	19.67 (26.32)	8.22 (16.64)	14.26	67.39	23.58		
2	Protection in 30-60 DAS	50.38 (45.24)	5.75 (11.97)	12.97 (21.07)	4.2 (10.24)	18.32	58.1	22.65		
3	Protection in 60-90 DAS	52.21 (46.29)	64.48 (53.47)	2.75 (6.66)	1.37 (3.39)	30.20	30.93	17.49		
4	Protection in 90-120 DAS	53.43 (46.99)	66.02 (54.41)	38.14 (38.15)	- (0.00)	39.39	9.92	15.73		
5	Protection in all stages	- (0.00)	- (0.00)	- (0.00)	- (0.00)	0	100	10.66		
6	Unprotected check	51.58 (47.43)	70.05 (56.84)	38.56 (38.39)	14.76 (22.54)	43.73	-	13.36		
	C _D at 5%	2.77	5.702	5.50	6.05			1.91		

Figures in parentheses are angular transformed values
DAS -Days after sowing

4.4 REACTION OF TOMATO VARIETIES AGAINST SERPENTINE LEAFMINER, *Liriomyza trifolii* Burgess :

To know the relative reaction of tomato cultivars against SLM, *Liriomyza trifolii*, seven varieties of tomato i.e. S-22, PKM-1, Arka Vikas, Pusa Ruby, Tomato Ruchi, Hybrid Cross - 08 and Hybrid Cross - 17 were grown at insectary, S.V.Agricultural College, Tirupati during *rabi* season of 2000-2001.

Preference of larva for feeding among all test varieties was expressed in terms of number larvae per branch. Observations revealed that Hybrid Cross-08 and Hybrid Cross 17 on an average harboured about 5.26 and 5.46 larvae followed by Tomato Ruchi with 6.66 larvae. Maximum number of larvae upto 18.4 per branch were observed in Pusa Ruby followed by Arka Vikas, PKM-1 and S-22 with a range of 13.6 to 15.6 larvae per branch (Table 8).

Observation on number of mined leaves per branch for individual cultivar showed that Pusa Ruby recorded maximum upto 5.96 and S-22 with 5.56 where as PKM-1 has 4.75 and Arka Vikas with 4.46 mined leaves per branch. Minimum number of leaves with mines could be seen in two hybrids, Hybrid Cross-08 and Hybrid Cross-17 with a range of 1.66 to 2.00 mined leaves per branch followed by Tomato Ruchi with 2.4 mined leaves per branch (Table 8).

Table 8 : Reaction of different varieties of tomato against serpentine leaf miner *Liriomyza trifolii* (B)

S.No.	Name of the variety	[§] No. of mined leaves / branch*	[§] No. of larvae / branch*	[†] Per cent miner infestation / plant*	Grade
1.	S-22	5.56 (2.28) _{ab}	15.60 (3.94) ^b	65.00 (53.86) ^{cd}	HS
2.	PKM-1	4.75 (2.17) _{ab}	14.90 (3.86) ^b	63.33 (52.79) ^c	HS
3.	Arka Vikas	4.46 (2.10) ^b	13.60 (3.59) ^b	50.00 (45.00) ^b	S
4.	Pusa Ruby	5.96 (2.37) ^a	18.40 (4.29) ^a	75.00 (60.26) ^d	HS
5.	Hybrid Cross - 08	1.66 (1.28) ^d	5.26 (2.28) ^c	20.00 (26.45) ^a	MR
6.	Tomato Ruchi	2.40 (1.54) ^c	6.66 (2.57) ^c	25.00 (29.92)	MR
7.	Hybrid Cross - 17	2.00 (1.41) ^{cd}	5.46 (2.33) ^c	23.33 (28.85) ^a	MR
	CD at 5%	0.23	0.34	6.97	

§ Figures in parentheses are square root transformed values

† Figures in parentheses are angular transformed values.

Means with different superscripts differ significantly.

* Average of 10 plants

Rating	Grade	Per cent infestation
Resistant	R	0-10%
Moderately Resistant	MR	10-30%
Susceptible	S	30-50%
Highly Susceptible	HS	50-100%

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S.No.	Name of the variety	[§] No. of mined leaves / branch*	[§] No. of larvae / branch*	[†] Per cent miner infestation / plant*	Grade
1.	S-22	5.56 (2.28) _{ab}	15.60 (3.94) ^b	65.00 (53.86) ^{cd}	HS
2.	PKM-1	4.75 (2.17) _{ab}	14.90 (3.86) ^b	63.33 (52.79) ^c	HS
3.	Arka Vikas	4.46 (2.10) ^b	13.60 (3.59) ^b	50.00 (45.00) ^b	S
4.	Pusa Ruby	5.96 (2.37) ^a	18.40 (4.29) ^a	75.00 (60.26) ^d	HS
5.	Hybrid Cross - 08	1.66 (1.28) ^d	5.26 (2.28) ^c	20.00 (26.45) ^a	MR
6.	Tomato Ruchi	2.40 (1.54) ^c	6.66 (2.57) ^c	25.00 (29.92)	MR
7.	Hybrid Cross - 17	2.00 (1.41) ^{cd}	5.46 (2.33) ^c	23.33 (28.85) ^a	MR
	CD at 5%	0.23	0.34	6.97	

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* Average of 10 plants

Rating	Grade	Per cent infestation
Resistant	R	0-10%
Moderately Resistant	MR	10-30%
Susceptible	S	30-50%
Highly Susceptible	HS	50-100%

Observations on per cent miner infestation per plant was recorded throughout the crop period revealed that Pusa Ruby recorded high pest infestation to the extent of 75 per cent followed by S-22 with 65 per cent and PKM-1 with 63.33 per cent. These were followed by Arka Vikas with 50 per cent miner infestation. Low miner infestation to the extent of 20 to 25 per cent was observed in Hybrid Cross - 08, Hybrid Cross - 17 and Tomato Ruchi.

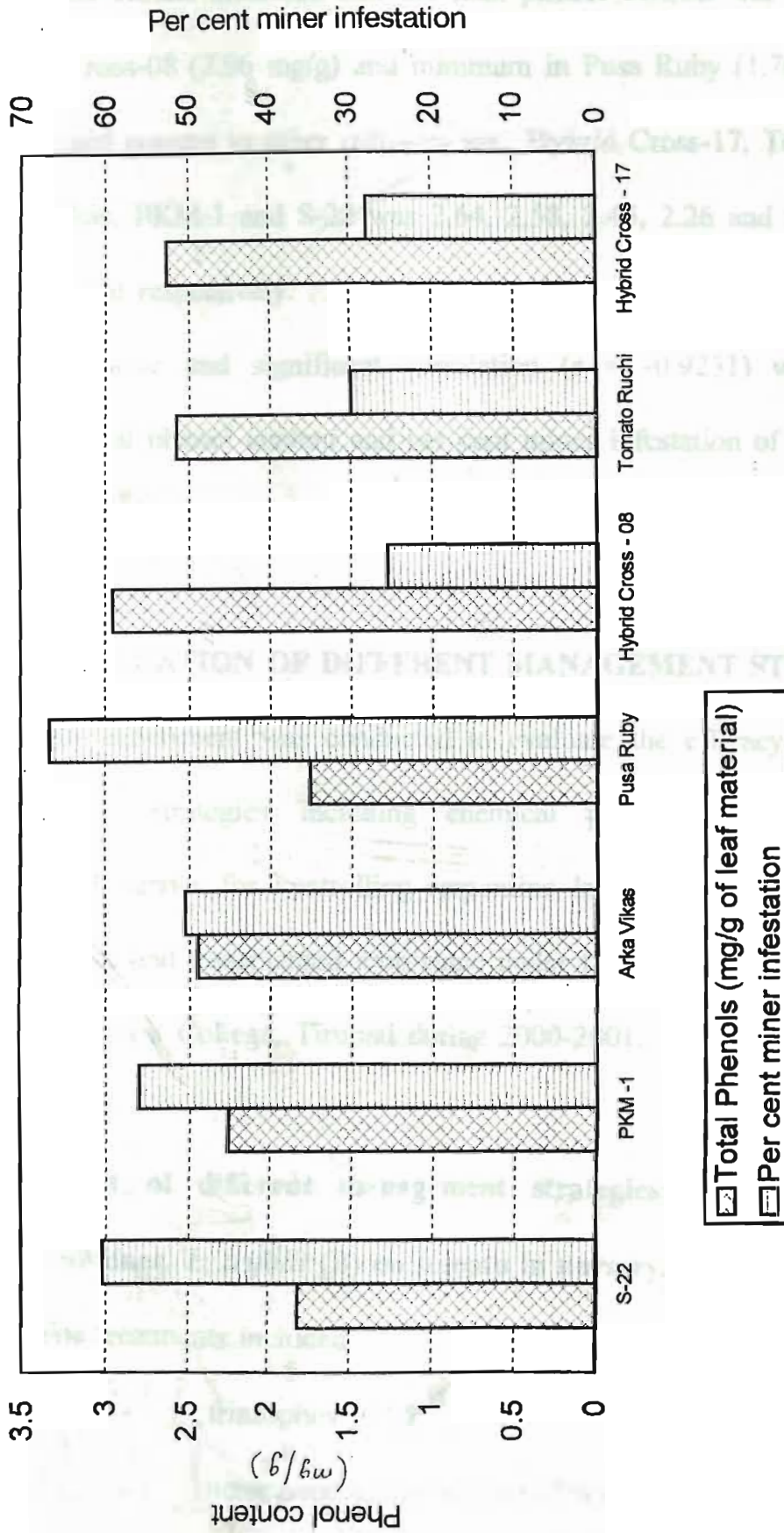
Based on per cent miner infestation the test varieties were classified into four grades (Table 8).

The results revealed that among the seven cultivars of tomato that were screened for their reaction, no cultivar was found resistant against *Liriomyza trifolii*. Three cultivars namely Pusa Ruby, S-22 and PKM-1 were found to be highly susceptible with 63.33 to 75 per cent miner infestation per plant. The cultivar, Arka Vikas was susceptible showing an average of 50 per cent miner infestation per plant where as Hybrid cross - 08, Hybrid cross - 17, Tomato Ruchi were found to be moderately resistant showing only 20 to 25 per cent miner infestation per plant.

4.4.1 Influence of total phenols in different tomato cultivars :

Information on total phenol content on per cent infestation of *Liriomyza trifolii* in leaves of different tomato cultivars namely Hybrid Cross-08, Hybrid Cross-17, Tomato Ruchi, Arka Vikas, Pusa Ruby, S-22 and PKM-1 were documented 45 days after sowing (Table 9, Fig. 4).

Fig. 4 Effect of total phenols on the per cent infestation of serpentine leaf miner *Liriomyza trifolii* (B) in different tomato varieties



The results indicated that the total phenol content was maximum in Hybrid Cross-08 (2.96 mg/g) and minimum in Pusa Ruby (1.76 mg/g). The total phenol content in other cultivars viz., Hybrid Cross-17, Tomato Ruchi, Arka Vikas, PKM-1 and S-22 was 2.64, 2.58, 2.45, 2.26 and 1.82 mg/g of leaf material respectively.

Negative and significant correlation ($r = -0.9251$) was observed between total phenol content and per cent miner infestation of leafminer on tomato.

4.5 EVALUATION OF DIFFERENT MANAGEMENT STRATEGIES:

An experiment was conducted to evaluate the efficacy of different management strategies including chemical pesticides, botanicals and mechanical barrier for controlling serpentine leafminer (*L.trifolii*) both in nursery stage and transplanted crop stage under field conditions at insectary, S.V.Agricultural College, Tirupati during 2000-2001.

4.5.1 Effect of different management strategies against serpentine leafminer, *L. trifolii* (B) on tomato in nursery stage :

The treatments included

- T₁ - triazophos (0.05%)
- T₂ - neem seed kernal extract (5%)
- T₃ - imidacloprid (5 g / kg seed) as seed treatment

The results indicated that the total phenol content was maximum in Hybrid Cross-08 (2.96 mg/g) and minimum in Pusa Ruby (1.76 mg/g). The total phenol content in other cultivars viz., Hybrid Cross-17, Tomato Ruchi, Arka Vikas, PKM-1 and S-22 was 2.64, 2.58, 2.45, 2.26 and 1.82 mg/g of leaf material respectively.

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The treatments included

- T₁ - triazophos (0.05%)
- T₂ - neem seed kernal extract (5%)
- T₃ - imidacloprid (5 g / kg seed) as seed treatment

T₄ - Mechanical barrier (60 mesh net)

T₅ - Untreated control (water)

Leaf miner infestation was recorded in terms of number of larvae per branch. The data on mean larval population per branch was recorded one day before spraying and one, three, five and ten days after spraying. Per cent reduction of larvae over pre-count were calculated and presented in Tables 10 & 11.

No miner infestation was observed in the treatment where the seedlings were protected by mechanical barrier (60 mesh net) starting from germination (Plate 11) upto to last observation time.

One day after spraying :

Observations on one day after spraying revealed that among all triazophos was found superior with a maximum of 82.4 per cent reduction of leafminer larval population followed by neem seed kernal extract recording 46 per cent reduction. Only 6.3 and 8.6 per cent of dead larvae was observed in treatments where plants were sprayed with water and seeds were treated with imidacloprid found on par with each other. The overall efficacy of treatments in decreasing order in terms of per cent mortality of larva was as follows.

Mechanical barrier (60 mesh net) > Triazophos > NSKE > imidacloprid > Water



Plate 11. Mechanical barrier (60 mesh net) in nursery stage

Three days after spraying :

Data on third day after spraying revealed that 100 per cent mortality of larvae was observed in case of triazophos followed by neem seed kernal extract with 79.3 per cent mortality. The remaining treatments imidacloprid and untreated check (water) recorded 17.8 and 15.8 per cent mortality, respectively. No significant difference was observed in these two treatments. The overall efficacy of treatments in decreasing order in terms of per cent mortality of larva was as follows.

Mechanical barrier (60 mesh net) = Triazophos > NSKE > imidacloprid > Water

Ten days after spraying :

Observations on tenth day after spraying revealed that reinfestation of miner was recorded in all treatments except the mechanical barrier as it completely protected the crop from pest attack. In triazophos 96.8 per cent mortality was recorded followed by NSKE with 86.4 per cent mortality which were on par with each other. The remaining treatments imidacloprid and untreated check were on par with each other with 24 and 12.15 per cent mortality. The overall efficacy of treatments in decreasing order in terms of per cent mortality of larva was as follows.

Mechanical barrier (60 mesh net) > Triazophos > NSKE > imidacloprid > Water

Table 10 : Evaluation of different management strategies against SLM, *Liriomyza trifolii* (B) on tomato in nursery stage

S. No.	Treatments	Pre-counting larvae / branch	Per cent reduction over pre count				Mean
			1 DAS	3 DAS	5 DAS	10 DAS	
1.	triazophos 40% EC	6.50	82.43 (67.93) ^c	100 (88.19) ^c	100 (88.19) ^c	96.87 (83.46) ^{bc}	94.82
2.	NSKE 5%	7.25	46.00 (42.70) ^b	79.30 (63.21) ^b	93.75 (79.74) ^c	86.45 (70.84) ^b	76.37
3.	imidacloprid 70 WS	5.75	8.55 (12.18) ^a	17.80 (21.35) ^a	37.50 (37.51) ^b	24.00 (28.87) ^a	30.73
4.	Mechanical barrier (60 mesh net)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
5.	Untreated check (water)	8.25	6.32 (10.40) ^a	15.82 (23.30) ^a	18.47 (22.00) ^a	12.15 (14.31) ^a	24.69
	CD at 5%		16.16	11.43	15.27	16.20	

Figures in parentheses are angular transformed values
Means with different superscripts differ significantly
DAS = Days after spraying

Table 11 : Influence and persistence of different management strategies on the larval population of *L. trifolii* (B) on tomato in nursery

Age of the crop / observation (days after spraying)	Effect of treatments in decreasing order of larval mortality				
1 DAS	Mechanical barrier (60 mesh net)	triazophos (82.43)	NSKE (46.00)	*imidacloprid (8.55)	Water (6.32)
3 DAS	Mechanical barrier (60 mesh net)	triazophos (100)	NSKE (79.30)	imidacloprid (17.80)	Water (15.82)
5 DAS	Mechanical barrier (60 mesh net)	triazophos (100)	NSKE (93.75)	imidacloprid (37.50)	Water (18.47)
10 DAS	Mechanical barrier (60 mesh net)	triazophos (96.87)	NSKE (86.45)	imidacloprid (24.00)	Water (12.15)
Overall efficacy	Mechanical barrier (60 mesh net)	triazophos (94.82)	NSKE (76.37)	imidacloprid (30.73)	Water (24.69)

* Imidacloprid as seed treatment chemical

DAS - Days after spraying

The data documented in Table 10 revealed that mechanical barrier (60 mesh net) is effective in preventing the incidence of miner through out the nursery stage upto 30 days of the crop.

Among all chemicals, Triazophos has given 94.82 per cent death of larva within 10 days after spray followed by neem seed kernel extract recording 76.37 per cent imidacloprid and untreated check remain on par with each other showing only 30.37 and 24.69 per cent mortality. All the treatments recorded reinfestation of leaf miner from tenth day onwards.

The cumulative efficacy of treatments in decreasing order in terms of per cent mortality of larva was as follows

$$T_4 > T_1 > T_2 > T_3 > T_5$$

Mechanical barrier (60 mesh net) > triazophos > NSKE > imidacloprid > Water

4.5.2 Effect of different management strategies against SLM, *L. trifolii*

(B) on tomato in transplanted crop :

A field trial was carried out at insectary, S.V.Agricultural College, Tirupati during June - September, 2001 to test the relative efficacy of different tactics including chemicals, botanicals and mechanical barrier against *L. trifolii*. The crop was transplanted at 30 days after sowing and 50 per cent incidence was recorded in transplanted crop was at 45 days old. The treatments imposed for the experiment were

- T₁ - imidacloprid (5 g / kg seed) for seed treatment,
- T₂ - neem seed kernal extract (5%),
- T₃ - azadirachtin (5 ml / lit water),
- T₄ - Annona seed extract (0.031%),
- T₅ - triazophos (0.05%),
- T₆ - profenophos (0.05%),
- T₇ - seed treatment + neem seed kernal extract (5%),
- T₈ - seed treatment + azadirachtin (5 ml / lit of water),
- T₉ - seed treatment + annona seed extract (0.031%),
- T₁₀ - seed treatment + triazophos (0.05%),
- T₁₁ - seed treatment + profenophos (0.05%),
- T₁₂ - preprotected crop in nursery stage with mechanical barrier 60 mesh net
and
- T₁₃ - untreated check

Two sprayings were given at an interval of 20 days. First spraying was carried out after noticing 50 per cent infestation in transplanted crop and second spraying was 20 days after first spraying when resurgence of pest was noticed. The data regarding mean larval population of miner per branch were recorded one day before spraying and 1, 5, 10 and 20 days after spraying. Per cent larval reduction over untreated check and cumulative reduction of two sprayings were calculated and the results are presented in Tables 12 & 13.

4.5.2.1 First spraying :

One day after spraying, the highest per cent mortality (78.4%) was observed in treatment with seed treatment + triazophos followed by triazophos (75.7%) alone which were on par with each other. These were followed by seed treatment + profenophos (63.6%), seed treatment + NSKE (60.6%), neem seed kernal extract alone (59.4%) and profenophos alone (58.01%) which were on par with each other. The treatments NSKE, profenophos alone and pre-protected crop with 60 mesh net (53.5%) were on par with each other. These were followed by seed treatment + azadirachtin (41.9%), seed treatment + annona seed extract (34.04%), azadirachtin (31%) and annona seed extract (25.8%). Azadirachtin alone was on par with both seed treatment + annona seed extract and annona seed extract alone. Lowest per cent mortality of larvae (8.7%) was observed in imidacloprid seed treated plot. The overall efficacy of management strategies in decreasing order in terms of per cent reduction of larva over control were as follows.

$$\underline{T_{10}} > \underline{T_5} > \underline{T_{11}} > \underline{T_7} > \underline{T_2} > \underline{T_6} > \underline{T_{12}} > \underline{T_8} > \underline{T_9} > \underline{T_3} > \underline{T_4} > \underline{T_1}$$

Five days after spraying :

The data on fifth day after spraying revealed that seed treatment + triazophos was found effective in recording highest per cent mortality of larva (98.5%) and significantly superior compared to other treatments followed by triazophos alone (95.9%), seed treatment + NSKE (86.88%), seed treatment

+ profenophos (82.81%) and neem seed kernel extract alone (81.89%). NSKE alone was on par with both seed treatment + profenophos, seed treatment + NSKE and profenophos alone (79.7%). Pre-protected crop with 60 mesh net (54.3%) and seed treatment + azadirachtin (47.8%) which were on par with each other followed by azadirachtin (40.9%), seed treatment + annona seed extract (39.4%) and annona seed extract (38.4%) which were on par with each other. Lowest per cent reduction (10.9%) was observed in seedlings where seed treatment with imidacloprid.

The overall efficacy of all treatments in decreasing order in terms of per cent reduction of larva was as follows.

$$T_{10} > T_5 > T_7 > T_{11} > \overline{T_2 > T_6} > T_{12} > T_8 > \overline{T_3 > T_9} > T_4 > T_1$$

Ten days after spraying :

Observations on tenth day after spraying revealed that though there was an increase in per cent reduction of larva from first day to fifth day after spraying, a decrease in per cent reduction of larva was noticed in all treatments. Seed treatment + triazophos (80.35%) was found significantly superior treatment followed by triazophos alone (79.05%) and seed treatment + NSKE (77.2%) which were on par with each other. Triazophos, seed treatment + NSKE and neem seed kernel extract alone (76.8%) were on par with each other, which were followed by seed treatment + profenophos (68.01%), profenophos alone (62%) and preprotected crop in nursery with 60

mesh net (60.2%). Seed treatment + azadirachtin (38.1%), azadirachtin (35.6%) and seed treatment + annona seed extract (35.1%) were on par with each other and were followed by annona seed extract (34.3%) and imidacloprid (11.5%). The overall efficacy for all treatments in decreasing order of larval reduction were as follows.

$$T_{10} > T_5 > T_7 > T_2 > T_{11} > T_6 > T_{12} > T_8 > T_3 > T_9 > T_4 > T_1$$

Twenty days after spaying :

Observations on twenty days after spraying revealed that resurgence of the pest was recorded in all treatments. Here pre-protected crop in nursery showed high per cent mortality of larvae (38.8%) followed by seed treatment + triazophos (35.2%), triazophos alone (31.7%), neem seed kernal extract alone (27.28%), seed treatment + neem seed kernal extract (24.44%), seed treatment + azadirachtin (21.9%), azadirachtin alone (18.3%) and seed treatment + profenophos (14.3%). The treatments profenophos alone (11.3%) and seed treatment + annona seed extract (10.8%) was on par with each other. Treatments annona seed extract alone (7.08%) and imidacloprid seed treatment (5.13%) recorded lowest per cent mortality of larva of leaf miner. Overall efficacy of treatments in decreasing order of per cent reduction of larva was as follows.

$$T_{12} > T_{10} > T_5 > T_2 > T_7 > T_8 > T_3 > T_{11} > T_6 > T_9 > T_4 > T_1$$

Table 12 : Relative effect of different management strategies against SLM, *L.trifolii* (B) on tomato after first spraying [Transplanted crop]

S. No.	Treatments	Pre-counting larvae / branch	Per cent mortality of larvae over untreated check				
			1 DAS	5 DAS	10 DAS	20 DAS	Mean
1.	Imidacloprid* (5 gm / kg seed)	13.75	8.69 (17.14) ^b	10.95 (19.32) ^b	11.53 (19.85) ^b	5.13 (13.05) ^k	9.07
2.	Neem seed kernal extract (5%)	15.25	59.44 (50.46) ^{bc}	81.89 (65.17) ^{cd}	76.83 (61.26) ^b	27.28 (31.47) ^d	61.36
3.	Azadirachtin (5 ml / lit of water)	14.75	31.00 (33.84) ^{ef}	40.96 (39.79) ^{fg}	35.59 (36.64) ^e	18.3 (25.31) ⁱ	31.46
4.	Annona seed extract (0.031%)	18.00	25.83 (30.54) ^f	38.40 (38.29) ^g	34.32 (35.84) ^f	7.08 (15.37) ^j	26.40
5.	Triazophos (0.05%)	19.50	75.72 (60.50) ^a	95.90 (79.53) ^b	79.05 (62.87) ^{ab}	31.74 (34.28) ^c	70.60
6.	Profenophos (0.05%)	20.00	58.01 (49.60) ^{bc}	79.74 (63.33) ^d	62.08 (52.00) ^d	11.33 (19.65) ^h	52.79
7.	Seed treatment + NSKE (5%)	16.25	60.60 (51.14) ^b	86.88 (68.73) ^c	77.23 (61.51) ^{ab}	24.40 (29.62) ^e	62.28
8.	Seed treatment + Azadirachtin (5 ml / lit of water)	13.50	41.92 (40.33) ^d	47.86 (43.75) ^{ef}	38.10 (38.12) ^e	21.90 (27.90) ^f	37.44
9.	Seed treatment + Annona seed extract (0.031%)	17.25	34.04 (35.68) ^e	39.47 (38.94) ^g	35.15 (36.37) ^{ef}	10.86 (19.24) ^{hi}	29.88
10.	Seed treatment + triazophos (0.05%)	18.75	78.47 (62.38) ^a	98.54 (84.75) ^a	80.35 (63.71) ^a	35.2 (36.39) ^b	73.14
11.	Seed treatment + Profenophos (0.05)	17.5	63.64 (52.94) ^b	82.81 (65.58) ^c	68.07 (55.60) ^c	14.32 (22.24) ^g	57.21
12.	Mechanical barrier (60 mesh net)	6.75	53.54 (47.03) ^c	54.37 (47.49) ^c	60.27 (50.95) ^d	38.83 (38.54) ^a	50.12
	Cd at 5%		4.00	4.732	2.266	1.077	

Figures in parenthesis are angular transformed values

Means with different superscripts differ significantly

DAS -Days after spraying

* Imidacloprid as seed treatment chemical

Overall effect of treatments against SLM, *L. trifolii* (B) after first spraying :

Triazophos alone and combined action of seeds treated with Imidacloprid were on par with each other showing 70.6 to 73.1 per cent reduction in pest upto 20 days after the spray. Neem seed kernal extract and profenophos when sprayed individually resulted in 61.3 and 52.7 per cent reduction of the pest.

26.4 to 37.4 per cent mortality of larvae was recorded in remaining treatments including seed treatment + azadirachtin, azadirachtin alone, seed treatment + annona seed extract, and annona seed extract. Lowest per cent reduction of larvae (9.07%) was recorded on imidacloprid seed treatment.

$$T_{10} > T_5 > T_7 > T_2 > T_{11} > T_6 > T_{12} > T_8 > T_3 > T_9 > T_4 > T_1$$

4.5.2.2 Second spraying :

Data recorded one day after spraying revealed that highest per cent mortality of larvae (81%) was recorded on seed treatment + triazophos followed by triazophos alone (73.1%) and seed treatment + neem seed kernel extract (68.3%). These treatments were followed by preprotected crop with 60 mesh net in nursery (66.4%), seed treatment + profenophos (60.9%) and neem seed kernal extract (59.6%) which were on par with each other. The treatments seed treatment + profenophos, NSKE and profenophos alone (56.9%) were on par with each other. Next in order seed treatment +

azadirachtin (36.5%), azadirachtin alone (33.8%) and seed treatment + annona seed extract (33.1%) were on par with each other, which were followed by annona seed extract (26.3%) and imidacloprid (15.5%). The overall efficacy of all treatments in decreasing order of per cent reduction of larva was as follows :

$$T_{10} > T_5 > T_7 > T_{12} > \overline{T_{11}} > T_2 > T_6 > T_8 > T_3 > T_9 > T_4 > T_1$$

Five days after spraying :

Observations on fifth day after spraying revealed that seed treatment + triazophos was found significantly superior to other treatment in reducing larval population (98.6%) followed by triazophos alone (98.1%) which were on par with each other. Seed treatment + NSKE (88.1%) and seed treatment + profenophos (84.5%) were next in order and on par with each other which were followed by profenophos alone (81.8%) and neem seed kernal extract (81.6%) were on par with each other. Lowest per cent reduction of larvae was recorded on imidacloprid (10.7%). The remaining treatments seed treatment + azadirachtin (68.9%) and pre-protected crop in nursery with 60 mesh net (67.8%) were on par with each other which were followed by azadirachtin (57.3%), seed treatment + annona seed extract (54.1%) and annona seed extract (53.9%). These three treatments were on par with each other. The overall efficacy of all treatments in decreasing order of larval mortality was as follows :

$$\underline{T_{10} > T_5} > \underline{T_7 > T_{11}} > T_6 > T_2 > \underline{T_8 > T_{12}} > T_3 > T_9 > T_4 > T_1$$

Ten days after spraying :

Observations on tenth day after spraying revealed that decrease in per cent reduction of larvae was observed. Highest per cent reduction of larva (87.7%) was recorded on seed treatment + triazophos followed by triazophos alone (84.3%). The treatments seed treatment + profenophos (75.9%), neem seed kernal extract alone (75.2%), seed treatment + NSKE (75%), preprotected crop in nursery (74.3%) and profenophos (71.8%) were next in order and on par with each other in reducing per cent larval population. These treatments were followed by seed treatment + azadirachtin (58%). The treatment, seed treatment + annona seed extract (46.6%) was on par with both azadirachtin (49.9%) and annona seed extract (42.4%). Seed treatment with imidacloprid was found less effective in controlling larvae (11.6%) of leaf miner. The overall efficacy of all treatments in decreasing order of larval mortality was as follows.

$$T_{10} > T_{15} > T_{11} > T_2 > T_7 > T_{12} > T_6 > T_8 > T_3 > T_9 > T_4 > T_1$$

Twenty days after spraying :

Minimum incidence of the pest was recorded in all treatments on twenty days after spraying due to older age (90 days after spraying) of the crop. High per cent reduction upto 57 per cent was recorded on seed

treatment + triazophos and triazophos and the nursery protected with 60 mesh net when compared to unprotected and untreated check. Besides this the plants with seed treatment + NSKE and neem seed kernal alone recorded 50.5 and 48.5 per cent reduction in miner. All these treatments were on par with each other. These were followed by azadirachtin alone (37.8%), seed treatment + azadirachtin (30%) and profenophos alone (21%) were on par with each other. The remaining treatments including profenophos alone (8.6%), annona seed extract showed no reduction in larval population and the other treatments recorded negative reaction in reducing larval population including seed treatment + annona seed extract (-6.6%) and imidacloprid (-10.0%). The overall efficacy of treatments in decreasing order of larval reduction was as follows.

$$\underline{T_{10} > T_5 > T_{12} > T_7 > T_2 > T_3 > T_8 > T_6 > T_{11} > T_4 > T_9 > T_1}$$

Overall effect of treatments against SLM, *L. trifolii* after second spraying:

The data documented in Table 12 revealed that 81 to 66 per cent larval reduction was recorded on seed treatment + triazophos, triazophos alone, seed treatment + NSKE, pre-protected crop is nursery with 60 mesh net and neem seed kernal extract alone. Profenophos recorded 57 per cent larval mortality. The remaining treatments recorded low per cent mortality of larvae from 48 to 31 per cent including seed treatment + azadirachtin, azadirachtin alone, seed treatment + annona seed extract and annona seed extract and the lowest per cent reduction of larvae (6.9%) was recorded on imidacloprid. Overall

Table 13 : Relative effect of different management strategies against SLM, *L.trifolii* (B) on tomato after second spraying [Transplanted C₂]

S. No.	Treatments	Pre-counting larvae / branch	Per cent mortality of larvae over untreated check				
			1 DAS	5 DAS	10 DAS	20 DAS	Mean
1.	Imidacloprid* (5 gm / kg seed)	17.25	15.54 (23.24) ^b	10.77 (19.18) ^f	11.65 (19.99) ^h	-10 (-14.93) ^g	6.99
2.	Neem seed kernal extract (5%)	12.75	59.62 (50.56) ^{dc}	81.63 (64.71) ^c	75.23 (60.25) ^{cd}	48.5 (44.14) ^{ab}	66.24
3.	Azadirachtin (5 ml / lit of water)	15.75	33.82 (35.56) ^f	57.39 (49.26) ^c	49.94 (44.98) ^f	37.83 (38.74) ^{bc}	44.74
4.	Annona seed extract (0.031%)	16.75	26.30 (30.87) ^B	53.94 (47.26) ^c	42.48 (40.69) ^B	0 (0.00) ^{ef}	31.73
5.	Triazophos (0.05%)	12.25	73.19 (58.83) ^b	98.16 (84.06) ^a	84.31 (66.71) ^b	57.58 (49.37) ^a	78.31
6.	Profenophos (0.05%)	14.50	56.97 (49.03) ^c	81.87 (64.85) ^c	71.82 (57.93) ^d	21.08 (27.27) ^c	57.93
7.	Seed treatment + NSKE (5%)	13.50	68.36 (54.64) ^c	88.15 (69.87) ^b	75.02 (60.17) ^{cd}	50.50 (45.28) ^a	70.50
8.	Seed treatment + Azadirachtin (5 ml / lit of water)	15.25	36.58 (37.22) ^f	68.98 (56.17) ^d	58.07 (49.55) ^c	30.00 (33.20) ^c	48.40
9.	Seed treatment + Annona seed extract (0.031%)	16.00	33.19 (35.18) ^f	54.09 (47.35) ^e	46.68 (43.13) ^B	-6.66 (-8.79) ^B	31.82
10.	Seed treatment + Triazophos (0.05%)	11.50	81.02 (64.20) ^a	98.66 (84.27) ^a	87.78 (69.59) ^a	57.66 (49.41) ^a	81.28
11.	Seed treatment + profenophos (0.05%)	14.00	60.91 (51.32) ^{dc}	84.51 (66.87) ^{bc}	75.95 (60.63) ^c	8.66 (17.07) ^d	57.50
12.	Mechanical barrier (60 mesh net)	11.00	66.47 (53.62) ^{cd}	67.88 (55.50) ^d	74.36 (59.61) ^{cd}	57.00 (49.02) ^a	66.42
	Cd at 5%		3.241	4.229	2.155	9.97	

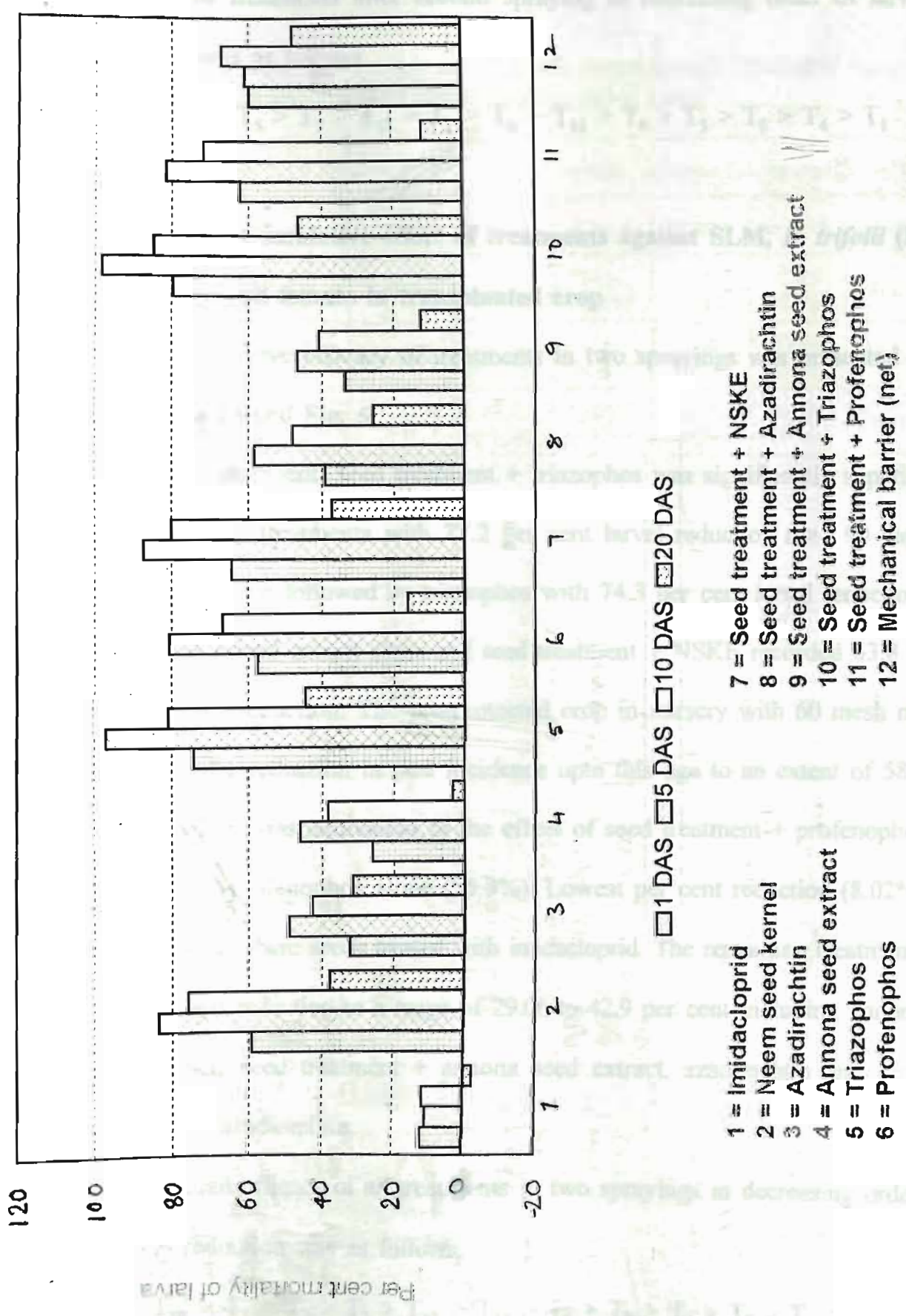
Figures in parenthesis are angular transformed values

Means with different superscripts differ significantly

DAS -Days after spraying

* Imidacloprid as seed treatment chemical

Fig 5 : Cumulative effect of different management strategies against *L. trifolii* (B) on tomato at field level



efficacy of treatments after second spraying in decreasing order of larval mortality was as follows.

$$T_{10} > T_5 > T_7 > T_{12} > T_2 > T_6 > T_{11} > T_8 > T_3 > T_9 > T_4 > T_1$$

4.5.2.3 Cumulative effect of treatments against SLM, *L. trifolii* (B) on tomato in transplanted crop

Cumulative efficacy of treatments in two sprayings was presented in Tables 14, 15 and Fig. 5

The treatment, seed treatment + triazophos was significantly superior over all other treatments with 77.2 per cent larval reduction upto 90 days aged tomato crop followed by triazophos with 74.3 per cent larval reduction. Neem seed kernal extract alone and seed treatment + NSKE recorded 63.8 to 66.3 per cent reduction. The pre-protected crop in nursery with 60 mesh net also showed a reduction in pest incidence upto this age to an extent of 58.2 per cent which was equivalent to the effect of seed treatment + profenophos (57.3%) and profenophos alone (55.3%). Lowest per cent reduction (8.02%) was recorded where seeds treated with imidacloprid. The remaining treatments recorded pest reduction to a range of 29.06 to 42.9 per cent including annona seed extract, seed treatment + annona seed extract, azadirachtin and seed treatment + azadirachtin.

Overall efficacy of all treatments in two sprayings in decreasing order of larval reduction was as follows.

$$T_{10} > T_5 > T_7 > T_2 > T_{12} > T_{11} > T_6 > T_8 > T_3 > T_9 > T_4 > T_1$$

Table 14 : Cumulative effect of different management strategies against SLM, *L.trifolii* (B) in transplanted crop

S. No.	Treatments	Pre-counting larvae / branch	Per cent mortality of larvae over untreated check				
			1 DAS	5 DAS	10 DAS	20 DAS	Mean
1.	Imidacloprid* (5 gm / kg seed)	15.5	12.10 (20.36) ⁱ	10.86 (19.24) ^f	11.59 (19.93) ⁱ	-2.44 (-8.86) ^g	8.02
2.	Neem seed kernal extract (5%)	14	59.53 (50.50) ^{dc}	83.66 (66.18) ^b	76.00 (60.71) ^c	37.89 (38.01) ^a	63.79
3.	Azadirachtin (5 ml / lit of water)	15.25	32.41 (34.70) ^g	49.17 (44.54) ^e	42.76 (40.84) ^g	31.56 (34.16) ^{bc}	38.10
4.	Annona seed extract (0.031%)	17.37	26.06 (30.70) ^h	46.10 (42.76) ^e	38.40 (38.28) ^h	3.54 (10.90) ^f	29.06
5.	Triazophos (0.05%)	15.87	74.45 (59.64) ^b	97.28 (80.82) ^a	81.01 (64.22) ^b	44.66 (41.94) ^a	74.35
6.	Profenophos (0.05%)	17.25	57.48 (49.31) ^e	80.81 (64.07) ^c	66.95 (54.92) ^c	16.20 (23.75) ^{dc}	55.36
7.	Seed treatment (ST) + NSKE (5%)	14.87	64.48 (53.43) ^c	87.47 (69.3) ^b	80.24 (60.77) ^c	37.45 (37.74) ^{ab}	66.39
8.	Seed treatment + Azadirachtin (5 ml / lit of water)	14.37	39.21 (38.76) ^f	58.42 (49.87) ^d	48.08 (43.93) ^f	25.95 (30.63) ^{cd}	42.92
9.	Seed treatment + Annona seed extract (0.031%)	16.62	33.61 (35.43) ^g	46.77 (43.17) ^e	40.91 (39.77) ^{gh}	12.30 (6.95) ^f	30.85
10.	Seed treatment + Triazophos (0.05%)	15.12	79.74 (65.26) ^a	98.35 (84.49) ^a	84.91 (67.16) ^a	46.50 (43.01) ^a	77.21
11.	Seed treatment + Profenophos (0.05%)	15.75	62.28 (52.11) ^{cd}	81.76 (64.76) ^{bc}	72.01 (58.08) ^d	11.49 (19.81) ^c	57.35
12.	Mechanical barrier (60 mesh net)	8.87	60.00 (50.77) ^d	61.12 (51.45) ^d	67.31 (55.12) ^e	47.91 (43.81) ^a	58.27
	Cd at 5%		0.967	6.752	1.299	7.14	

Figures in parenthesis are angular transformed values
Means with different superscripts differ significantly
DAS -Days after spraying
* Imidacloprid as seed treatment chemical

Table 15 : Overall influence and persistence of different management strategies against *L. trifolii* (B) in transplanted crop**

Efficacy of pesticides in decreasing order of larval mortality		1	2	3	4	5	6	7	8	9	10	11	12
Age of the crop / observation (days after spraying)		1	2	3	4	5	6	7	8	9	10	11	12
1 DAS	Seed treatment + triazophos (79.74)	triazophos (74.45)	Seed treatment + NSKE (64.48)	Seed treatment + Profenophos (62.28)	*Pre-protected crop (60.00)	NSKE (59.53)	profenophos (57.48)	Seed treatment + azadirachtin (39.21)	Seed treatment + annona seed extract (33.61)	azadirachtin (32.41)	Annona seed extract (26.06)	Seed treatment + (12.10)	
5 DAS	Seed treatment + triazophos (98.35)	triazophos (97.28)	Seed treatment + NSKE (87.47)	NSKE (83.66)	Seed treatment + Profenophos (81.76)	Profenophos (80.81)	Preprotected crop (61.12)	Seed treatment + azadirachtin (58.42)	Azadirachtin (49.17)	Seed treatment + Annona seed extract (46.77)	Annona seed extract (46.60)	Seed treatment (10.86)	
10 DAS	Seed treatment + triazophos (84.91)	triazophos (81.01)	Seed treatment + NSKE (80.21)	NSKE (76.00)	Seed treatment + Profenophos (72.01)	pre-protected (67.31)	profenophos (66.95)	Seed treatment + azadirachtin (48.08)	azadirachtin (42.76)	Seed treatment + Annona seed extract (40.91)	Annona seed extract (38.40)	Seed treatment (11.59)	
20 DAS	*Pre-protected crop (47.91)	Seed treatment + triazophos (46.50)	triazophos (44.66)	NSKE (37.89)	Seed treatment + NSKE (37.45)	azadirachtin (31.56)	Seed treatment + azadirachtin (25.95)	profenophos (16.20)	Seed treatment + Annona seed extract (12.30)	profenophos (11.49)	Annona seed extract (3.54)	Seed treatment (-2.44)	
Over all efficacy	Seed treatment + triazophos (77.21)	triazophos (74.35)	Seed treatment + NSKE (66.39)	NSKE (63.99)	Pre-protected crop (58.27)	Seed treatment + Profenophos (57.35)	profenophos (55.36)	Seed treatment + azadirachtin (42.92)	azadirachtin (38.10)	Seed treatment + Annona seed extract (30.85)	Annona seed extract (29.06)	Seed treatment (8.03)	

+ : Seed treatment with Imidacloprid

* : 60 mesh net in nursery stage

** : Cumulative effect of two sprayings

DAS : Days after spraying

Chapter - V

... various studies ...
... effect of chemical spraying on the
... serpentine leafminer, *Liriomyza trifolii* Burgess are discussed
... headings.

PHYTOLOGY AND MORPHOMETRICS OF SERPENTINE

MINER, *Liriomyza trifolii* Burgess ON TOMATO

... of the *Sp.*, *Liriomyza trifolii* (B) including the ...
... developmental ... of different life stages i.e. from ...
... morphometrics, fecundity, feeding behaviour were carried out under
... conditions when the mean temperature was 25.9°C.,
... leaf miner (m) in close proximity to each other in the
... tissue of leaf and they were partly whitish and translucent

... similar observations were reported by ...
... Chakraverty (1978) and Sanjeeva Kumar ...
... *L. trifolii* was observed ... 0.83 days ...

Discussion

... and ... (1990). However, the ...
... (1978), Chakraverty, (1978) and Sanjeeva

CHAPTER - V

DISCUSSION

The results documented through various studies on the biology, seasonal incidence, varietal screening and effect of chemical spraying on the incidence of serpentine leafminer, *Liriomyza trifolii* Burgess are discussed here under different headings.

5.1 BIOLOGY AND MORPHOMETRICS OF SERPENTINE LEAFMINER, *Liriomyza trifolii* Burgess ON TOMATO :

Biology of the SLM, *Liriomyza trifolii* (B) including the studies confined to the developmental durations of different life stages i.e. from egg to adult, morphometrics, fecundity, feeding behaviour were carried out under laboratory conditions when the mean temperature was 25.9°C.

Eggs were laid singly (or) in close proximity to each other in the mesophyll tissue of leaf and they were pearly whitish and translucent in colour. Similar observations were reported by Bethke and Parrella (1985), Parrella (1987), Chakravarthy (1993) and Sanjeeva Rao (1995). Incubation period of *L. trifolii* was observed as 2.9 ± 0.83 days during October - December months which is in conformity with the range observed by Parrella (1987) and Minkenberg and Helderman (1990). However, the reports of several other workers (Minkenberg, 1988 ; Chakravarthy, 1993 and Sanjeeva

Rao, 1995) showed some difference compared to the present findings. This could be attributed to the variations in the local conditions. The size in terms of length and width of eggs were 0.19 x 0.11 mm which are comparable with those observed by Chakravarthy (1993), Sanjeeva Rao (1995) and Park Jong Dae and Park (1996). Three distinct larval instars were recorded which have cylindrical body with anterior tapering and posterior truncated ends as observed by Parrella (1987).

The results pertaining the duration of larval stage was found to be 4 ± 0.77 days. The matured larva was yellow with a size measured as 2.05 x 0.53 mm. Marginal deviation from the present observation was recorded from that of Beri (1974), Zoebisch and Schuster (1987b), Elferen and Yathom (1989), Chakravarthy (1993), Sanjeeva Rao (1995) which can be attributed to the influence of environmental factors including the host plant. The reports of Park Jong Dae and Park (1996) with reference to the size of the larva support our documentation.

The mean prepupal period observed was 3.25 ± 0.24 hours which is in close conformity with that of Leibee (1984), Oatman and Michelbacher (1958), Chakravarthy (1993) and Sanjeeva Rao (1995).

In the present investigation, duration of pupal stage ranged from 8-10 days. This is comparable with the observations of Parrella (1987) and Minkenberg and Helderma (1990). However, according to Chakravarthy (1993) and Sanjeeva Rao (1995) the pupal period was 6.46 days and 7.46

days respectively. This may be due to variation in the location of experimentation and season. Size of pupa on an average was measured as 1.59 x 0.73 mm which is comparable with that of Park Jong Dae and Park (1996).

The mean developmental period from egg to adult was recorded 16.6 ± 2.73 days. Variation was observed by some authors with regard to total life period on different hosts viz., 18.4 days on 'celery' (Leibee, 1984), 20 days on 'bell pepper' (Chandler and Gilstrap, 1987b), 14.50 days on castor and 13.20 days on 'tomato' (Chakravarthy, 1993). This clearly shows the influence of host plant *vis-a-vis* nutritional factors.

In the present investigations, adult emergence was observed occurring between 6 to 9 am and 4 to 6 pm. The emergence was found completing within 12 to 15 min. This is comparable with the observations of several workers viz., Parrella (1987), Oatman and Michelbacher (1958), Chakravarthy (1993) and Sanjeeva Rao (1995). Morphological characters of adults are also similar to that recorded by Spencer (1973), Artherton and Rudich (1986), Viraktamath *et al.*, (1993) and Srinivasan *et al.*, (1995).

Duration of pre-mating and mating activity ranged from 8-10 hours and 30 to 75 minutes respectively. These observations are similar to those of Oatman and Michelbacher (1958), Chakravarthy (1993) and Sanjeeva Rao (1995), who reported it as less than 24 hours.

Adult longevity ranged from 10-12 days with two per cent sugar solution as source of food material. This is in deviation to the documentation made by Chakravarthy (1993) and Sanjeeva Rao (1995) might be due to variation in the source of food material.

Results pertaining to male to female sex ratio of *Liriomyza trifolii* was observed to be 1:1.14 which remained in close conformity with the observations of Parrella (1987), Chakravarthy (1993) and Sanjeeva Rao (1995).

Average number of eggs laid per female was 12.25 which is comparable with those observed by Chakravarthy (1993). But difference in fecundity was also observed by several workers viz., Leibe (1984), Fagoonee and Toory (1984) and Sanjeeva Rao (1995) which might be due to variation in the season during the experimentation period.

5.2 SEASONAL INCIDENCE AND EFFECT OF CROP PHENOLOGY ON SLM, *Liriomyza trifolii* Burgess INFESTATION

The seasonal incidence of serpentine leafminer *Liriomyza trifolii* was recorded on tomato at insectary, S.V.Agricultural College, Tirupati from July 2000 to June 2001 and the results are discussed here under.

The incidence of leafminer first appeared in the month of June and July and reached to its peak level showing 2.20 larvae per leaf and 93.3 per cent miner infestation per branch during first week of October. Another peak

level of incidence was observed during first week of January with 2.40 larvae per leaf and 93.20 per cent miner infestation per branch. From July onwards miner incidence gradually increased and continued upto January. Similar findings were documented by Ramesh (1993), Issa and Marcano (1994) and Sanjeeva Rao (1995). However, the peaks in the population fluctuation of SLM during January were found contradictory to the observations of the earlier workers. This might be due to the influence of location and season specific climatic conditions.

In the present findings the comparative analysis between weather factors and miner incidence revealed that maximum and minimum temperatures had a significant negative relationship and relative humidity had a positive relationship. Similar findings were documented by Sanjeeva Rao (1995). Rainfall had a positive correlation with miner infestation by *Liriomyza trifolii*. This is in confirmation with the observation of Ramesh (1993). However, these findings deviate from that of Singh *et al.*, (1991) who have observed adverse effect of heavy rain on larval population.

The results on the distribution of the pest in terms of number of mined leaves, number of larvae and number of mines per branch revealed that there was profound influence of crop growth (stage) on it. Low miner infestation was observed in terms of number of mined leaves per branch (0.50, 1.08, 2.00, 2.80 and 3.00) in early crop growth stages viz., 10, 17, 24, 31 and 38 days after sowing, respectively as was already described by Chakravarthy

(1993). This might be due to the insignificant leaf size in tomato in early stages. According to Oatman and Michelbacher (1958), Johnson *et al.*, (1980) and Chandler and Thomas (1983), mining ability of larva was more during cotyledonary stage of the crops like garden pea, celery, bell pepper etc. as compared to the small and thick leaf in tomato plant.

Maximum miner incidence or severity of the pest in terms of number of larvae per branch in mined leaves was recorded during early stages (24 DAS) and also flowering period (45 DAS) showing 8.16 larvae per two leaves and 18.80 larvae per 6.16 leaves, respectively which might be due to the vulnerable crop stage as well as high relative humidity ranging from 69 to 77 per cent. This is comparable with the findings of Lakshminarayana *et al.*, (1992), who have recorded more pest incidence in terms of live larvae during younger stages of the crop.

Studies on the influence of mechanical barrier, 60 mesh net set at different crop stages of tomato in checking infestation of leaf miner, *L. trifolii* revealed that net was considered as one of the major element that can be included in pest management programme of SLM, *L. trifolii*. When the tomato crop was protected throughout the nursery stage upto 30 days with net, it has resulted in preventing infestation by the pest. This clearly indicates that 60 mesh net has prevented the entry of the miner in to nursery bed as observed by Antignus *et al.*, (1998). The wide usage of net or screens for pest control in case of vegetables, flowers and fresh herbs was also explained by Berlinger *et al.* (1991) and Ausher (1997) as the density of the net or screen

caused blocking effect which interfered with penetration of small insects like whiteflies, leaf miners and aphids. Further protection of tomato crop only in nursery stage, resulted in less incidence of the pest upto 14.26 per cent in transplanted crop. This might be due to the inherent capacity of the plant that perpetuates the initial vigour evidenced with the capacity to resist further pest infestation in field resulting in higher yield (23.58 kgs.).

Protecting the crop from 30 to 60, 60 to 90 and 90 to 120 days differently for a definite period showed that preventing the pest infestation at peak period of infestation as evidenced by earlier studies i.e. from 30 to 60 days after sowing also made the crop to escape from it. Results showed only 5.75 per cent miner infestation in protected crop compared to 60 to 70 per cent in unprotected crop at 30 to 60 days and less incidence of the pest upto 18.37 per cent recorded at last stages of the crop. Providing protection with screen at 60-90 and 90 to 120 days did not reduce the pest incidence which was said to be the miner incidence ranging from 30.2 to 39.4 per cent. But protection throughout the crop period both in nursery and transplanted stages was also found not advisable since it has affected the crop growth resulting in thickening of leaf, stunting of the plants, reduced flowering and further yields. This might be due to reduction of light penetration in to net that might have resulted in poor crop growth and yield (10.66 kg). These results are in conformity with observations of Antignus *et al.* (1998) who reported about the disadvantage of using nets in green house for pest control in vegetables.

5.3 VARIETAL REACTION :

Seven varieties of tomato were screened for their reaction against serpentine leafminer, *Liriomyza trifolii* under field conditions. The results obtained in this study revealed that the cultivars viz., Hybrid Cross -08, Hybrid Cross - 17 and Tomato Ruchi hybrids were found to be moderately resistant to *Liriomyza trifolii*, showing 20.00, 23.33 and 25 per cent miner infestation per plant respectively. The cultivar, "Arka Vikas" was found susceptible showing an average of 50 per cent miner infestation per plant, whereas "Pusa Ruby", "S-22" and "PKM-1" were highly susceptible recording 75.00, 65.00 and 63.33 per cent miner infestation per plant, respectively. These results are comparable with the findings given by Hawthorne *et al.*, (1992) and Erb *et al.*, (1993) for resistance to leafminer in compared to cultivated tomato, non-preference for leafminer persisted in all *Lycopersicon* interspecific hybrids at maturity stage of the crop offering resistance to the pest. The variation in preferring different tomato cultivars by *Liriomyza trifolii* might be due to the morphohistological as well as biochemical characters of leaves. Based on the performance against serpentine leafminer when seven tomato cultivars were tested for their biochemical constituents like phenol content, revealed that a negative correlation was observed between phenolic content and incidence of leafminer, *Liriomyza trifolii*. All the seven tomato cultivars were found differing significantly with each other.

Maximum phenol content was observed In Hybrid Cross-08. Similar type of host plant resistance was observed in Chrysanthemum, where the cultivars with high phenols were found resistant to insect pests. Minimum phenol content was observed in the leaves of "Pusa Ruby" showing high miner infestation which is comparable with the findings of Ipe M Ipe and Sadaruddin (1984), where low phenolic contents in the leaves made them more vulnerable to high rate of attack by *Liriomyza* sp. A factor responsible for the high miner infestation might be due to the concentration of phenols, which react with sugars, the phagostimulants resulting in the formation of tannins that tends to reduce the availability of free sugars which are necessary for oviposition and feeding preference by the pest. Besides this as the older leaves consists of reduced quantity of these free sugars, tomato leaves with 70 to 120 days age have resulted in low pest load (Haslam 1966).

The relative susceptibility of different tomato cultivars to leaf miner was also evidenced by number of larvae mining per leaves of a branch. Maximum number of larvae of about 18.4 were recorded in "Pusa Ruby" where as minimum of 5.26 to 5.46 was recorded in Hybrid Cross - 08 and Hybrid Cross - 17. The difference in larval preference could also be attributed to the biochemical component of the leaves, i.e. phenolic compounds in a particular variety.

5.4 EFFICACY OF DIFFERENT MANAGEMENT STRATEGIES AGAINST SLM, *L. trifolii* (B) ON TOMATO :

In the present investigation, popularly used pesticides, botanicals and mechanical barrier (60 mesh net) were evaluated for their efficiency against incidence of *L. trifolii* in tomato crop both in nursery and transplanted crop. Imidacloprid was used as seed treatment chemical alone and in combination with other treatments.

Triazophos with 94.8 per cent larval reduction and neem seed kernal extract with 76.3 per cent larval mortality were found promising upto 30 days, i.e. in nursery stage. The efficacy of these chemical were comparable with that of mechanical barrier treatment (erecting 60 nylon mesh) where the incidence could be practically eliminated.

In case of transplanted crop, in all treatments, the larval mortality gradually increased from first day after spraying and mortality was found varying from 29 to 74.3 per cent. Maximum suppression of larval development was observed at five days after spraying. Triazophos and neem seed kernal extract treatment alone as well as in combination with prior seed treatment with imidacloprid were found significantly superior recording 97.2, 83.6, 98.3 and 87.4 per cent larval mortality respectively. The efficacy of these treatments persisted upto 20 days after application.

From the above results it is evident that triazophos (0.05%) alone or along with imidacloprid as seed dressing chemical were highly

effective in controlling larvae of *L. trifolii* to an extent of 94.8 per cent in nursery and 74.35 to 77.2 per cent in transplanted crop. This confirms the findings of Jagannatha (1994) and Jeyakumar and Uthamasamy (1997).

Neem seed kernel extract (5%) alone and imidacloprid were effective in reducing larval population of *L. trifolii* to an extent of 76.37 per cent in nursery and 63.8 to 66.4 per cent in transplanted crop. These findings get support with results of Stein and Parrella (1985), Larew *et al.*, (1985), Knodel *et al.*, (1986), Parkman and Piekowski (1990), Viraktamath *et al.*, (1993), Jagannatha (1994), Pawar *et al.*, (1996), Jeyakumar and Uthamasamy (1997) and Choudary and Rosaiah (2001).

The commercial formulation of azadirachtin was less effective against *L. trifolii* on tomato under field conditions. This is in agreement with the findings of Jeyakumar and Uthamasamy (1997) and Choudary and Rosaiah (2001). But Stein and Parrella (1985) and Knodel *et al.*, (1986) reported the effectiveness of commercial neem formulations viz., neemazal, Margosan-D in reducing the pest under laboratory conditions.

Seed treatment with imidacloprid was found ineffective in reducing larval population only to an extent of 12.1 to -2.44 per cent. The ineffectiveness of imidacloprid might be due to quick degradation of chemical by weather conditions. These results corroborate with the findings of Saito *et al.*, (1992), Ichikawa *et al.*, (1996) and Choudary and Rosaiah (2001). But Stein and Parrella (1985) recorded imidacloprid which was proved to be toxic

to prepupae under laboratory conditions but failed to perform well under field conditions.

No leafminer incidence was also recorded in the plots where nylon mesh net was used. However, the miner incidence gradually increased and recorded 11 larvae per branch at 70 days when the barrier was removed. Even then this treatment of nylon mesh protection recorded 58.2 per cent reduction of larval population compared to untreated control. This low miner incidence compared to other treatments in protected crop might be due to the capacity of plant during protected period to resist the initial damage as well as development of larva indicating the importance of protecting the crop at nursery that impaired the pest incidence and development in later stages of crop growth. This is in agreement with the findings of Antignus *et al.*, (1998) who has reported that bionet 50 mesh screens serve as improved barriers which is sufficient to interfere with the penetration of wide range of insect pests including leaf miners. So, 60 mesh net may serve as a major element of integrated pest management to avoid the involvement of toxic chemicals for leaf miner reduction in tomato.

Chapter - VI

Summary

CHAPTER - VI

SUMMARY

Studies on biology, seasonal incidence, influence of tomato varieties for the reaction of leafminer infestation and impact of different management strategies on *Liriomyza trifolii* Burgess were carried out at S.V. Agricultural College, Tirupati, Chittoor District, Andhra Pradesh during July 2000 to June 2001.

Studies on the biology of SLM, *L. trifolii* were oriented towards the morphometrics and developmental durations of different stages were documented in the insectary under laboratory conditions at a mean temperature of 25.9°C. The female fly laid on an average of 10-15 eggs by inserting its ovipositor into the mesophyll tissue of leaf in the tubular leaf punctures. Oval shaped eggs were laid either singly or in close proximity, which were pearly whitish and translucent in colour. The length and width of the eggs were 0.19 ± 0.02 and 0.11 ± 0.01 mm, respectively. The mean incubation period was found to be 2.9 ± 0.83 days. During the period of development, three larval instars were observed. The mean body length and width of different instars of larva ranged from 0.57 to 2.05 mm and 0.14 to 0.53 mm respectively, ascendingly varying as the maggots grow. The total larval duration was found to be 4 ± 0.77 days. The size of pupa was measured as 1.59 x 0.73 mm. The duration of prepupa and pupa was $3.25 \pm$

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0.24 hours and 9 ± 0.83 days respectively. Adult longevity lasted for 11 ± 0.77 days when two per cent sugar solution provided as source of food material. Total developmental period from egg to adult ranged from 13 to 20 days with an average of 16.6 ± 2.73 days.

The female and male adult flies measured with an average body length of 1.80 ± 0.05 mm and 1.61 ± 0.06 mm, abdomen length of 0.81 ± 0.06 mm and 0.69 ± 0.04 mm and an average wingspan of 2.33 ± 0.07 mm and 2.14 ± 0.06 mm respectively. The male to female sex ratio was observed to be 1:1.14.

Tomato crop variety Pusa Ruby was raised regularly throughout the year at 15 days interval to observe seasonal incidence and peak periods of infestation of SLM, *L. trifolii* Burgess from July 2000 to June 2001. Initial incidence of leafminer, *L. trifolii* was observed during first week of July (27th Standard week) showing 38.7 per cent miner infestation with 0.4 larva per leaf and the pest increased gradually in subsequent months. The peak incidence of leafminer to an extent of 2.2 to 2.4 larva per leaf and 93.2 to 93.3 per cent miner infestation was recorded during first week of October and first week of January (40th and 1st standard weeks). During this period the average maximum temperature, minimum temperature, relative humidity and rainfall were 29.6°C, 20.6°C, 74.82 per cent, and 61.77 mm respectively. From February onwards the miner incidence decreased gradually and no incidence was observed during April and May months.

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Maximum temperature showed non-significant and negative correlation with mean larval population ($r = -0.83$) and per cent miner infestation ($r = -0.85$). But minimum temperature had negative and non-significant correlation with mean larval population ($r = -0.55$) and had negative and significant correlation with per cent miner infestation (-0.781). Where as relative humidity had a significant positive correlation with mean larval population ($r = 0.861$) and per cent miner infestation ($r = 0.815$) but rainfall had a non-significant positive correlation with mean larval population and per cent miner infestation ($r = 0.382$ and 0.217 respectively).

Studies on distribution of the pest expressed in terms of number of mined leaves, number of larvae and number of mines per branch revealed that these observations varied depending upon the stage of the crop. Initial mining was observed on fourth leaf stage on seedlings of 10 days old that gradually increased. Maximum infestation was recorded at 24, 31 and 45 days after sowing recorded 2.00, 2.83 and 6.16 mined leaves per branch 8.16, 9.16 and 18.80 larvae per branch and 5.61, 11.6 and 15.5 mines per branch, respectively. Minimum miner incidence was observed at 94 and 101 days after sowing recording 1.50 and 0.42 mined leaves, 2.0 and 1.75 larvae and 1.66 and 1.25 mines per branch, respectively.

Observation on the influence of mechanical barrier, 60 mesh net at different crop stages of tomato in checking infestation of leafminer, *L. trifolii* revealed that net was considered as one of the major element of pest

management programme. When tomato crop was protected throughout the nursery stage upto 30 days resulted in only 14.26 per cent infestation and yield of 23.58 kg per 20 m² and from 30 to 60 days in transplanted crop documented the miner incidence of 18.37 per cent and yield of 22.65 kgs per 20 m². Protection of crop with net throughout the crop period affected the crop growth resulted in thickening of leaf, stunting of plant and reduced flowering and yield (10.66 kg / 20 sq.m). Protection of the crop during 60 to 90, 90 to 120 days did not showed any significant reduction of the pest, showing 30.2 to 39.4 per cent miner incidence and yield of 15.7 to 17.4 kgs per 20 m².

When seven cultivars of tomato were screened under field conditions during *rabi* season of 2000-2001 against serpentine leafminer, *L. trifolii*, The cultivars viz., Hybrid Cross-08 with 20 per cent, Hybrid Cross-17 with 23.33 per cent and Tomato Ruchi with 25 per cent miner infestation were found to be moderately resistant. The cultivar, Arka Vikas was found susceptible showing an average of 50 per cent miner infestation whereas Pusa Ruby, S-22 and PKM-1 were highly susceptible recording leafminer infestation to an extent of 63.33 to 75 per cent.

Studies on the estimation of biochemical constituents of tomato leaves revealed that the total phenols were more (2.96 mg/g) in the cultivar Hybrid Cross-08 that found moderately resistant to leafminer. Low phenol content observed in Pusa Ruby (1.76 mg/g) made it highly susceptible to leafminer.

Negative and significant correlation ($r = -0.9251$) was observed between total phenol content of the leaf and per cent miner infestation on tomato.

A field trial was conducted to evaluate the efficacy of different management strategies including chemical pesticides, botanicals and mechanical barrier against *L. trifolii* both in nursery and transplanted crop stages. Data documented in nursery stage revealed that among all chemicals, triazophos has given 94.82 per cent death of larva followed by NSKE recorded 76.37 per cent. Imidacloprid as seed treatment and water remain on par with each other with only 30.37 and 24.69 per cent mortality of larva with in 10 days after spraying over pre count.

In transplanted crop stage, the results after two consecutive sprayings revealed that the treatments, triazophos and neem seed kernal extract alone as well as in combination of seeds treated with imidacloprid were significantly superior with 63.8 to 77.2 per cent reduction of larva compared to untreated control. These were followed by seed treatment + profenophos (57.3%) and profenophos alone (55.3%). Minimum reduction of the pest to an extent of 8.03 per cent was observed in seedlings where seed was treated with imidacloprid. Other treatments including annona seed extract, seed treatment + annona seed extract, azadirachtin and seed treatment + azadirachtin showed pest reduction only to an extent of 29.06 to 42.9 per cent. No leafminer incidence was recorded in plots where mechanical barrier, 60 mesh net was used. However the miner incidence

gradually increased and recorded 11 larvae per branch at 70 days when the barrier was removed. Even then this treatment of 60 mesh net protection recorded 58.2 per cent reduction of larval population compared to untreated control.

Literature cited

LITERATURE CITED

Acharya N.G. Patil Agricultural University

R. and Ghosh C. S. 1982 Damage by serpentine leafminer near Mysore (Diptera : Agromyzidae). *Journal of Horticultural Science* 75: 483-491

Lapidot M., Hinder O., Messika Y and Shlomohi 1998 Insect Absorbing Screens serve as optical barriers to protect crops from virus and insect pests. *Journal of Economic Entomology* 91(6): 835

Literature cited

1977 Implementation of integrated pest management in fruit orchards 25: 511-515

1982 Bericht von dem auf den Blättern der Bäume und Sträucher vorkommenden Schlangen - Gattung *Agromyza*

1914 Ecology of a leafminer, *Agromyza brassicae* (Kiley). *Agromyzid Journal of Natural History* 85: 143-151

M. J. Montoya and J. A. 1992 Application of... into greenhouses in the state

LITERATURE CITED

(As per Acharya N.G. Ranga Agricultural University regulations)

- Alverson D R and Gorsuch C S 1982 Damage by serpentine leafminer *Liriomyza trifolii* (B) (Diptera : Agromyzidae) Journal of Economic Entomology 75: 888-891.
- Antignus Y, Lapidot M, Hadar D, Messika Y and Shlomocohen 1998 Ultraviolet Absorbing Screens serve as optical barriers to protect crops from virus and insect pests. Journal of Economic Entomology 91(6): 1401-1405.
- Artherton J G and Rudich J 1986 The tomato crop : a scientific basis for improvement. Chapman and Hall Ltd. New York, 661 pages.
- Ausher R 1997 Implementation of integrated pest management in Israel. Phytoparasitica 25: 919-924.
- *Beckman J C 1680 Bericht von denen auff den Blattern der Baume in diesem 1680 tem Jhrehaufig gefundenen Schlangen - Gestalten. Frankfurt /o.
- *Beri S K 1974 Biology of a leafminer, *Liriomyza brassicae* (Riley) (Diptera : Agromyzidae). Journal of Natural History 8: 143-151.
- Berlinger M J, Mordecchi S and Leeper A 1991 Application of screens to prevent whitefly penetration into greenhouses in the Mediterranean Basin. IOBC / WPRS Bull. XIV. 105-110.

Bethke J A and Parrella M P 1985 Leaf puncturing, feeding and oviposition behaviour of *Liriomyza trifolii*. *Entomologia Experimentalis et Applicata* 39: 149-154.

Burgess E 1880 The cover oscanis (*Oscanis trifolii* Burgess n.sp.). Reprints of United States Department of Agriculture 1879: 200-201.

Chakravarthy M S 1993 Bionomics and host range of serpentine leafminer, *Liriomyza trifolii* (B) (Diptera : Agromyzidae). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad. 118 pages.

Chakravarthy M S, Raman Goud T and Singh T V K 1995 Host range and extent of damage of the American Serpentine leafminer, *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae). *Pest Management and Economic Zoology* 3(1): 61-63.

*Chandler L D 1984 Seasonal population fluctuations of *Liriomyza sativae* Blanchard in bell pepper. *South Western Entomologist* 9: 334-340.

Chandler L D 1985 Flight activity of *Liriomyza trifolii* (Diptera : Agromyzidae) in relationship to placement of yellow traps in Bell pepper. *Journal of Economic Entomology* 78: 825-828.

Chandler L D and Gilstrap F E 1987a Seasonal fluctuations and age structure of *Liriomyza trifolii* larval populations on bell pepper. *Journal of Economic Entomology* 80: 102-106.

Chandler L D and Gilstrap F E 1986 within plant larval distribution of *Liriomyza trifolii* (Burgess) on bell pepper. Environmental Entomology 15: 96-99.

*Chandler L D and Gilstrap F E 1987b Biology of *Liriomyza trifolii* (Burgess) on bell pepper under constant temperature conditions. South Western Entomologist 11: 269-276.

*Chandler L D and Thomas E C 1983 Seasonal population trends and foliar damage of agromyzid leafminers on cantaloup in the lower Rio Grande valley, Texas. Journal of Georgia Entomological Society 18: 112-120.

Choudary D P R and Rosaiah B 2001 Evaluation of different insecticides against serpentine leafminer *Liriomyza trifolii* (Burgess) (Agromyzidae : Diptera) on Tomato. Pestology XXV(2): 37-39.

Cox D L, Remick D M, Lasota J A and Dybas R A 1995 Toxicity of avermectin to *Liriomyza trifolii* (Diptera : Agromyzidae) larvae and adult. Journal of Economic Entomology 88(5): 1415-1419.

Elferen J H W M and Yathom V S 1989 The bionomics of *Liriomyza trifolii* on gypsophia and bean leaves. Phytoparasitica 17: 241-250.

Erb A W, Lindquist R K, Flickinger J and Coasey M L 1993 Resistance of selected interspecific *Lycopersicon* hybrids to *Liriomyza trifolii* (Diptera : Agromyzidae) Journal of Economic Entomology 86(1): 100-109.

- Fagoonee I and Toory V 1984 Contribution to the study of the biology and ecology of the leafminer, *Liriomyza trifolii*. Insect Science and Application 5: 25-30.
- Hanna H Y, Story R N and Adams J 1987 Influence of cultivar, nitrogen and frequency of insecticide application on vegetable leafminer (Diptera : Agromyzidae) population density and dispersion on Snap Beans. Journal of Economic Entomology 80: 107-110.
- Haslam E 1966 Chemistry of vegetable tannins. Academic Press, New York 179 pp.
- Hawthorne D J, Shaprio J A, Tingey W M and Mutschler M A 1992 Trichome borne and artificially applied acylsugars of wild tomato deter feeding and oviposition of the leafminer, *Liriomyza trifolii* Entomologia Experimentalis et Applicata 65(1): 65-73.
- Hussey N W, Read W H and Hesling J J 1969 The pests of protected cultivation. The biology and control of glass house and mushroom pests. Edward Arnold, London, 404 pages.
- *Ichikawa K, Ohno T and Nakagome T 1996 Control of the legume leafminer *Liriomyza trifolii* (Burgess) on tomatoes. Research Bulletin of the Aichi Ken Agricultural Research Centre 28: 177-187.
- Ipe M Ipe and Sadaruddin 1984 Infestation and host specificity of *Liriomyza brassicae* Riley and the role of phenolic compounds in host plant resistance. Entomon 9(4): 265-269.

121
*Issa S and Marcano R 1994 Population dynamics of *Liriomyza sativae* and its parasites on tomato Turrjalba 44(1): 24-30.

Jagannatha R 1994 Comparative biology, ecology and management of American Serpentine leafminer, *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae). M.Sc. (Ag.) Thesis, University of Agricultural Sciences, Bangalore, India 126 pages.

Jagannatha R and Viraktamath C A 1997 Host preference by the female leafminer, *Liriomyza trifolii* (Diptera : Agromyzidae). Insect environment 2(4): 137.

Jeyakumar P and Uthamasamy S 1996 Ecological Barrier for *Liriomyza trifolii* (Burgess). Insect Environment 2(2): 55-56.

Jeyakumar P and Uthamasamy S 1997 Bio-efficacy of some synthetic insecticides and botanicals against *Liriomyza trifolii* (B). Indian Journal of Entomology 59(4): 347-350.

Jeyakumar P and Uthamasamy S 1998 Ovipositional preference of *Liriomyza trifolii* (Burgess) to different host plants. Pest management in Horticultural Ecosystem 4(1): 43-45.

Johnson M W, Oatman E R, Wyman J A and Van Steenwyk R A 1980 A technique for monitoring *L. sativae* in fresh market tomatoes. Journal of Economic Entomology 73: 552-555.

- Johnson M W, Witer S C, Toscano N C, Ting I P and Trumble J T 1983 Reduction of tomato leaflet photosynthesis rates by mining activity of *Liriomyza sativae*. *Journal of Economic Entomology* 76: 1061-3.
- Jyani D B, Patel N C, Jhala R C and Patel J R 1995 Bioefficacy of neem and synthetic insecticides on serpentine leafminer, *Liriomyza trifolii* (Diptera: Agromyzidae) infesting pea (*Pisum sativum*). *Indian Journal of Agricultural Science* 65(5): 373-376.
- Knodel J J, Larew H G and Webb R E 1986 Margosan-O a commercial formulation of neem seed extract, controls *Liriomyza trifolii* in *Chrysanthemum*. *Journal of Economic Entomology* 79: 80-84.
- Lakshminarayana M, Basappa H and Singh V 1992 Report on the incidence of hitherto unknown leafminer, *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae) in celery. *Environmental Entomology* 21: 497-501.
- Larew H G, Knodel M J J, Webb R E and Warthen J D 1985 *Liriomyza trifolii* (B) (Diptera : Agromyzidae) control on *Chrysanthemum* by NSKE applied to soil. *Journal of Economic Entomology* 78: 80-84.
- *Laterrot H, Bordat M, Renand M and Moretti A 1987 Various levels of leafminer resistance in *Lycopersicon* genus. *Tomato Genetic Cooperative* 37: 47-49.
- Leibee G L 1984 Influence of temperature on development and fecundity of *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae) on celery. *Environmental Entomology* 13: 497-501.

- *Lindquist R K and Casey M L 1988 Evaluation of cyromazine formulations and aldicarb 10 G for leafminer control on potted Chrysanthemums, marigolds and Zinnias. Ohio Florists Association Bulletin 700: 7-8.
- Lyra-netto A M C, Canadias J A, Wanderley L J B and Monezes D 1989 Control of *Thrips tabaci* (Thripidae) and *Liriomyza trifolii* (Burgess 1880) (Diptera : Agromyzidae) on onion. Annals of Society Entomology 18: 43-49.
- Mason G A, Johnson M W and Tabashnik B E 1987 Susceptibility of *Liriomyza sativae* and *Liriomyza trifolii* (Diptera : Agromyzidae) to permethrin and fenvalerate. Journal of Economic Entomology 80(6): 1262-1266.
- Menken S B J and Ulenberg S A 1983 Diagnosis of the agromyzids *Liriomyza bryoniae* and *L. trifolii* by means of starch gel electrophoresis. Entomologia Experimentalis et Applicata 34: 205-208.
- Minkenberg O P J M 1988 Life history of agromyzid fly *Liriomyza trifolii* on tomato at different temperatures. Entomologia Experimentalis et Applicata 48: 73-84.
- Minkenberg O P J M and Fredrix M J J 1989 Preference and performance of an herbivorous fly *Liriomyza trifolii* on tomato plants differing in leaf nitrogen. Annals of the Entomological Society of America 82(3): 350-354.

- Minkenbergh O P J M and Helderman C A J 1990 Effects of temperature on the life history of *Liriomyza bryoniae* on tomato. Journal of Economic Entomology 83: 117-125.
- *Minkenbergh O P J M and Ohenheim J J G W 1990 Effect of leaf nitrogen content of tomato plants on preference and performance of a leafmining fly. Oecologia 83(3): 291-298.
- Murthy K S and Prasad Y G 1996 Management of Serpentine leafminer on castor. Insect Environment 2: 3-5.
- Oatman E R and Kennedy G G 1976 Methomyl induced outbreak of *Liriomyza sativae* on tomato. Journal of Economic Entomology 69: 667-668.
- Oatman E R and Michelbacher A E 1958 The melon leafminer, *Liriomyza pictella* (Thomson) (Diptera : Agromyzidae). Annals of Entomological Society of America 51: 557-566.
- Oatman E R and Michelbacher A E 1959 The melon leafminer, *Liriomyza pictella* (Thomson) (Diptera : Agromyzidae). II Ecological Studies. Journal of Economic Entomology 52: 83-89.
- *Ozawa A, Olita M and Kohayashi H 1998a Control of American Serpentine leafminer, *Liriomyza trifolii* (Burgess) by nitenpyran granule application (in Japan). Proceedings of Kanto-Tosan Plant Protection Society 45: 175-177.

Ozawa A, Saito T and Ikeda F 1998 Adult counts on yellow sticky traps and pupal counts in trays at estimate larval occurrence of *Liriomyza trifolii* (Burgess) in tomato greenhouse. Japanese Journal of Applied Entomology and Zoology 42(3): 141-147.

Ozawa A, Saito T and Ikeda F 1999 Effect of host plant and temperature on reproduction of American serpentine leafminer, *Liriomyza trifolii* (Burgess). Japanese Journal of Applied Entomology and Zoology 43(1): 41-48.

*Park - Jong Dae and Park J D 1996 Host ranges and temperature effects on the development of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae). Korean Journal of Applied Entomology 35(4): 302-308.

Parkman P and Pienkowski R L 1990 Sublethal effects of NSKE on adults of *Liriomyza trifolii* (Diptera: Agromyzidae). Journal of Economic Entomology 83(4): 1246-1249.

Parrella M P 1987 Biology of *Liriomyza*. Annual Review of Entomology 32: 201-24.

Parrella M P and Bethke J A 1984 Biological studies of *Liriomyza huidobrensis* (Diptera : Agromyzidae) on *Chrysanthemum*, aster and Pea. Journal of Economic Entomology 77: 342-345.

Parrella M P, Christie G D and Robb K L 1983 Compatibility of insect growth regulators and *Chrysocharis parksi* (Hymenoptera : Eulophidae) for the control of *Liriomyza trifolii* (Diptera : Agromyzidae). Journal of Economic Entomology 76: 949-951

- *Parrella M P, Keil C B and Morse J G 1984 Insecticide resistance in *Liriomyza trifolii*. California Agriculture 38: 22-33.
- Parrella M P, Robb K L and Bethke J 1983 Influence of selected host plants on the biology of *Liriomyza trifolii* (Diptera: Agromyzidae). Annals of Entomological Society of America 76: 112-115.
- Parrella M P, Robb K L and Morishita P 1982 Response of *Liriomyza trifolii* (Diptera : Agromyzidae) larvae to insecticides, with notes about efficacy testing. Journal of Economic Entomology 75: 1104-1108.
- Parrella M P, Jones V P, Youngman R R and Lebeck L M 1985 Effect of leaf mining and leaf stippling of *Liriomyza* sp. on photosynthetic rates of *Chrysanthemum*. Annals of Entomological Society of America 78: 90-93.
- Patanik H P 1997 Studies on neem formulations against serpentine leafminer and tobacco caterpillar on tomato. Insect Environment 3(1): 10.
- Patel J J, Patel N C, Jyani D B and Patel J R 1998 Cyromazine - an effective insecticide against the American serpentine leafminer, *Liriomyza trifolii* infesting tomato. Indian Journal of Agricultural Sciences 68(12): 782-783.
- Patil B V, Somasekhar, Asiram T K, Rehman M and Nadagouda S 1997 Vegetative growth loss estimation due to serpentine leaf miner, *Liriomyza trifolii* on cotton and castor. Indian Journal of Entomology 59(4): 351-353.

Pawar D B, Lawande K E and Warade S D 1996 Control of *Liriomyza trifolii* on Tomato. Journal of Maharashtra Agricultural Universities 21(1): 166-167.

Ramesh P 1993 A technique to extract leaf miner larva from infested leaves. Pest management in Horticultural Ecosystem 351-353.

Reddy N K 1988 Studies on the varietal screening against leafminer, *Phyllocnistis citrella* Starnton (Lepidoptera: Phyllocnistidae) and chemical control of the pest complex of citrus. M.Sc. (Ag.) Thesis, Andhra Pradesh Agricultural University, Hyderabad 125 pages.

*Richter S and Tsegaye Y 1988 Rearing *Liriomyza trifolii* (Burgess) on *Phaseolus vulgaris* L. in the laboratory and the development of the test method. Beitrage Zur Tropischen Landwirtschaft and Veterinaermedizin 26: 387-394.

Robb K L and Parrella M P 1984 Sublethal effects of two insect growth regulators applied to larvae of *Liriomyza trifolii* (Diptera : Agromyzidae). Journal of Economic Entomology 77: 1288-1292.

Robin M R and Mitchell W C 1987 Sticky trap for monitoring leafminers *Liriomyza sativae* and *Liriomyza trifolii* (Diptera : Agromyzidae) and their associated Hymenopterous parasites in Watermelon. Journal of Economic Entomology 80(6): 1345-1347.

Rosaiah B 2001 Effect of different plant products against serpentine leafminer *Liriomyza trifolii* (B) on ridge gourd *Lifa accutangula*. Pestology XXV(4): 7-9.

*Rushtapakornchai W and Petchuichit P 1996 Efficiency of some insecticides for controlling tobacco whitefly *Bemisia tabaci* and leafminer *Liriomyza trifolii* on tomato. Kaen - Kaset Khon Kaen Agricultural Journal 24(4): 184-189.

Sadasivan S and Manickam A 1996 Biochemical methods. New age International (P) Limited Publishers, New Delhi 11: 193-194.

Saito T, Oishi T, Ikeda F and Sawaki J 1992 Effect of insecticides on the serpentine leafminer, *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae). Japanese Journal of Applied Entomology and Zoology 36: 183-191.

*Saito T, Oishi T, Ozawa A and Ikeda F 1995 Effects of temperature, photoperiod and host plants on development and oviposition of *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae). Proceedings of the Kanto Tosan Plant Protection Society 39(2): 127-134.

Sanderson J P, Parrella M P and Trumble J T 1989 Monitoring insecticide resistance in *Liriomyza trifolii* (Diptera : Agromyzidae) with yellow sticky cards. Journal of Economic Entomology 82(4): 1011-1018.

Sanjeeva Rao D 1995 Bioecology and management of serpentine leafminer *Liriomyza trifolii* (B). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad 145 pages.

Schuster D J and Everett P H 1983 Response of *Liriomyza trifolii* (Diptera: Agromyzidae) to insecticides on tomato. Journal of Economic Entomology 76: 1170-1174.

- *Rushtapakornchai W and Petchuichit P 1996 Efficiency of some insecticides for controlling tobacco whitefly *Bemisia tabaci* and leafminer *Liriomyza trifolii* on tomato. Kaen - Kaset Khon Kaen Agricultural Journal 24(4): 184-189.
- Sadasivan S and Manickam A 1996 Biochemical methods. New age International (P) Limited Publishers, New Delhi 11: 193-194.
- Saito T, Oishi T, Ikeda F and Sawaki J 1992 Effect of insecticides on the serpentine leafminer, *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae). Japanese Journal of Applied Entomology and Zoology 36: 183-191.
- *Saito T, Oishi T, Ozawa A and Ikeda F 1995 Effects of temperature, photoperiod and host plants on development and oviposition of *Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae). Proceedings of the Kanto Tosan Plant Protection Society 39(2): 127-134.
- Sanderson J P, Parrella M P and Trumble J T 1989 Monitoring insecticide resistance in *Liriomyza trifolii* (Diptera : Agromyzidae) with yellow sticky cards. Journal of Economic Entomology 82(4): 1011-1018.
- Sanjeeva Rao D 1995 Bioecology and management of serpentine leafminer *Liriomyza trifolii* (B). M.Sc. (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad 145 pages.
- Schuster D J and Everett P H 1983 Response of *Liriomyza trifolii* (Diptera: Agromyzidae) to insecticides on tomato. Journal of Economic Entomology 76: 1170-1174.

- 129
- Schuster D J, Waddill V H, Augustine J J and Volin R B 1979 Field comparisons of *Lycopersicon* accessions for resistance to the tomato pinworm and vegetable leafminer. *Journal of American Society of Horticultural Science* 104(2): 170-172.
- Singh T V K 1991 Outbreak of leafminer on vegetables and red hairy caterpillar on Sorghum in Andhra Pradesh, India. *Quarterly Newsletter* 34: 3&4.
- Singh I P, Agnes I P E and Ipe M Ipe 1991 Control of *Liriomyza brassicae* Riley by flooding. *Entomon* 16(1): 83-85.
- *Spencer K A 1973 Agromyzidae (Diptera) of economic importance. *Series Entomologica* 9: 1-418.
- Spencer K A and Steyskal G C 1986 *Manual of Agromyzidae (Diptera) of the United States*, USDA Agriculture Handbook pp. 638.
- Srinivasan K 1992 Pest management in solanaceous crops. In *Annual Report of Indian Institute of Horticultural Research 1992*. p. 10.
- Srinivasan K, Viraktamath C V, Meera Gupta and Tewari G C 1995 Geographical distribution, host range and parasitoids of serpentine leafminer, *Liriomyza trifolii* in South India. *Pest Management in Horticultural Ecosystems* 1(2): 93-100.
- *Stein U and Parrella M P 1985 Seed extract shows promise in leafminer control. *California Agriculture* 39: 7-8, 19-20.

- Talekar N S, Ying Fu Chang and Song Tay Lee 1983 Tomato insect pests: major management strategies. Proc. Symp. Insect control of vegetables (Taiwan) pp. 1-19.
- Viraktamath G A, Tiwari G C, Srinivasan K and Gupta Meera 1993 American serpentine Leafminer is new threat to crops. Indian Farming 43: 102.
- *Zehnder G W, Trumble J T and White W R 1983 Discrimination of *Liriomyza* species (Diptera : Agromyzidae) using electrophoresis and scanning electron microscope. Proceedings of Entomological Society of Washington 85: 564-74.
- Zoebisch T G and Schuster D J 1987a Longevity and fecundity of *Liriomyza trifolii* (Diptera : Agromyzidae) exposed to tomato foliage and honey dew in the laboratory. Environmental Entomology 16: 1001-1003.
- Zoebisch T G and Schuster D J 1987b Suitability of foliage of tomatoes and three weed hosts for oviposition and development of *Liriomyza trifolii* (Diptera: Agromyzidae). Journal of Economic Entomology 80: 758-762.
- Zoebisch T G, Schuster D J, Smerage G H and Stimach J C 1992 Mathematical descriptions of oviposition and egg and larval development of *Liriomyza trifolii* (Diptera : Agromyzidae) on tomato foliage. Environmental Entomology 21: 1341-1344.

* Originals are not seen.

