MANAGEMENT OF AMERICAN SERPENTINE LEAF MINER *Liriomyza trifolii* (Burgess) Dietars IN TOMATO

by

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(2015-11-007)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"MANAGEMENT OF AMERICAN SERPENTINE LEAF MINER *Liriomyza trifolii* (Burgess) Dietars IN TOMATO"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

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LIST OF ABBREVIATIONS AND SYMBOLS USED

@	At the rate of
^0C	Degree Celsius
%	Per cent
CD	Critical difference
cm	Centimetre
CRD	Completely Randomised Design
DAS	Days after spraying
DAT	Days after transplanting
et al.	And Others
Fig.	Figure
g	Gram
g L^{-1}	Gram Per litre
hr	Hour
ha	Hectare
ha^{-1}	Per hectare
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
km	Kilometre
L	litre
L^{-1}	Per litre

mg	Milligram
mL^{-1}	Per millilitre
mm	Millimetre
NBAIR	National Bureau of Agricultural Insect Resources
NS	Non -significant
No.	Number
$Plant^{-1}$	Per Plant
Sl.	Serial
sp. or spp.	Species (Singular and Plural)
viz.	Namely

Introduction

1. INTRODUCTION

Tomato, *Solanum lycopersicum* (L.), is one of the widely grown vegetables in the world, renowned for its nutritional quality and culinary properties and is a rich source of flavonoids, phenolics, vitamins and minerals. Presence of higher quantities of antioxidant lycopene reduces the menace of cancer, cardiac disorders and gerontological disorders (Anand and Sankari, 2015). Globally, tomato occupied an area of 48.13 lakh ha with an annual production of 1625 lakh MT and productivity of 33.90 t ha^{-1} (FAO, 2015). In India, it was cultivated in 8.82 lakh ha with an annual production of 18.74 lakh tonnes and productivity of 21.2 t ha^{-1} [NHB, 2015].

Out of the several factors that hinder the production of tomato, insect pest infestation accounts for a major share (Patra *et al.,* 2016). Tomato is infested by several pests which comprise of fruit borers, leaf miners and sucking pest complex. Among the several pests recorded, American serpentine leaf miner *Liriomyza trifolii* (Burgess) is a notorious invasive alien pest distributed all over the world and is more abundant in the temperate regions.

The genus *Liriomyza* is composed of more than 300 species, out of which 23 are economically important which instigate severe damage in crop plants. Among the *Liriomyza* spp., *L. trifolii* is an important polyphagous pest, believed to be originated in United States of America and initially described as *Oscinis trifolii* (Burgess) observed from white clover (Spencer, 1973).

As a result of globalization, transportation of goods and movement of humans became customary which resulted in unintentional introduction of harmful organisms to new geographical areas. *L. trifolii* was introduced to India along with chrysanthemum planting materials in 1991 and it was first recorded from castor plants in Hyderabad (DOR, 1991; Viraktamath *et al.,* 1993). Later, it was recorded from 79 host plants in south India and 48 host plants in Kerala, which underscores the severity of the pest (Srinivasan *et al.*, 1995; Smitha, 2004).

The adult leaf miner causes direct and indirect damage to the host plants through extensive mining of leaf tissues resulting in killing of young seedlings, diminishing quality of ornamentals and reduction in yield. Indirectly, they also act as vector of many diseases. Severe infestation reduces the photosynthetic rate of leaves to the tune of 62 per cent and caused 35 per cent yield loss in tomato (Johnson *et al.,* 1983; Krishnakumar, 1998).

Management of leaf miner is very difficult due to the characters like small body size, brief life stages, high oviposition rate and hidden larval stages (Pawar and Patil, 2013). Indiscriminate use of highly toxic synthetic insecticides for the management of *L. trifolii* give rise to pesticide resistance problems and other environmental hazards. Furthermore, reduction in natural enemy population, pest resurgence, secondary pest outbreak and pesticide residue problems also questions the uniqueness of conventional insecticides.

Natural enemies played an important role in the management of *L. trifolii.* Forty species of hymenopteran parasitoids were recorded from *L. trifolii* which emphasizes the importance of natural enemy conservation (Johnson and Hara, 1987). In this scenario, non-chemicals and botanicals gained more importance because of their higher decomposition rate, absence of residue hazards and safety to human and environment. Growing of tolerant varieties is an economically viable and environmental friendly option which can be well integrated with IPM strategies. Green labeled insecticides with different mode of action can also be incorporated in the management of *L. trifolii* in tomato as a substitute for conventional toxic chemicals.

Based on these facts, the study was conducted to meet the following objectives:

1. To document the pests of tomato at vegetative and reproductive stages of the crop.
2. To record natural enemies associated with the pests of tomato.
3. To evaluate tomato cultivars for field tolerance to *L. trifolii.*
4. To identify an effective and safe management option for *L. trifoii* in tomato.

Review of Literature

2. REVIEW OF LITERATURE

Tomato, *Solanum lycopersicum* (L.), is one of the most important and demanding vegetable crops in the world that belongs to the family solanaceae. Among the tomato growing countries, India ranks second in position next to China. Even though, the area under tomato cultivation is supplementary, productivity is comparatively low in India due to various factors, in which pest infestation accounts for a significant portion (Patra *et al.,* 2016).

2.1 PESTS OF TOMATO

Tomato acts as a host crop for many pests which included tomato fruit borer *Helicoverpa armigera* (Hubner), tobacco caterpillar *Spodoptera litura* (Fabricius), American serpentine leaf miner *Liriomyza trifolii* (Burgess), hadda beetle *Henosepilachna vigintioctopunctata* (Fabricius), sucking pests like aphid *Aphis gossypii* (Glover), silver leaf whitefly *Bemisia tabaci* (Gennadius), glass house whitefly *Trialeurodes vaporariorum* (Westwood), spiralling whitefly *Aleurodicus dispersus* (Russell), solenopsis mealy bug *Phenacoccus solenopsis* (Tinsley) and red spider mite *Tetranychyus* sp. (Sharma *et al.,* 2013 ; Kousika *et al.,* 2015).

Tomato fruit borer *H. armigera,* one of the most devastating pests of tomato belongs to the family Noctuidae of order lepidoptera. Adult moth lays eggs on leaves, flowers, fruits and oviposition rates ranged from 1000 to 1500 eggs female^{-1}(Fye and Mc Ada, 1972). *H. armigera* infestation observed at both vegetative and fruiting stage of the crop resulting in an extensive damage. This polyphagous pest was observed in 181 plant species under 45 families in India (Manjunath *et al.,* 1985). As a result of severe infestation, yield loss of about 22 to 38 per cent was reported from various parts of India (Dhandapani *et al.*, 2003). Early instar larva feeds on the foliage and late instar larva bores in to the fruit and feed the internal contents (Mustafiz *et al.,* 2015).

Tobacco caterpillar *S. litura* (Family: Noctuidae), a polyphagous pest, was reported from 120 plant species in India. Adult moth laid 2000 to 2500 eggs and the emerged larva undergo six instars and pupated in soil (Rao *et al.,* 1993). Infestation was mainly observed at the vegetative stage of the crop where the larva feed on the leaves, later it bores in to the fruits causing an yield loss of 12 to 23 per cent at rainy season and 9 to 27 per cent at winter season in tomato (Patnaik, 1998).

American serpentine leaf miner *L. trifolii* (Family: Agromyzidae), an invasive pest caused damage to an extent of 70 per cent in tomato (Zoebisch *et al.,* 1984). Adult fly inserted 100 to 600 eggs on the leaf surface. Females caused damage by creating feeding and oviposition punctures and the emerged maggots feed on mesophyll cells and make serpentine mines on leaves (Patil *et al.,* 2001).

H. vigintioctopunctata (Family: Coccinellidae), an important pest which mainly attacked solanaceous crops. Adult and grub colonized on leaves and scraped the epidermal layer resulted in skeltonization and further drying up of plants (Khan *et al.,* 2000).

A. gossypii (Family: Aphididae), a major sucking pest observed in tomato, colonized on various plant parts and sucked sap resulting in yellowing and drying of plant parts. Severe infestation resulted in disfiguration and stunted growth. It was also reported as a vector of viral diseases (Konar *et al.,* 2011)

Silver leaf whitefly *B. tabaci* (Family: Aleyrodidae), an important pest in tomato distributed all over the world. Both adults and nymphs suck sap from the lower surface of the plants causing yellowing and drying of plant parts. Adult insect lays elongated to oval shaped eggs on the under surface of the leaves and emerged nymphs undergo three nymphal instars and a pre pupal stage. Besides the feeding damage, it also acts as a vector of viral diseases in tomato (Jamuna *et al.,* 2016).

Glass house whitefly *T. vaporariorum* (Family: Aleyrodidae), usually observed in green house tomatoes which colonized on leaves and sucks plant juices from leaves. It also produces honey dew which on accumulation led to development of sooty mould which reduced the photosynthetic area of the leaves (Inbar and Gerling, 2008).

Spiralling whitefly *A. dispersus* (Family: Aleyrodidae), an introduced pest recorded first time from Kerala in 1993 (Palaniswami *et al.,* 1995). Srinivasa (2000) reported a wide host range of 481 host species under 90 families from India. Adult lays eggs in a spiral pattern and the emerged nymphs and adults suck sap from various plant parts and ensued in sooty mould growth. As a result, photosynthetic area of the plants get reduced (Mware *et al.,* 2010).

Solenopsis mealy bug *P. solenopsis* (Family: Pseudococcidae), infested on 202 plants under 55 families (Hodgson *et al.,* 2008). Ovo viviparous adults lay 150 to 600 eggs and the emerged nymphs colonized on various plant parts. Adults and nymphs suck sap from leaf and stem resulting in twisting of stem and malformation of leaves (Dhawan and Saini, 2009).

Red spider mite *Tetranychus* sp., an important non insect pest caused considerable economic damage to tomato plants (Reddy and Bhaskaran, 1987). Adults and nymphs inhabit the mature leaves and suck sap from the leaves. As a result of continuous feeding, white specks were formed on the leaves and were covered with nympal webs (Knapp *et al.,* 2003).

2.2 NATURAL ENEMIES

Tomato ecosystem is well occupied by the natural enemy fauna which play a considerable role in maintaining the pest population under check. Barbour *et al.* (1997) reported that coccinellid predator *Coelomegilla maculate* (De Geer) and reduviid *Geocoris punctipes* (Fallen) were present in tomato ecosystem which effectively predate on *Helicoverpa* sp. and *Manduca sexta* (L.).

Coccinellid predators like *Axinoscymnus puttarudriahi* (Kapur and Munshi), *Cryptolaemus mountrouzieri* Mulsant and *Scymnus coccivora* (Ayyar), chrysopids like *Mallada* sp. and *Apterochrysa* sp. were also reported as predators of *A. dispersus* in tomato (Dhandapani *et al.,* 2003). Ravi *et al*. (2008) reported that predatory mirids *Macrolophus* sp., spiders like *Thomisus* sp. and *Argiope* sp. performed as efficient predators in the tomato ecosystem. Predators like *Menochilus sexmaculatus* (Fabricius), *Syrphus corolla* (Fabricius), and *Chrysoperla carnea* (Stephens) were also observed in tomato fields (Ghosh and Chatterjee, 2009). *Neoseiulus longispinosus* (Evans) was effective in reducing the population of red spider mites by voracious feeding on mite eggs (Jayasinghe and Malik, 2014). Castro *et al.* (2016) identified *Chrysoperla externa* (Hagen) (Chrysopidae) as a predator of *T. vaporariorum* nymphs.

Mirid bug predators *Macrolophus caliginosus* (Wagner) and *Dicyphus tamaninii* (Wagner) were reported from greenhouse tomato crop which predated on various pest species (Castane *et al.,* 2004). *Nesidiocoris tenuis* (Reuter) predated on *B. tabaci* and *Tuta absoluta* (Meyrick) in tomato ecosystem (Zappala *et al.,* 2013). Bueno *et al.* (2013) reported that *Macrolophous* sp. fed on the eggs of *T. absoluta. Dicyphus hesperus* (Knight), a common mirid bug predator which is used as an effective biological control agent against whitefly, *B. tabaci* and psyllid *Bactericera cockerelli* Sulc (Calvo *et al.,* 2016).

Cambell *et al.* (1991) detected *Trichogramma exiguum* Pinto & Platner and *T. pretiosum* Riley as primary egg parasitoids of tomato lepidopterous pest complex. Hymenopteran parasitoid *Compoletis chloridae* Uchida and Dipteran *Servillia transversa* Tothill (Tachinidae) were helpful in managing the *H. armigera* population in tomato (Romeis and Shanower, 1996). *T. chilonis* Ishii is also considered as an efficient parasitoid of tomato fruit borer *H. armigera* (Khan, 2011).

2.3 SERPENTINE LEAF MINER *Liriomyza* spp.

Liriomyza belongs to the family Agromyzidae of Diptera is polyphagous in nature and is cosmopolitan in distribution. The larval stages of agromyzid flies are usually leaf miners, stem borers or sometimes gall formers. Agromyzid leaf miners are characterized by cylindrical body and the presence of anterior and posterior spiracles in both larval and pupal stages (EPPO, 2005).

Liriomyza spp. caused direct and indirect damage. The main damage was due to extensive mining of leaves by the larval stages which ensued in reduction in photosynthesis and premature abscission of leaves. Feeding and oviposition punctures resulted in destruction of leaf surface. The secondary damage was *via* transmission of diseases in plants by adult flies (Zitter and Tsai, 1977).

The economically important species under *Liriomyza* genus are *Liriomyza bryoniae* (Kaltenbach), *Liriomyza huidobrensis* (Blanchard), *Liriomyza sativae* (Blanchard) and *Liriomyza trifolii* (Burgess) (EPPO, 2005).

2.3.1 *L. bryoniae*

The adult fly is small with a black mesonotum and yellow femora with brownish markings (Minkenberg and Lenteren, 1986). It is a polyphagous pest reported from 16 plant families and the important crops included tomato, cucurbits, beans, and lettuce (Spencer, 1990).

2.3.2 *L. huidobrensis*

Adult fly is characterized by shiny black mesonotum, yellow frons and yellow femur with black markings. It was reported to be originated from South American region and recorded from 14 families of host plants and considered as an important pest in sugar beet, spinach, peas and ornamentals (Spencer, 1990).

2.3.3 *L. sativae*

L. sativae, native of Argentina, first reported as a pest of alfalfa. It infested on nine different plant families which included solanaceae, fabaceae and cucurbitaceae. It is distinguished by the presence of a shiny black mesonotum and yellow femur (Spencer, 1990).

2.3.4 *L. trifolii*

American serpentine leaf miner *L. trifolii*, probably originated from Florida of USA is one of the important pests of tomato. It was initially identified as *Oscinis trifolii,* recorded from white clover in 1880, under the family chloropidae. In 1898, it was shifted to the genus *Agromyza* in the family Agromyzidae by Coquillet and further shifted to *Liriomyza* in 1925 by de Meijere (Spencer, 1973).

In India *L. trifolii* was first reported from Hyderabad on castor plants in 1991 (DOR, 1991). It was later reported from Gujarat, Karnataka, Delhi and Maharashtra (Viraktamath *et. al.,* 1993; Srinivasan *et al.,* 1995). Severe incidence of *L. trifolii* was first observed in Kerala on cowpea in 1996 (Reghunath and Gokulapalan, 1996).

2.3.4.1 Biology of L. trifolii

2.3.4.1.1 Egg

Adult flies laid eggs on upper surface of leaves one by one adjacent to each other. The oviposition rate of *L. trifolli* on tomato was recorded as 64.23 ± 4.07 at 25 ^{0} C (Minkenberg and Lantern, 1986). The oviposition rates differed in different crops and it was 142.20 in tomato, 113.10 in cotton and 130.00 in cowpea in Tamil Nadu (Jeyakumar and Uthamasamy, 1998). Smitha (2004) reported that oviposition rate of *L. trifolii* on cowpea was 48 to 50 eggs female^{-1} and the oviposition period lasted for 4 days in Kerala.

Lakshminarayana *et al.* (1992) reported that 2 to 3 days were required for the hatching of *L. trifolii* eggs in Andhra Pradesh on castor. But in Karnataka it completed the egg stage within 2.59 to 3.74 days on cowpea (Nadagouda *et al.*, 1997). The egg period was 1.5 to 3 days in Kerala, while it was 96.2 ± 10.3 hrs in Tamil Nadu on cowpea (Smitha, 2004: Ganapathy *et al.*, 2010).

Temperature played an important role in determining the egg development in *L. trifolii.* The optimum temperature needed for egg development in *Phaseolus* sp. and *Chrysanthemum* sp. was 10 ^{0} C and 13.4 ^{0} C respectively (Charlton and Allen, 1981).

2.3.4.1.2 Larva

L. trifolii larva usually preferred palisade mesophyll tissues of the leaf and under severe competition, they mined through leaf stalks and stem of the plant (Speyer and Parr, 1949). The larva had undergone four larval instars before reaching the pupal stage. The fourth instar larva, a non-feeding stage emerged out of the mine and pupated immediately (Parella, 1987).

The larval period was observed to be completed on tomato within 3.51 ± 0.06 days at 32 ^{0} C and 5.02 ± 0.03 days at 25 ^{0} C (Zoebisch *et al.,* 1992). Lakshminarayana *et al.* (1992) reported that larval period extended up to 6 to 9 days on castor in Andhra Pradesh whereas Jagannatha (1994) reported that it was 5.4 days on cowpea in Karnataka. Nadagouda *et al.* (1997) reported that the larval duration was 4.05 to 5.02 days in Karnataka whereas it was 7.5 ± 2.2 days in Tamil Nadu on cowpea (Ganapathy *et al.*, 2010).

In Kerala, larval duration was 0.90 days, 1.15 days, 1.26 days and 0.10 days for the first, second, third and fourth instar larva respectively on cowpea. As the larval stages advanced, the length of mine was also increased from 8 to 15 mm (first instar), 16 to 35 mm (second instar) and 25 to 57 mm (third instar) (Smitha, 2004).

2.3.4.1.3 Pupa

Parella (1987) recorded that pupal period was completed within 28 days on tomato at 15 ^{0} C and 8 to 11 days on chrysanthemum in United States of America. Lekshminarayana *et al.* (1992) identified the pupal duration on castor in Hyderabad as 6 to 7 days. In cowpea, pupal duration extended from 9.82 to 10.65 in Karnataka (Nadagouda *et al.,* 1997). In Kerala, pupal stage was completed within 7.9 days on cowpea whereas it was 9.5 ± 0.9 days in Tamil Nadu (Smitha, 2004: Ganapathy *et al.,* 2010). Pupation usually takes place in soil but in some cases golden yellow coloured pupa can be seen on leaf axil, leaves or stems (Jyothy, 2014).

2.3.4.1.4 Adults

Adult fly is small in size and characterized by presence of yellow patch on the hind part of mesonotum and bright yellowish scutellum, frons and third antennal segment. Adults usually emerged at early morning hours and the females were comparatively larger than males (Oatman and Michelbacher, 1958). Parella (1987) described that longevity of adults mainly depend on the accessibility to food source. Life span of females was comparatively more than the males. Female life span lasted for 7.5 ± 0.32 at 20 ^{0} C while it was 4.86 ± 0.21 at 25 ^{0} C on tomato (Zoebisch *et al.,* 1992).

Adult female was 1.70 mm long and 0.59 cm wide while male was 1.49 mm long and 0.50 mm wide (Smitha, 2004). Ganapathy *et al.* (2010) reported that female life span was about 6 to 7 days while that of male was about 4.1 days in cowpea.

2.3.4.2 Nature of Damage

Adult flies deposited eggs by making oviposition punctures on the leaf surface. Emerged maggots feed on the mesophyll tissues and constructed characteristic serpentine mines.

As the size of the larva increased, mine width also increased which resulted in extensive leaf damage (Parella *et al.*, 1985). Female flies also made feeding punctures using their ovipositor and feed on the leaf secretions. The adult males depended on the punctures made by the females for nourishment (Parella, 1987).

Johnson *et al.* (1983) reported that due to the severe leaf mining on tomato, photosynthetic capacity of the leaves reduced to 62 per cent. It also affected the stomatal conductance and photosynthetic rate of leaves which led to reduction in yield. Chandler and Gilstrap (1987) reported that as a result of increased number of leaf mines, photosynthetic capacity of leaves reduced which in turn resulted in decline of yield parameters in tomato. The infested tomato leaves twisted, malformed and finally dried (Patil *et al.*, 2001).

Severe infestation of the pest at early stages led to complete destruction of celery and muskmelon seedlings (Trumble, 1985; Cheng, 1994). Early stage infestation of *L. trifolii* in cotton led to reduction in growth and height of the plant due to low photosynthetic rates of leaves. Severe infestation resulted in premature shedding of leaves in cotton (Nadagouda *et al.*, 2010).

Adult flies also act as vectors of diseases like celery mosaic, water melon mosaic, tobacco and soyabean mosaic (Zitter and Tsai, 1977).

2.3.4.3 Extent of Crop Loss

Wolfenbarger and Wolfenbarger (1966) reported that the presence of more than one mine leaf^{-1} led to yield loss in tomato. According to Schuster (1978) in Florida, 90 per cent damage occurred in tomato foliage due to the infestation of serpentine leaf miner, if adequate management measures were not adopted. Zoebisch *et al.* (1984) identified that American serpentine leaf miner caused damage to the extent of 70 per cent in tomato in Florida.

According to Lee *et al.* (2004) if the number of mines per leaflet exceeds two, it resulted in 5 per cent leaf area loss in tomato. *L. trifolii* infestation in nursery stage resulted in death of tomato seedling, if the number of mines plant^{-1} exceeded 1.67 or the percentage infestation was more than 13.21 per cent. Heavily infested tomato plants did not set fruits in the final stage of crop which led to the reduction in yield in Uttar Pradesh (Singh and Nath, 2006).

Krishnakumar (1998) reported that the crop loss due to the incidence of leaf miner in tomato was 35 per cent in Karnataka while it was 15 to 70 per cent and 31 per cent in French bean and cucumber respectively. Mean infestation index of *L. trifolii* on cowpea was 31.75 per cent and 67.63 per cent at vegetative stage and reproductive stage respectively in summer in Kerala (Reji, 2002). Severe infestation of *L. trifolii* in cotton at vegetative stage led to 45.75 per cent crop loss in Karnataka (Nadagouda *et al.,* 2010).

2.3.4.4 Host Plants

Stegmaier (1966) identified 59 plant species under 10 families in Florida as host plants of *L. trifolii*. The important families reported were caryophyllaceae, chenopodiaceae, asteraceae, cucurbitaceae, leguminosae, lilliaceae, malvaceae, solanaceae, umbelliferae and zygophyllaceae. Schuster *et al.* (1991) reported seven weed genera as host plants of *L. trifolii* in Florida which include *Solanum americanum* Mill., *Erechtites hieracifolia* (L.) , *Bidens alba* (L.), *Gnaphalium* spp., *Physalis* spp., *Sonchus* spp., and *Rumex obtusifolius* (L.). About 400 plant species under 28 families were reported as host plants of *L. trifolii* and most severe infestation was shown by asteraceae, apiaceae, cucubrbitaceae, fabaceae and solanaceae over the world (Bogran, 2005).

Srinivasan *et al.* (1995) reported that *L. trifolii* was observed in 79 host plants under 16 different families in India. The infestation was more prominent in tomato, cowpea, okra, ridge gourd, cucumber, potato, cotton and castor. Saradhi and Patnaik (2004) conducted a survey to identify the host plants of *L. trifolii* and reported 25 species of vegetables and 27 species of weeds from Orissa.

Reji (2002) recorded seven weeds as host plants of *L. trifolii* from Kerala, which comprised of *Amaranthus viridis* L., *Heliotropium indicum* L., *Cleome viscosa* L., *Achyranthus aspera* L., *Physalis minima* L., *Desmodium gyrans* L., and *Cleome monophylla* Mutohotoho. A study conducted in Kerala disclosed 48 host plants of leaf miner which belongs to 13 families. New weed hosts recorded were *Physalis minima* (L)., *Stachytarpheta indica* (L.) Vahl, *Aerva lanata* (L.) A. L. Juss. ex Schultes, *Vernonia cinerea* (L.) Less, *Emilia sonchifolia* (L.) DC., *Spilanthes calva* (DC), *Borreria hispida* (L.) and *Coccinia* spp. New report of four ornamental plants like *Zinnia elegans* (Jacq), *Melampodium* spp, *Verbena* spp and *Ocimum sanctum* (Linn.) were also recorded from Kerala (Smitha, 2004).

2.3.4.5 Stage of the Crop

Chandler and Gilstrap (1987) stated that infestation of leaf miner just after germination led to complete destruction of tomato plants. Hemalatha and Maheswari (2004) reported that first incidence of leaf miner was noted in 10 days old seedlings and highest infestation was at 15 days old seedlings in tomato. Singh and Nath (2006) also claimed that the most critical stage of tomato leaf miner infestation was at the nursery stage.

The peak incidence of *L. trifolii* was observed in the vegetative stage of the crop and persisted in the field till the end of crop period in tomato (Reddy and Kumar, 2005). The field incidence of serpentine leaf miner in tomato was severe during the fruiting stage of the crop and the infestation was higher on older leaves in comparison with younger leaves. It was also recorded that infestation of leaf miners was severe in shaded conditions (Rai *et al*., 2013). Variya and Bhut (2014) reported that tomato plants were highly susceptible to leaf miner infestation at early growth stage and flowering stage.

Severe puncturing of seedlings of musk melon by *L. trifolii* resulted in death of seedlings (Cheng, 1994). Nandakumar (1999) reported that peak incidence of *L. trifolii* was noted at three week old bitter gourd plants. According to Nadagouda *et al.* (2010) cotton was more prone to leaf miner infestation at early stages which led to reduction in biometric characters of the plant.

2.3.4.6 Season of Incidence

According to Choudhari and Senapati (2001) higher infestation of *L. trifolii* was reported in tomato during the month of March to May due to the high temperature and relative humidity which promoted the growth and development of leaf miner in West Bengal. Kharpuse (2005) reported that peak activity period of leaf miner in tomato was in March with a percentage infestation of 76.67 in Jabalpur. Durairaj (2007) also reported that the peak infestation period of *L. trifolii* was in March and lowest incidence was in September to December in Tamil Nadu. The pest infestation started from January and persisted in the field till August.

The first incidence of *L. trifolii* was reported in the tomato field during first week of January and peak infestation was noted in February. The population remained highest until March in West Bengal (Chakraborty, 2011). Sharma and Chandel (2011) identified the infestation period of *L. trifolii* as May to September with a peak infestation during August in Himachal Pradesh. Variya and Bhut (2014) discovered that leaf miner infestation was present in the field during the period of October to January. Highest infestation was recorded in January with a percentage damage of 29.4 in tomato in Gujarat.

According to Mandloi *et al.* (2015) leaf miner was present in tomato during the entire crop growth stage. Maximum infestation of 46 per cent was reported in tomato during March in Madhya Pradesh. An increasing trend of leaf miner activity was observed in the crop as stage of the crop advanced. The first incidence of *L. trifolii* was in February and highest infestation was noted in April in tomato field in Uttarakhand (Selvaraj *et al.,* 2016).

Palumbo *et al.* (1999) reported that in Arizona, USA, the maximum activity of leaf miner was recorded in summer months and peak infestation was noted in August in cotton. In Kerala, peak incidence of serpentine leaf miner was observed in the second fortnight of November and persisted in the field till second fortnight of April (Smitha, 2004). In cowpea maximum leaf miner incidence of 32.5 per cent was observed in March and minimum of 9 per cent in November. Lowest incidence was recorded in cooler months with a percentage infestation ranging from 9 to 13.7 per cent in tomato (Ganapathy *et al.,* 2010).

2.3.4.7 Correlation of Leaf Miner Population with Weather Parameters

Choudhary and Rosaiah (2000) stated that sunshine hours exhibited a negative correlation with leaf miner incidence on tomato whereas evening relative humidity and minimum temperature expressed a positive association in Andhra Pradesh. Number of rainy days and rainfall showed a significant negative correlation with incidence of *L. trifolii* on tomato in Karnataka (Reddy and Kumar, 2005).

Variya and Bhut (2014) stated that there was significant negative correlation observed in the number of mines, number of larvae and leaf damage percentage with maximum temperature, minimum temperature and mean vapour pressure and evening relative humidity in tomato in Gujarat. Number of mines showed positive correlation with maximum temperature (0.231), evening relative humidity (0.161) and rainy days (0.386) whereas it exhibited negative correlation with minimum temperature (-0.155) and morning relative humidity (-0.148) in

Madhya Pradesh in tomato (Mandloi *et al.*, 2015). Selvaraj *et al.* (2016) reported that serpentine leaf miner incidence in tomato was significantly correlated with sunshine hours with a positive correlation coefficient of 0.578 while morning relative humidity and evening relative humidity exhibited a significant negative relationship with correlation coefficients of -0.603 and -0.758 respectively in Uttarakhand.

A significant correlation was observed in between number of larvae and weather parameters on cowpea in Kerala. Wind velocity, sunshine hours and evaporation rate showed a positive significant correlation with number of larvae with correlation coefficients of 0.723, 0.511 and 0.562 respectively whereas relative humidity and rainfall expressed significant negative correlation with correlation coefficients of -0.51 and -0.421 (Smitha, 2004).

2.3.4.8 Natural Enemies of L. trifolii

2.3.4.8.1 Predators

American serpentine leaf miner was mainly predated by insects of the order thysanoptera, hemiptera and diptera. *Franklinothrips vespiformis* Crawford was identified as a predator of larval stages of *L. trifolii* (Arakaki and Okajima, 1998). Adults and nymphs of mirid bugs, *Dicyphus cerastii* Wagner and *M. caliginosus* were also reported as predators of leaf miner (Castane *et al.*, 2004). Insects belongs to dolichopodidae were reported as a predator of adult leaf miner flies in cowpea from Kerala (Jyothy, 2014).

2.3.4.8.2 Parasitoids

Parasitoids play an important role in reducing the leaf miner below economic injury levels. The different parasitoids reported from various parts of the world are included in the Table 1.

Table1. Parasitoids of *L. trifolii* reported from various parts of the world

Sl. No	Scientific name	Family	Area of study	Reference
1	*Opius* sp.	Braconidae	Florida	Stegmaier, 1966
	Chrysocharis sp. *Closterocerus* sp. *Derostenus* sp. *D. agromyza* (Crawford) *D. variipes* (Crawford) *Diglyphus* sp. *Mirzagrammosoma lineaticeps* (Girault)	Eulophidae		
	Halticoptera patellana (Dalman)	Pteromalidae		
2	*Opius dissitus* (Muesebeck) *Oenonogastra microrhopalae* (Ashmead),	Braconidae	Florida	Schuster *et al.*, 1991
	Halticoptera circulus (Walker)	Pteromalidae		
	Neochrysocharis punctiventris (Crawford) *Diglyphus begini* (Ashmead) *D. intermedius* (Girault)	Eulophidae		
3	*Chrysonotomyia rexia* (Narendran) *Aescodes* sp. *Closterocerus agromyzae* (Narayan, Subba Rao and Ramachandra) *Hemiptarsenus brevipedicellus* (Shafee and Rizwi)	Eulophidae	Kerala	Reji, 2002
	Agathidini sp.	Braconidae		
	Herbertia indica (Burks)	Pteromalidae		
	Entomacis sp.	Diapriidae		

Table (continued)

Sl. No	Scientific name	Family	Area of study	Reference
4	*Chrysonotomia rexia* (Narendran) *Oomyzus liriomyzae* (Narendran)	Eulophidae	Maharashtra	Galanade and Ghorpade, 2007
5	*Opius dissitus* (Muesebeck) *O. dimidatus* (Ashmead) *O. bruneipes* (Ashmead)	Braconidae	South Texas	Hernandez *et al.*, 2011
	Diglyphus isaea (Walker) *Neochrysocharis formosa* (Westwood) *Closterocerus* sp. *Chrysocharis* sp.	Eulophidae		
	Gonaspidium pusillae Weld *G. nigrimanus* (Kieffer) *Disorygma pacifica* (Yoshimoto) *Agrostocynips robusta* (Ashmead)	Figitidae		
6	*Opius dissitus* (Muesebeck) *Eucopius* sp.	Braconidae	South Florida	Li, 2011
	Diaulinopsis callichroma (Crawford) *Diglyphus begini* (Ashmead) *D. isaea* (Walker) *Neochrysocharis* sp. *Closterocerus* sp. *Zagrammosoma lineaticeps* (Girault) *Chrysocharis* sp.	Eulophidae		
	Halticoptera sp.	Pteromalidae		

Table (continued)

Sl. No	Scientific name	Family	Area of study	Reference
7	*Neochrysocharis formosa* (Westwood) *Diglyphus* sp. *Asecodes* sp. *Chrysocharis* sp.	Eulophidae	Himachal pradesh	Sharma *et al.*, 2011
	Opius sp.	Braconidae		
9	*Clostercerus* sp. *Chrysonotomyia* sp. *Cirrospilus brevicorpus* (Shafee and Rizwi) *C. acadius* (Narendran) *Tetrastichius* sp.	Eulophidae	Kerala	Jyothy, 2014
	Toxares sp.	Braconidae		
8	*Opius sp.*	Braconidae	Mexico	Escoboza et al., 2015
	Neochrysocharis sp. *Clostocerus sp.*	Eulophidae		

2.3.4.9 Field Tolerance of Varieties

Varietal trial conducted in West Bengal revealed that tomato hybrids were more prone to leaf miner infestation than that of other varieties. Highest infestation was reported in hybrid Avinash 11 and field tolerance to leaf miner was reported from Arjuna and Rupali (Choudhary *et al.,* 2000). Tandon and Bhakthavalsalan (2002) evaluated 10 tomato genotypes against *L. trifolii.* The study revealed that highest incidence was in Hybrid 101- super and lowest incidence was in Varalakshmi under greenhouse conditions. All other genotypes were found to be susceptible to the pest.

Lasker and Ghosh (2005) conducted field evaluation of 10 tomato cultivars against *L. trifolii* in West Bengal. According to their findings, hybrids were more susceptible to leaf miner infestation rather than other varieties. Hybrid Rupali F-1 had the highest leaf infestation of 34.70 per cent. Number of larvae leaf $^{-1}$ and mean mine length was also found to be more in Rupali F-1. No varieties were reported to have tolerance against leaf miner, though Kalimpong local and Pusa Upahar recorded least leaf damage of 20.40 per cent and 24.60 per cent respectively. Out of the 16 genotypes of tomato screened in Madhya Pradesh, Pusa Ruby was found to be less preferable to *L. trifolii* with a damage of 5.93 per cent whereas IIVR sel-1 recorded highest leaf infestation of 9.46 per cent damage (Naik *et al.,* 2005).

Among the thirteen genotypes of tomato screened in Raipur, Hybrid Ganapati was found to be more preferable to leaf miners with a maximum mine length of 2.68 cm followed by Pusa Ruby (2.40 cm). S-22 (1.63 cm), NS-101 (1.70 cm), Sun 5715 (1.83 cm) were less preferable to *L. trifolii* with minimum length of mines. In addition to this, they discovered that the leaf area had a positive correlation with the length of mines. They also reported that there was a negative correlation between the number of mines and trichome density (Sahu and Shaw, 2006).

Rai *et al*. (2013) screened 30 varieties of tomato in north west plains of Uttar Pradesh to identify the field tolerance to *L. trifolii* based on the mean number of leaf mines on leaves at different growth stages. As per cumulative susceptibility index, 21 varieties were recorded as resistant or least susceptible to leaf miner attack. Among these, lowest infestation was reported in variety Meenakshi H1. Nine varieties were moderately susceptible to leaf miner infestation and variety Avinash showed maximum infestation. No variety was recorded as highly susceptible to leaf miner infestation.

Among the five gerbera varieties tested for field tolerance against *L. trifolii,* Fuego was found to be the most tolerant variety with leaf area damage of 340.4 mm^2 while maximum damage was observed in variety Ambition, in Taiwan (Yu Chuan and Tsong Hong, 2000). An experiment conducted in West Bengal to screen seven pumpkin cultivars against *L. trifolii* revealed that none of the varieties were resistant to leaf miner. Among the seven varieties, Arka Suryamukhi was most severely infested while NDPK- 130 was least damaged variety (Sahoo and Karmakar, 2004). Field susceptibility of four Faba bean varieties Misr 1, Misr 2, Giza 40 and Giza 429 were tested against *L. trifolii* in Egypt. Out of the four varieties, Giza 40 was most susceptible followed by Misr1. However the least susceptible variety was Misr 2 with a percentage leaf damage of 18.2 (Salwa *et al.,* 2006).

2.3.4.9 Management of L. trifolii

2.3.4.9.1 Botanicals

2.3.4.9.1.1 Neem oil

Ramesh and Ukey (2007) reported that neem oil 1% was effective in reducing leaf miner infestation and number of mines in tomato. Ganapathy *et al.* (2010) reported that neem oil 3 % can be used for the management of *L. trifolii* in cowpea which caused a larval mortality of 37.60 per cent. The percentage leaf damage of 29.7 per cent was reported in neem oil 3 % as compared to 43 per cent in control plot in Tamil Nadu.

Neem oil 10 mL kg^{-1} and 20 mL kg^{-1} can be used for seed treatment and were found to be effective in managing leaf miner population in castor. The percentage leaf damage due to *L. trifolii* in plots with seeds treated with neem oil 10 mL kg^{-1} was reported to be 0.27, 0.86 and 0.99 at 25, 30 and 35 days after emergence of plant respectively. Neem oil (20 mL kg^{-1}) was effective in reducing leaf miner infestation in the leaves to the range of 0.13, 1.62, and 0.85 at 25, 30, 35 days after emergence of seedlings (Suradaker and Ukey, 2015).

Prophylactic spraying of neem oil 2.5 % resulted in reduced leaf infestation and number of mines in cowpea plants under field situations. Prophylactic application in laboratory conditions resulted in 100 per cent mortality of larva and 100 per cent reduction in pupal and adult emergence. It caused 100 per cent reduction in emergence of adults, 99.38 per cent reduction over control in percentage of emergence of pupa and 93.93 per cent larval mortality under laboratory conditions when applied after infestation (Reji, 2002).

2.3.4.9.1.2 Neem Seed Kernel Extract

Neem seed kernel extract 5 % had a good impact in reducing leaf miner infestation in tomato. NSKE 5 % treated plots showed a reduced infestation of 19.99 per cent at 7 days after spraying, while it was 34.02 per cent in control plots (Ramesh and Ukey, 2007). Kumar *et al.* (2010) reported that NSKE 5 % at 10 days interval was effective in controlling leaf miner in soya bean. Ganapathy *et al.* (2010) highlighted the superiority of NSKE 5 % that induced 53.4 per cent maggot mortality in cowpea. The percentage leaf damage (25.5) and mine length (2.3 cm) was found to be lowest in NSKE 5 % treatment.

NSKE can be considered as an excellent option for the management of *L. trifolii* as compared to some of the insecticides commonly used for the management of leaf miners. It caused a percentage mortality of 64.01 in *L. trifolii* maggots in cucumber (Pawar and Patil, 2013). According to Chavan *et al*. (2015), NSKE 5 % was a viable option for leaf miner management in tomato. The percentage decrease of number of live mines was 76.33, 73.14, and 74.53 per cent after first, second and third sprays respectively.

2.3.4.9.1.3 Other plant products

Jeyakumar and Uthamasamy (1998) reported that application of illupai oil 3 % resulted in reduction of leaf miner larval population in cotton. Reji (2002) reported that the prophylactic application of illupai oil (2.5 %) and marotti oil (2.5%) caused a higher mortality of *L. trifolii* maggots and a higher yield was reported from plots treated with marotti oil 2.5 %. Marotti oil 2.5 % caused a larval mortality of 85.34 per cent while illupai oil 2.5 % caused a mortality of 89.61 per cent in laboratory conditions. Among the tested plant oils, no oil caused maggot mortality when it was applied after incidence of leaf miner. Ramesh and Ukey (2007) reported that jatropha oil 1 % reduced the leaf infestation in tomato but to a lesser extent when compared to other treatments.

2.3.4.9.2 Biological control

Borisov and Ushchekov (1997) reported that *Metarhizium anisopliae* (Metschnikoff) and *Paecilomyces lilacinus* (Thom) Samson were effective in managing leaf miner population which led to a decline in adult emergence to the tune of 70 to 94 and 60 to 88 per cent respectively. *M. anisopliae* was effective in controlling leaf miner than that of *Beauvaria bassiana* (Balsamo), *Lecanicillium lecanii* (Zimmerman) and *P. lilacinus,* causing 68.9 per cent reduction in larval population after two sprayings (El salam *et al.*, 2013).

Bacillus thuringiensis (Berliner) at 75 g 100 L^{-1} was used for the management of leaf miners in beans. Highest yield was also recorded in *B. thuringiensis* treated plots (Cikman and Comlekcioglu, 2006).

Entomopathogenic nematodes like *Steinernema carpocapsae* Weiser was identified as an effective management option to *L. trifolii* larvae which caused 64 per cent mortality of the maggots (Haris *et al.*, 1990). Tomalak *et al.* (2005) stated that American serpentine leaf miner population was managed by entomopathogenic nematodes of the genus Heterorhabditidae and Steinernematidae which recorded a maggot mortality of 48 to 98 per cent. Jacob and Mathew (2015) reported that foliar spraying of *Heterorhabditis indica* Poinar, Karunakar and David at 32 IJ $larva^{-1}$ caused a leaf miner larval mortality of 18.98 per cent in cowpea. *S. carpocapsae* isolate-1 (Kannara) was found to be superior and caused 100 per cent larval mortality of *L. trifolii* in cowpea under laboratory conditions (Jacob and Mathew, 2016).

2.3.4.9.3 Chemical management

Chemical insecticides were widely used for the management of *L. trifolii* in vegetable crops. Murthy and Prasad (1996) identified chlorpyriphos 1.5 % EC at 3 g kg^{-1} was effective in the management of *L. trifolii* in castor. Logiswaran and Bhuvaneswari (2000) reported that Vertimec 1.8 EC at the rate of 20 g a.i ha^{-1} at twenty days interval as a good option for minimizing the damage caused by *L. trifolii* in tomato. Chaudhuri and Senapathi (2001) revealed that abamectin 0.01 % decreased the leaf miner infestation to 44.18 per cent in tomato. Abamectin at 10 g a.i ha^{-1} was reported to be an effective insecticide which caused lowest percentage leaf damage (17.78) in tomato at 7 days after spraying and also recorded highest yield (Walunj *et. al.*, 2002). Babu *et al.* (2002) reported that abamectin 10 g a.i. $ha^{-1}$and 7 g a.i. ha^{-1} suppressed the leaf miner damage to the extent of 17.78 and 21.11 per cent in tomato. An experiment conducted by Reji (2002) also showed that among the various insecticides evaluated against *L. trifolii,* abamectin 0.003 % was superior which caused larval mortality of 100 per cent at prophylactic treatment and 69.21 per cent when applied after infestation.

Bhai (2012) evaluated nine insecticides for the management of serpentine leaf miner in tomato in Gujarat, revealed that emamectin benzoate 0.025 % was superior with 3.03 mines per leaf which was on par with diafenthiuron 0.05 % with 3.15 mines per leaf. Lowest population of larvae was observed in diafenthiuron 0.05 % and emamectin benzoate 0.025 % with 0.71 and 0.82 leaf^{-1} respectively whereas methyl-o-demeton recorded highest larval population of 1.96 leaf^{-1}. Among the five insecticides and biorationals evaluated against *L. trifolii* in snap bean in Southern Floida, abamectin 9.7 g a.i ha^{-1} was found to be most effective followed by spinosad 176 g a.i ha^{-1} (Devacote *et al.,* 2016).

Spinosad was found to be effective against leaf miner which caused 100 per cent mortality in first instar larvae and 89.3 per cent in third instar larvae (Gabbiche, 2001). Akashe *et al.* (2009) conducted an experiment to identify the efficacy of various chemicals against *L. trifolii* in castor and reported that spinosad 45 SC 0.018 % was the best treatment compared to carbaryl 50 WP 0.2 %, endosulphan 35 EC 0.05 % and fipronil 5 EC 0.01 % .

Ozawa *et al.* (2002) identified clothianidin 50 WP, a neonicotinoid insecticide as a viable solution for leaf miner damage which caused a larval mortality of 54.20 per cent. According to Civelek and Weintraub (2003) bensultap, a nereistoxin analogue at the rate of 3 kg ha^{-1} was effective in reducing the leaf miner damage in tomato plants.

As per the research findings of Tokumaru *et al.* (2005), among the twenty five insecticides tested, chlorpyriphos, thiocyclam, cyromyzine, emamectin benzoate and spinosad were found to be effective against second instar larvae of *L. trifollii.* The tertiary amine group of insecticides like cartap hydrochloride and thiocyclam, biorational insecticides like spinosad and emamectin benzoate were found to be excellent choices to reduce the feeding and oviposition punctures made by the female adult flies. Saradhi and Patnaik (2006) identified that insecticidal mixture of chlorpyriphos + cypermethrin (0.005 %) caused a considerable larval mortality of 65.42 per cent in tomato and 59.34 per cent in french bean. Ganapathy *et al.* (2010) reported that, of the six chemicals tested against *L. trifolii* attacking cowpea in Tamil Nadu, chlorpyriphos 20 EC 0.05 % was the best treatment with a larval mortality of 74.90 per cent followed by triazophos 40 EC 0.04 % with 67.30 per cent larval mortality. Cypermethrin (60 g a.i ha^{-1}), lambda- cyhalothrin (15g a.i ha^{-1}), chlorpyriphos (200 g a.i ha^{-1}) and spinosad 45 SC (84 g a.i ha^{-1}) were equally effective in the management of leaf miner population (Sharma and Chandel, 2011).

Kumar *et al.* (2010) reported imidacloprid 70 WS as seed treatment at 3g kg^{-1} was effective against *L. trifolii* in soyabean. Rai *et al.* (2014) identified that Imidacloprid 17.8 SL at 0.35 mL L^{-1} was found to be effective against *L. trifolii* when it is applied before the flowering stage.

Jyotsana *et al.* (2013) stated that among the various insecticides tested against *L. trifolii* in gherkin, thiacloprid 120 g a.i ha^{-1} was reported to be the most superior chemical which caused 74.96 per cent reduction of leaf miners. Flubendiamide + thiacloprid (48 + 48 g a.i. ha^{-1}) and flubendiamide at 60 g a.i. ha^{-1} were also reported to be effective against leaf miner which caused substantial reduction in leaf miner population to the extent of 71.57 per cent and 61.92 per cent respectively. An experiment for evaluating the bio efficacy of various insecticides against *L. trifolii* in gherkins showed that cyantraniliprole 10 % OD (cyazpyr) which is an anthranilic diamide at 90 g and 105 g a.i ha^{-1} recorded lowest number of adult flies per 20 leaves to the range of 0.31 to 0.74 at 7 days after spraying. The lowest number of mines was reported from the same treatments and an increased yield of 93 to 97 per cent over the control plots were also recorded (Misra, 2015).

According to Bharthi *et al.* (2011) chlorantraniliprole 20 % SC 0.03 % was effective in reducing leaf miner population in bitter gourd, and also recorded highest yield from the same treatment plots. Chlorantraniliprole 4.3 % + abamectin 1.7 % SC mixture was reported to be efficient in reducing *L. trifolii* damage to the level of 48.66 to 78.28 per cent than that of control plots. It also reduced the number of leaf miners to 89.73 to 99.36 per cent over control plots in tomato ecosystem (Kousika *et al.,* 2015). Patra *et. al.* (2016) reported that chlorantraniliprole 10 % + thiomethoxam 20 % at the rate of 150 g a.i ha^{-1} was an excellent management option for American serpentine leaf miner. Thamilarasi (2016) reported that chlorantraniiliprole 18.5 % SC at 0.30 mL L^{-1} caused 100 per cent mortality of *L. trifolii* maggots at five days after spraying in cowpea.

Materials and Methods

3. MATERIALS AND METHODS

A study on "Management of American serpentine leaf miner *Liriomyza trifolii* (Burgess) Dietars in tomato" was conducted at College of Agriculture, Vellayani during the period 2015 - 2017. The main objectives of the study were to evaluate tomato varieties for field tolerance to *L. trifolii* and to evolve effective method for the management of *L. trifolii* in tomato.

3.1. DOCUMENTATION OF PESTS AND NATURAL ENEMIES OF TOMATO AND ASSESSMENT OF DAMAGE BY PESTS.

3.1.1 Pests of Tomato

Observations on incidence of pests in tomato were recorded from the field at vegetative and reproductive stage of the crop. The entire field was divided in to five plots and five plants were randomly selected from each plot and recorded the number of insect as per the standard sampling methods set forth for different pests. The total number of leaves, number of leaves damaged, total number of fruits and number of fruits damaged were recorded. The percentage infestation of various pests in tomato was also calculated (NICRA, 2012).

3.1.2 Incidence of Natural Enemies

The predators collected from the field were preserved in 70 % ethyl alcohol solution and sent for identification. Spiders present in the tomato ecosystem were collected and preserved in 70 % ethyl alcohol in a glass bottle and the specimens were sent for identification. Parasitized larva and pupa of *L. trifolii* was collected from field and placed inside a Petri dish or polythene cover. Emerged parasitoids were preserved in alcohol solution and sent for identification.

3.1.3 Host plants of *Liriomyza* spp.

Host plants of *Liriomyza* spp. were recorded from. Instructional Farm, Vellayani during the study period.

3.1.4 Correlation Studies of *L. trifolii* Incidence with Weather Parameters

Correlation between various weather parameters like maximum and minimum temperature, morning and evening relative humidity, wind velocity, rainfall and sunshine hours with number of mines plant^{-1} were worked out and recorded the correlation coefficients during the crop period from April 2016 to June 2016. The weekly weather data was collected from the Department of Meteorology, College of Agriculture, Vellayani.

3.2 EVALUATION OF CULTIVARS FOR FIELD TOLERANCE TO *L. trifolii.*

A pot culture experiment was conducted at Instructional farm, Vellayani to assess the field tolerance of tomato cultivars to *L. trifolii.* Fifteen cultivars of tomato including hybrids, KAU released varieties and varieties released from various research institutes were included in the study (Table.2).

One month old seedlings were transplanted in grow bags. Observations were taken at monthly intervals, starting from one month after transplanting.

3.2.1 Observations

3.2.1.1 Total Number of Leaves

The number of leaves were counted and denoted as total number of leaves per plant.

3.2.1.2 Number of Damaged Leaves

The number of leaves damaged by the infestation of *L. trifolii* were counted and expressed as number of damaged leaves per plant.

3.2.1.3 Number of Mines Plant^{-1}

Total number of mines on the leaves due to the incidence of *L. trifolii* were recorded and expressed as number of mines plant^{-1}.

Table 2. Tomato cultivars used for evaluation of field tolerance to *L. trifolii.*

Sl:No.	Cultivars	Source
1	Vellayani Vijai	Department of Olericulture, College of Agriculture, Vellayani
2	Akshaya	Department of Olericulture, College of Agriculture, Vellayani
3	Manulekshmi	Department of Olericulture, College of Agriculture, Vellayani
4	Anagha	Department of Olericulture, College of Agriculture, Vellayani
5	LE 20	Department of Olericulture, College of Agriculture, Vellayani
6	Pusa Ruby	Indian Agricultural Research Institute , New Delhi
7	Swaraksha	Namdhari Seeds Pvt. Ltd. Bengaluru
8	NS-538	Namdhari Seeds Pvt. Ltd. Bengaluru
9	Arka Abha	Indian Institute of Horticultural Research, Bengaluru
10	Arka Meghali	Indian Institute of Horticultural Research, Bengaluru
11	Arka Alok	Indian Institute of Horticultural Research, Bengaluru
12	Arka Vikas	Indian Institute of Horticultural Research, Bengaluru
13	Arka Rakshak	Indian Institute of Horticultural Research, Bengaluru
14	Arka Samrat	Indian Institute of Horticultural Research, Bengaluru
15	Hissar Lalith	Haryana Agricultural University , Haryana

3.2.1.4 Number of Larvae Plant^{-1}

The larval population on the mines were recorded and expressed as number of larvae plant $^{-1}$.

3.2.2 Biometric Characters

3.2.2.1 Plant Height (cm)

Height of the plant from the base to the top most leaf bud was measured using a measuring scale and recorded.

3.2.2.2 Number of Branches

The total number of branches plant^{-1}was recorded

3.2.2.3 Leaf Area

Using a measuring scale, total length and width of leaves were taken and these values were multiplied with a constant 0.9 (Achnlither, 1978). The length of leaf was measured from the base of the petiole to the tip of the leaf and width was measured at the area of maximum width.

3.2.2.4 Length Width Ratio of Leaves

The length of the leaves was divided with width of the leaves and expressed as length width ratio.

3.2.3 Yield (kg plant^{-1})

The total number of fruits and total weight of fruits were recorded after each harvest.

3.2.4 Classification of Cultivars

Fifteen cultivars of tomato were categorized in to different groups based on mean leaf damage (percentage).

Leaf infestation (Percentage)	Ratings	Category
0	0	Highly tolerant
1-20	1	Tolerant
21-40	2	Moderately tolerant
41-60	3	Susceptible
>60	4	Highly susceptible

3.2.5 Correlation of Different Independent and Dependent Variables

Leaf damage (percentage), number of mines plant $^{-1}$, number of larvae plant^{-1} of fifteen varieties were correlated with leaf area and length width ratio and recorded the correlation coefficients.

3.3 MANAGEMENT OF *L. trifolii*

A pot culture experiment was conducted to evaluate the effectiveness of various non-chemicals and green labeled chemicals against *L. trifolii* in tomato at Instructional farm, College of Agriculture, Vellayani.

Design: CRD

Replication: 3

Treatments : 15

Variety : Vellayani Vijai

T1 : Neem oil 2.5 % at 10 days interval

T2 : Neem seed kernel extract 5 % at 10 days interval

T3 : Oxuron 0.5 % at 10 days interval

T4 : Fish amino acid 0.5 % at 10 days interval

T5 : Flubendiamide 20 WG 0.005 % at 10 days interval

T6 : Chlorantraniliprole 18.5 SC 0.006 % at 10 days interval

T7 : Neem oil 2.5 % at 20 days interval

T8 : Neem seed kernel extract 5 % at 20 days interval

T9 : Oxuron 0.5 % at 20 days interval

T10 : Fish amino acid 0.5 % at 20 days interval

T11 : Flubendiamide 20 WG 0.005 % at 20 days interval

T12 : Chlorantraniliprole 18.5 SC 0.006 % at 20 days interval

T13 : Untreated check

One month old seedlings were transplanted in grow bags and it was maintained as per Package of practices recommendation (KAU, 2016). The treatments were given from one week after transplanting.

3.3.1 Preparation of Spray Solutions

3.3.1.1 Neem oil 2.5 %

Six gram of soap is dissolved in 500 mL water and mixed with 25 mL neem oil and made up to 1000 mL.

3.3.1.2 Neem Seed Kernel Extract 5 %

Neem seed kernels (50 g) crushed and tied in a muslin cloth and is immersed in 500 mL of water in a beaker overnight. Then the cloth bag is squeezed repeatedly until the solution became brown in colour and is made up to 1000 mL to obtain NSKE 5 %.

3.3.1.3 Oxuron 0.5 %

Pipetted out 5 mL of commercial formulation of oxuron and mixed with 1000 mL of water.

3.3.1.4 Fish Amino Acid 0.5 %

One kg of jaggery mixed with one kilogram of sardine fish . These mixture was stored in a dry place for 30 days. 5 mL of the solution is diluted to 1000 mL.

3.3.1.5 Flubendiamide 20 WG 0.005 %

0.25 g of flubendiamide 20 WG has taken in 1000 mL of water.

3.3.1.6 Chlorantraniliprole 18.5 SC 0.006 %

0.3 mL of chlorantraniliprole 18.5 SC has taken in 1000 mL of water.

3.3.2 Observations

The observations on total number of leaves, number of damaged leaves, number of mines plant^{-1} and number of larvae plant^{-1} were recorded at regular intervals from various treatments as described in *3.2.1.1 to 3.2.1.4*. The total number of fruits and weight of fruits plant^{-1} were also recorded after each harvest as described in 3.2.3.

3.3.3 Statistical Analysis

Collected data were analyzed statistically after proper transformation using WASP software (Panse and Sukhatme, 1967).

Results

4. RESULTS

An experiment was conducted at College of Agriculture, Vellayani during 2016 to 2017 to evaluate tomato cultivars for their field tolerance to *L. trifolii* and to evolve an effective method for the management of *L. trifolii*. The data were analyzed statistically after proper transformation and the important findings obtained from the present study are explained below.

4.1 DOCUMENTATION OF PESTS AND NATURAL ENEMIES AND ASSESSMENT OF DAMAGE

4.1.1 Pests of Tomato

The important pests observed in tomato ecosystem at different crop growth period are presented in Table 3.

The important pests observed were American serpentine leaf miner *L. trifolii* Burgess (Diptera: Agromyzidae), tomato fruit borer *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae), tobacco caterpillar *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae), green semilooper *Argyrogramma signata* Fabricius (Lepidoptera: Noctuidae), leaf beetle *Luperomorpha vittata* Duvivier, (Coleoptera: Chrysomelidae), hadda beetle *Henosepilachna vigintioctopunctata* Fabricius (Coleoptera: Coccinellidae), solanum whitefly *Aleurothrixus trachoides* (Back) (Hemiptera: Aleyrodidae), spiralling whitefly *Aleurodicus dispersus* Russell (Hemiptera: Aleyrodidae), mealy bug *Phenacoccus solenopsis* Tinsley, scale insect *Saissetia* sp. (Hemiptera: Coccidae) and aphid *Myzus persicae* Sulzer (Hemiptera: Aphididae).

L. trifolii is a tiny black insect with yellow coloured scutellum, frons and hind part of mesonotum bears yellow marking. Infestation was observed at both vegetative and reproductive stages of the crop. Adult female inserted eggs in leaf epidermis and emerging larva mined through the leaf lamina and made serpentine leaf mines. Last instar larva came out of the mine and pupated in soil (Plate 1). Severe leaf mining resulted in drying of leaves.

Table 3. Incidence of pests at vegetative and reproductive stages of tomato

Sl. No	Common name	Scientific name	Family	Vegetative stage	Reproductive stage	Plant part infested
1	American serpentine leaf miner	*Liriomyza trifolii* (Burgess)	Agromyzidae	+	+	Leaves
2	Tomato fruit borer	*Helicoverpa armigera* (Hubner)	Noctuidae	-	+	Leaves, fruits
3	Tobacco caterpillar	*Spodoptera litura* (Fabricius)	Noctuidae	+	+	Leaves, fruits
4	Green semilooper	*Argyrogramma signata* (Fabricius)	Noctuidae	+	+	Leaves
5	Leaf beetle	*Luperomorpha vittata* (Duvivier)	Chrysomelidae	+	-	Leaves
6	Hadda beetle	*Henosepilachna vigintioctopunctata* (Fabricius)	Coccinellidae	+	+	Leaves
7	Solanum whitefly	*Aleurothrixus trachoides* (Back)	Aleyrodidae	+	+	Leaves
8	Spiralling whitefly	*Aleurodicus dispersus* (Russell)	Aleyrodidae	-	+	Leaves
9	Mealy bug	*Phenacoccus solenopsis* (Tinsely)	Pseudococcidae	+	+	Leaves, stem, flowers, fruits
10	Scale	*Saissetia* sp.	Coccidae	+	-	Stem
11	Aphid	*Myzus persicae* (Sulzer)	Aphididae	+	-	Terminal plant parts

H. armigera, one of the most severe pests of tomato was observed at reproductive stage of the crop. Adult is a brown coloured moth with v shaped spot on fore wings and a dark patch on the hind wing. Early instar larva fed on the leaves and later instar bored in to the fruits and fed on the internal contents. Pupation was in soil (Plate 2).

S. litura infested the tomato crop during vegetative and reproductive stages. Adult has a greyish brown fore wings with patterns and hind wing is white with brown boarder. Egg masses were light brownish in colour. Larval stages voraciously fed on the leaves and defoliated the plants. It also bored in to the fruits and fed on the fruit parts. Pupation was in soil (Plate 3).

A. signata was present in tomato throughout the crop period. Adult is a brown coloured moth with white spots on the fore wings. Green coloured larva fed on the leaves resulted in defoliation. Pupa is green coloured and pupated on plant parts (Plate 4).

L. vittata was a minor pest observed at vegetative stage of the crop. Adult is a brownish beetle which scraped the leaf surface and fed on the leaf epidermis (Plate 5)

H. vigintioctopunctata was observed at both vegetative and reproductive stage of the crop. Adult beetles were orange coloured characterized by twenty eight black spots on the elytra. Adult female laid yellowish eggs in groups. Grubs were yellowish-orange in colour and covered with tubercles. They scraped the green matter of leaves resulted in skeltonization of leaves (Plate 6).

A. trachoides was observed at both vegetative and reproductive stage of the crop. This pest is reported for the first time in tomato from Kerala. Adult whitefly was small, white in colour with waxy coating over the body. Eggs were elongate, yellow to brown in colour and laid on under side of the leaves. Nymphs were white in colour and later changed to pale-yellow. Black coloured pupa was observed on under surface of the leaves. Adults and nymphs sucked sap from the leaf which caused yellowing, drying and premature abscission of leaves (Plate 7).

A. dispersus was observed at reproductive stage of the crop and severe incidence was noticed. Adults and nymphs were small white coloured insects with waxy coating over the body. Eggs laid in characteristic spiral manner and emerged nymphs and adults sucked sap from the leaves resulted in drying of leaves (Plate 8).

P. solenopsis, was observed at both stages of the crop and they colonized on leaves, stem, terminal plant parts, flowers and fruits. Adults and nymphs were small and covered with whitish cotton like material. They sucked sap from plant parts and resulted in stunting and disfiguration of the affected parts (Plate 9).

Saissetia sp. was recorded at vegetative stage of the plant which colonized on stem of tomato. Adult female was hemispherical and brown in colour with waxy secretions over the body. Adult males were winged while females were wingless. They sucked the plant sap from stem resulted in yellowing of the plants (Plate 10).

M. persicae was noticed at vegetative stage of the crop which congregated on terminal plant parts. Adults and nymphs were small, yellow to green in colour and sucked sap from plant parts resulted in yellowing (Plate 11).

4.1.1.1 Intensity of Damage Caused by Pests of Tomato

Extent of damage caused by various pests of tomato is presented in Table 4.

L. trifolii infestation caused a leaf damage of 21.27 per cent with a mean number of one larva plant^{-1} at reproductive stage of the crop while it caused a leaf damage of 21.16 per cent at vegetative stage with 1.56 larvae plant^{-1}. *H. armigera* was observed at reproductive stage of the crop which caused a leaf damage of 10.16 per cent and fruit damage of 13.86 per cent with 0.64 larva plant^{-1}. *A. dispersus* was also observed at reproductive stage of the crop which caused leaf damage of 23.13 per cent with mean number of 17.28 insects plant^{-1}.

4.1.2 Incidence of Natural Enemies

4.1.2.1 Insect Predators

The insect predators recorded from pests of tomato are presented in Table 5.

Table 4. Intensity of damage caused by pests of tomato

Sl. No	Pest	Leaf damage (Percentage)	Fruit damage (Percentage)	Mean number of insects $plant^{-1}$
1	*L. trifolii* (vegetative stage)	21.16	-	1
2	*L. trifolii* (reproductive stage)	21.27	-	1.56
3	*H. armigera* (reproductive stage)	10.16	13.86	0.64
4	*A. dispersus* (reproductive stage)	23.13	-	17.28

*Mean of 25 plants

Table 5. Insect predators of pests of tomato recorded from Vellayani

Sl.No	Predators	Scientific name	Family	Prey species
1	Mirid bug	*Nesidiocoris tenuis* Reuter	Miridae	Whitefly
2	Lady bird beetle	*Axinoscymnus puttarudriahi* Kapur & Munshi	Coccinellidae	Whitefly
3	Lady bird beetle	*Coccinella transversalis* Fabricius	Coccinellidae	Aphid
4	Midge	Unidentified sp.	Cecidomyiidae	Mealybug

The important predators recorded were mirid bug *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae), lady bird beetles, *Axinoscymnus puttarudriahi* Kapur and Munshi (Coleoptera: Coccinellidae), *Coccinella transversalis* Fabricius (Coleoptera: Coccinellidae) and a predatory midge (Diptera: Cecidomyiidae).

Adults of mirid bug *N. tenuis* were green in colour with black markings on the hind wing. Nymphs were yellowish green with bright red eyes. Adults and nymphs were observed on undersurface of leaves and terminal plant parts. It is an active predator of nymphs of whitefly, *A. trachoides* (Plate 12).

Coccinellid beetle *A. puttarudriahi* was recorded as a predator of whitefly *A. tracheoides* (Plate13). Adult beetle was small in size with yellowish head and brownish black elytra with two large yellow spots on the elytra (Plate 13)

Transverse lady bird beetle, *C. transversalis* was black beetle with red colour elytra banded with transverse black markings. It was found on tomato plants and predated on aphid *M. persicae* (Plate 14).

Small brownish midge with long antennae was observed in the mealy bug colonies in tomato. Yellow coloured larvae voraciously predated on nymphs and adults of mealy bugs in tomato (Plate 15).

4.1.2.2 Spiders

Spiders observed from tomato plants are presented in Table. 6.

The important ecological guilds identified were orb web weavers, stalkers and ambushers, in which orb web weavers were the predominant spider group. Eight species of spiders were included in orb-web weaver guild which consisted of families araneidae and tetragnathidae. Family araneidae exhibited maximum species diversity and were abundant in tomato ecosystem. Under, araneidae four species of *Neoscona* and two species of *Argiope* were observed whereas under tetragnathidae two species of spiders were recorded. Family oxyopidae comprised of three species which were *Oxyopes* sp., *Oxyopes shewtha* Tikader and *Peucetia viridans* Hentz. Three spiders *viz.,* *Camaricus formosus* Thorell, *Dieta virens* Thorell and *Thomisus lobosus* Tikader were also observed under the ecological guild ambushers (Plate 16).

Table 6. Spiders recorded from tomato plants

Sl. No	Common name	Scientific name	Family	Ecological guild
1	Spotted orb weaver	*Neoscona* sp.	Araneidae	Orb web weavers
2	Spotted orb weaver	*Neoscona* sp.	Araneidae	Orb web weavers
3	Spotted orb weaver	*Neoscona* sp.	Araneidae	Orb web weavers
4	Spotted orb weaver	*Neoscona* sp.	Araneidae	Orb web weavers
5	Signature spider	*Argiope anasuja* Thorell	Araneidae	Orb web weavers
6	Signature spider	*Argiope* sp.	Araneidae	Orb web weavers
7	Long-jawed orb-weaver	*Tetragnatha* sp.	Tetragnathidae	Orb web weavers
8	Long-jawed orb-weaver	*Tetragnatha* sp.	Tetragnathidae	Orb web weavers
9	Lynx spider	*Oxyopes* sp.	Oxyopidae	Stalkers
10	Lynx spider	*Oxyopes shewtha* Tikader	Oxyopidae	Stalkers
11	Green lynx spider	*Peucetia viridans* Hentz	Oxyopidae	Stalkers
12	Brown flower spider	*Camaricus formosus* Thorell	Thomisidae	Ambushers
13	Green crab spider	*Dieta virens* Thorell	Thomisidae	Ambushers
14	Crab spider	*Thomisus lobosus* Tikader	Thomisidae	Ambushers

Identified by- Dr. Sunil Jose, Assistant Professor, Department of Zoology, Devamatha College, Kuruvilangad

4.1.2.3 Parasitoids

The parasitoids of American serpentine leaf miner, *L. trifolii* are listed in Table.7

Three parasitoids of order hymenoptera were recorded from American serpentine leaf miner in tomato. *Neochrysocharis* sp. (Eulophidae) was the most abundant parasitoid observed in *L. trifolii* on tomato from Vellayani which parasitized the larval stage of leaf miner. Parasitized larvae became blackened and died inside the mines. Adult parasitoids were metallic blue green in colour (Plate 17).

Opius sp. (Braconidae) was a larval- pupal parasitoid which infested the larval stages of *L. trifolii.* Adult parasitoids emerged from pupal stage of leaf miner and were solitary in nature (Plate 18). Another braconid parasitoid was also observed from the pupa of *L. trifolii* (Plate 19).

4.1.3 Host Plants of *Liriomyza* spp.

The details on host plants of *Liriomyza* spp. observed from Instructional Farm, Vellayani are depicted in Table 8, 9 and 10

Forty one host plants of *Liriomyza* spp. were observed, out of which twenty two species were vegetables and maximum host plants were recorded from cucurbitaceae family. In cucurbitaceae, nine plant species *viz.,* ash gourd, bitter gourd, bottle gourd, cucumber, ivy gourd, pumpkin, ridge gourd, snake gourd, and watermelon were observed as host plants of *Liriomyza* spp. The second abundant family was leguminosae which comprised of three species *viz.,* cowpea, green gram and jack bean. Brinjal and tomato (solanaceae), cabbage and cauliflower (cruciferae), red and green amaranth (amaranthaceae), mustard (brassicaceae) and bhindi (malvaceae) were also infested by the leaf miner. Incidence of *Liriomyza* spp. was also observed in minor vegetables like clove bean and basella (Plate 20)

Seven ornamental plants were observed as hosts of *Liriomyza* spp. which comprised of three members from asteraceae (dahlia, gerbera and marigold), two members from oleaceae (jasmine and royal jasmine) and one member each from lamiaceae (tulsi) and begoniaceae (begonia). Star apple, black pepper and castor were also observed as host plants of *Liriomyza* spp. (Plate 21).

Table 7. Parasitoids of American serpentine leaf miner *L. trifolii* recorded from Vellayani

Sl.No	Parasitoids	Type of Parasitism	Family
1	*Neochrysocharis* sp.	Larval parasitoid	Eulophidae
2	*Opius* sp.	Pupal parasitoid	Braconidae
3	Unidentified parasitoid	Pupal parasitoid	Braconidae

Table 8. Host plants of *Liriomyza* spp. recorded from Instructional Farm,Vellayani (vegetables)

Sl.No.	Common name	Scientific name	Family
1	Ash gourd	*Benincasa hispida* (Thumb.) Cogn.	Cucurbitaceae
2	Bitter gourd	*Momordica charantia* (L.)	Cucurbitaceae
3	Bottle gourd	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae
4	Cucumber	*Cucumis melo var. conomon* (L.)	Cucurbitaceae
5	Ivy gourd	*Coccinia grandis* (L.) Voigt.	Cucurbitaceae
6	Pumpkin	*Cucurbita pepo* (L.)	Cucurbitaceae
7	Ridge gourd	*Luffa acutangula* (Roxb.)	Cucurbitaceae
8	Snake gourd	*Trichosanthes cucumerina* (L.)	Cucurbitaceae
9	Water melon	*Citrullus lanatus* (Thumb) Matsum & Nakai.	Cucurbitaceae
10	Cowpea	*Vigna unguiculata* (L.) Walp.	Leguminosae
11	Green gram	*Vigna radiata* (L.)	Leguminosae
12	Jack bean	*Canavalia ensiformis* (L.) DC.	Leguminosae
13	Brinjal	*Solanum melongena* (L.)	Solanaceae
14	Tomato	*Solanum lycopersicum* (L.)	Solanaceae
15	Cabbage	*Brassica oleraceae var. capitata* (L.)	Cruciferae
16	Cauliflower	*Brassica oleraceae var. botrytis* (L.)	Cruciferae
17	Green amaranth	*Amaranthus viridis* (L.)	Amaranthaceae
18	Red amaranth	*Amaranthus* sp.	Amaranthaceae
19	Mustard	*Brassica nigra* (L.)	Brassicaceae
20	Bhindi	*Abelmoschus esculentus* (L.)	Malvaceae
21	Clove bean	*Ipomoea muricata* (L.)	Convolvulaceae
22	Basella	*Basella rubra* (L.)	Basellaceae

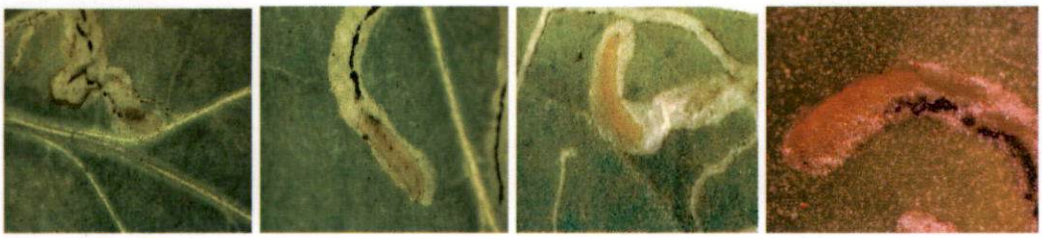
Table 9. Host plants of *Liriomyza* spp. recorded from Instructional Farm, Vellayani (ornamentals plants and other plants).

Sl.No.	Common name	Scientific name	Family
1	Dahlia	*Dahlia* sp.	Asteraceae
2	Gerbera	*Gerbera* sp.	Asteraceae
3	Marigold	*Tagetes* sp.	Asteraceae
4	Begonia	*Begonia* sp.	Begoniaceae
5	Jasmine	*Jasminum sambac* (L.) Aiton	Oleaceae
6	Royal jasmine	*Jasminum grandiflorum* (L.)	Oleaceae
7	Tulsi	*Ocimum sanctum* (L.)	Lamiaceae
8	Star apple	*Chrysophyllum cainito* (L.)	Sapotaceae
9	Black pepper	*Piper nigrum* (L.)	Piperaceae
10	Castor	*Ricinus communis* (L.)	Euphorbiaceae

Table 10. Host plants of *Liriomyza* spp. recorded from Instructional Farm, Vellayani (weeds)

Sl.No.	Common name	Scientific name	Family
1	Muyalcheviyan (lilac tassel flower)	*Emilia sonchifolia* (L.)	Asteraceae.
2	Kammal poovu (marsh para cress)	*Acmella uliginosa* Cass.	Asteraceae.
3	Poovamkurunnila (little iron weed)	*Vernonia cinerea* (L.)	Asteraceae.
4	Kattukadugu (Asian spider flower)	*Cleome viscosa* (L.)	Capparaceae
5	Kulamarinji (rangoon creeper)	*Combretum indicum* (L.)	Combretaceae
6	Ramanamapacha (telegraph plant)	*Desmodium gyrans* (L.)	Fabaceae
7	Manathakkali (black night shade)	*Solanum nigrum* (L.)	Solanaceae
8	Takara (sickle senna)	*Cassia tora* (L.)	Caesalpiniaceae
9	Kova (scarlet gourd)	*Coccinia rehmanii* (Cogn).	Cucurbitaceae

A. Egg



B. Larval instars

Early stage pupa

Late stage pupa

C. Pupa

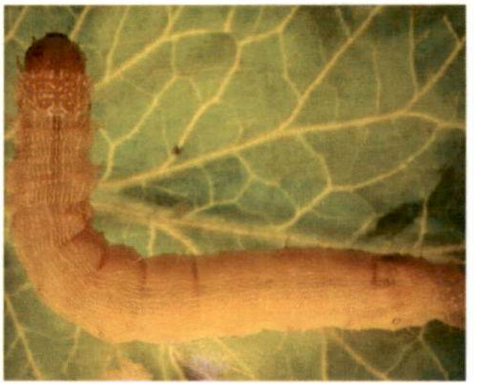
Adult fly emerged from pupa

Adult fly- Lateral view

D. Adult

Plate 1. Life stages of *Liriomyza trifolii*

Early instar larva



Late instar larva

Pupa

Adult

A. Life stages of *H. armigera.*

B. Symptoms of damage caused by *H. armigera.*

Plate 2. Life stages and symptoms of damage of *Helicoverpa armigera.*

Egg

Larva

Pupa

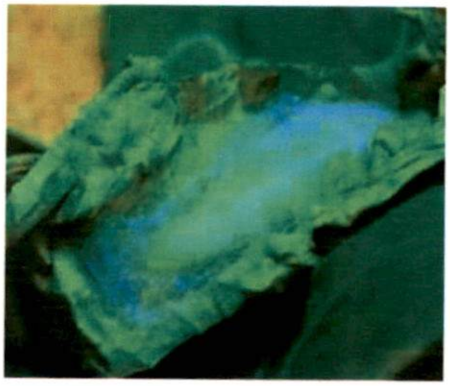
Adult

A. Life stages of *S. litura.*

B. Symptoms of damage

Plate 3. Life stages and symptoms of damage of *Spodoptera litura.*

Larva

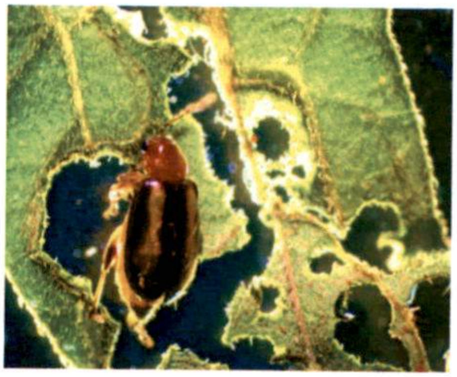


Pupa

Adult

Plate 4. Life stages of *Argyrogramma signata*

Adult



Symptoms of damage

Plate 5. *Luperomorpha vittata* and symptoms of damage

Egg

Grub

Pupa

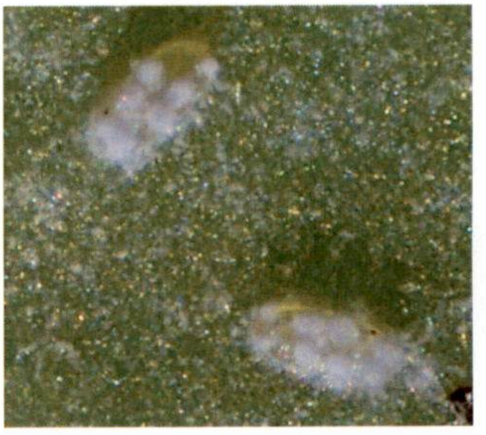
Adult

A. Life stages of *H. vigintioctopunctata*

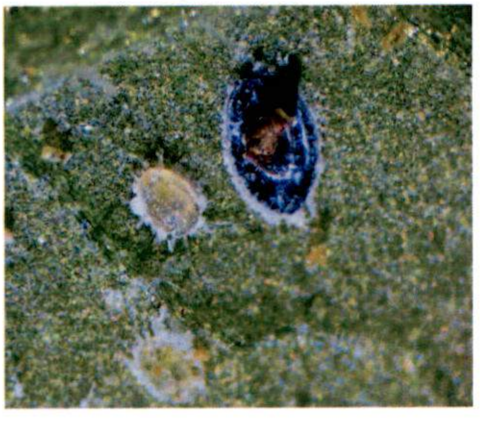
B. Symptoms of damage caused by *H. vigintioctopunctata*

Plate 6. Life stages and symptoms of damage of *Henosepilachna vigintioctopunctata*

Egg



Early instar nymph

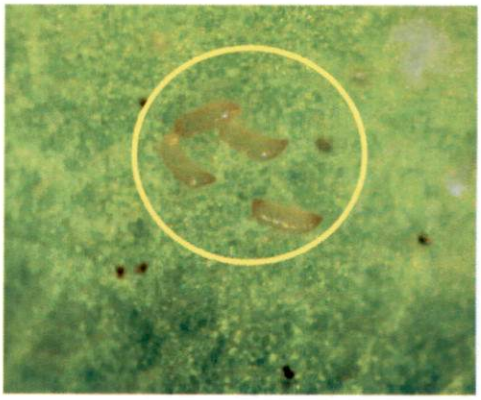


Nymph and Pupa

Adult

Plate 7. Life stages of *Aleurothrixus trachoides*.

Spiralling pattern on leaves



Egg

Nymph

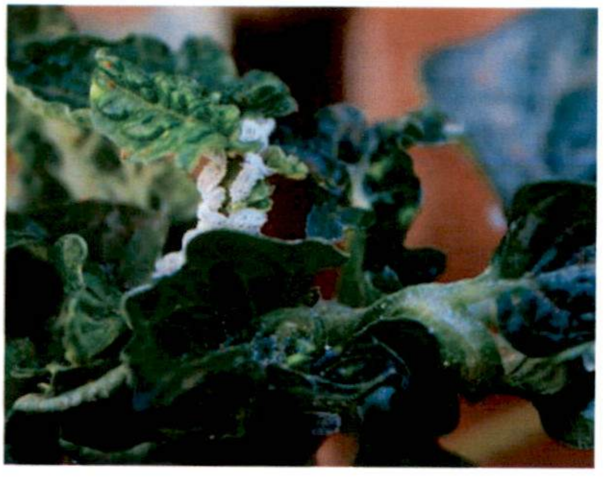
Adult

Plate 8. Life stages of *Aleurodicus dispersus*

Female mealy bug with crawlers

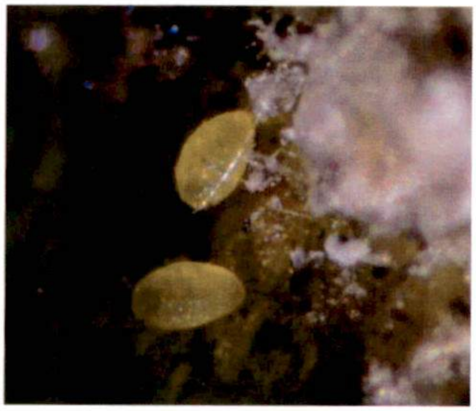
Nymph Adult

A. Life stages of *P. solenopsis*

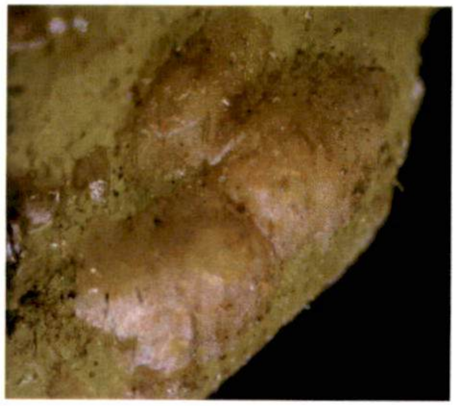


B.Symptoms of damage

Plate 9. Life stages and symptoms of damage of *Phenacoccus solenopsis*

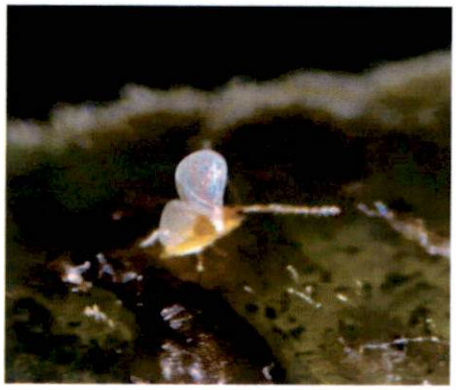


Crawlers



Late instar nymph

Adult female



Adult male

Plate 10. Life stages of *Saissetia* sp.

Adult

Winged Adult

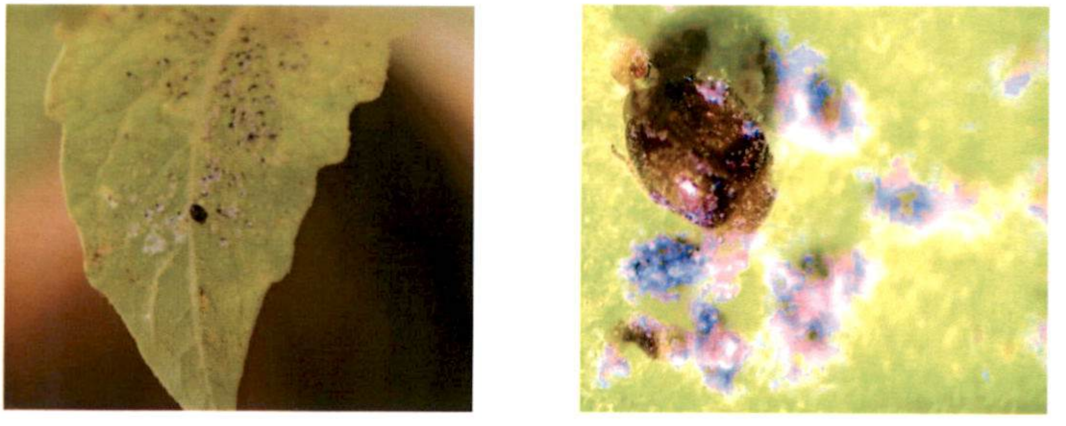
Plate.11. Life stages of *Myzus persicae*

Mirid bug in whitefly colony

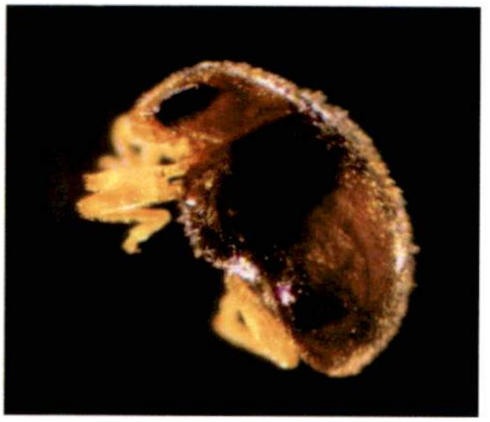
Nymph

Adult

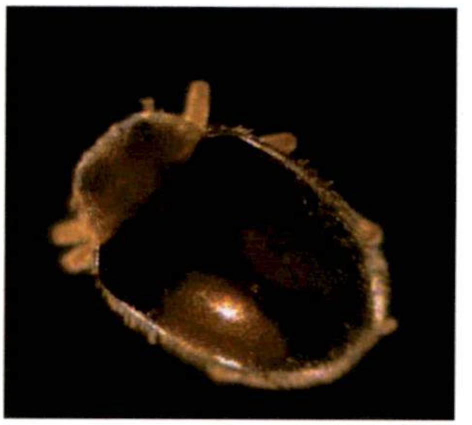
Plate 12. Life stages of mirid bug, *Nesidiocoris tenuis.*



A. *Axinoscymnus puttarudriahi* in the white fly colony



B. Adult beetle lateral view



C. Dorsal view

Plate13. Coccinellid beetle, *Axinoscymnus puttarudriahi*

Plate 14.*Coccinella transversalis*

A. Larva

B. Predatory midge

Plate 15. Predatory midge

A. *Neoscona* sp.

B. *Neoscona* sp.

C. *Neoscona* sp.

D. *Neoscona* sp.

E. *Argiope anasuja*

F. *Argiope* sp.

Plate 16. Spiders observed in tomato plants.

Tetragnatha sp.

Tetragnatha sp.

Oxyopes shewtha

Oxyopes sp.

Peucetia viridans

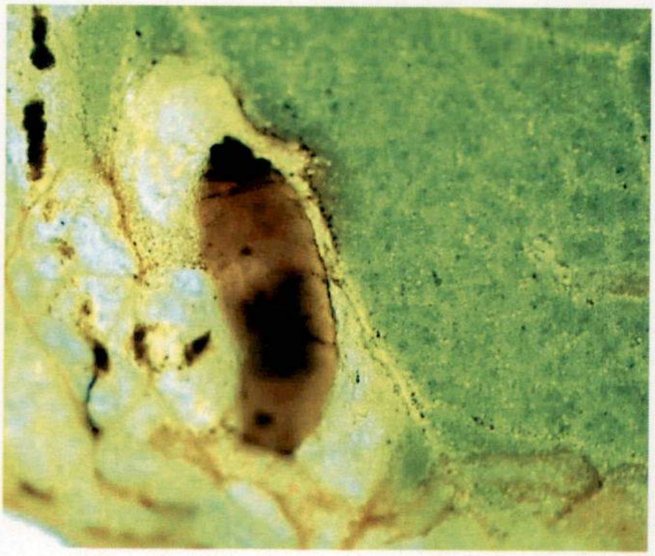
Plate 16 Spiders observed in tomato plants

Thomisus lobosus

Camaricus formosus

Dieta virens

Plate 16. Spiders observed in tomato plants



A. Parasitized larva

B. Male insect

C. Female insect

Plate 17. *Neochrysocharis* sp.

Plate 18. *Opius* sp.

Plate 19. Unidentified sp.

Ash gourd

Bitter gourd

Bottle gourd

Cucumber

Ivy gourd

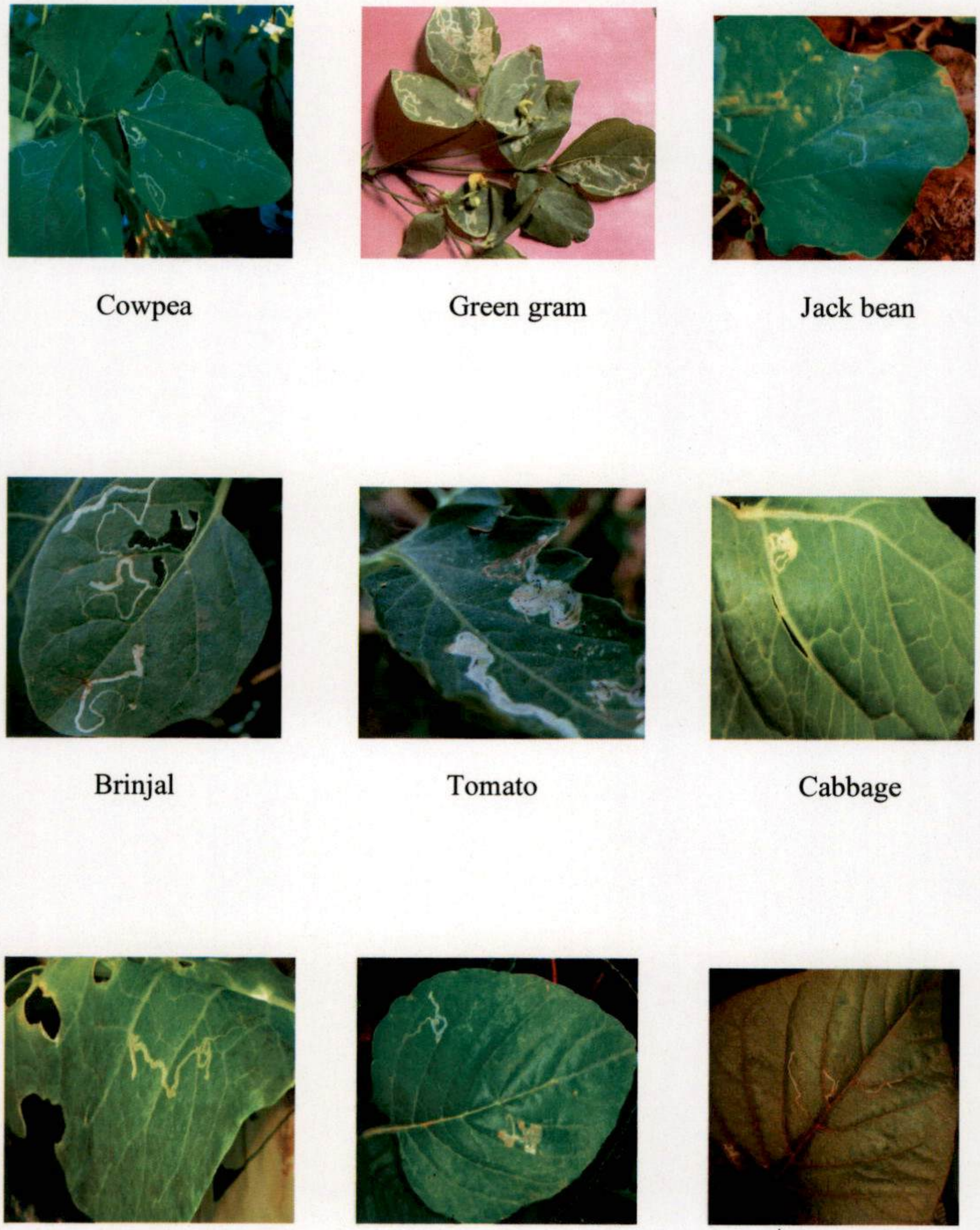
Pumpkin

Ridge gourd

Snake gourd

Water melon

Plate 20.Host plants of *Liriomyza* spp. (vegetables)



Cowpea
Green gram
Jack bean
Brinjal
Tomato
Cabbage
Cauliflower
Green amaranth
Red amaranth

Plate 20.Host plants of *Liriomyza* spp. (vegetables)

Mustard

Bhindi

Clove bean

Basella

Plate 20.Host plants of *Liriomyza* spp. (vegetables)

Dahlia

Gerbera

Plate 21. Host plants of *Liriomyza* spp. (ornamentals and other plants)

Marigold

Begonia

Jasmine

Royal jasmine

Tulsi

Star apple

Black pepper

Castor

Plate 21. Host plants of *Liriomyza* spp. (ornamentals and other plants)

Lilac tassel flower

Asian spider flower

Little iron weed

Asian spider flower

Rangoon creeper

Telegraph plant

Black nightshade

sickle senna

scarlet gourd

Plate 22. Host plants of *Liriomyza* spp. (weeds)

Nine species of weeds were recorded as host plants of *Liriomyza* spp. under seven families which include asteraceae, capparaceae, combretaceae, fabaceae, solanaceae, caesalpiniaceae and cucurbitaceae which were commonly seen in tomato plots. The important weeds observed under asteraceae were *Emilia sonchifolia* (L.), *Acmella uliginosa* (Cass) and *Vernonia cinerea* (L.). Other weed hosts infested by *Liriomyza* spp. were *Cleome viscosa* (L.), *Combretum indicum* (L.), *Desmodium gyrans* (L.), *Solanum nigrum* (L.), *Cassia tora* (L.) and *Coccinia rehmanii* (Cogn.) (Plate 22)

4.1.4 Correlation of *L. trifolii* Incidence with Weather Parameters

4.1.4.1 Incidence of L. trifolii on Tomato

The details on incidence of leaf miner on tomato during the crop period are given in Table 11.

The infestation started from one week after transplanting with 1.27 mines plant^{-1} and persisted up to the harvesting stage with 18.53 mines plant^{-1}. Number of mines plant^{-1} ranged from 1.27 to 24 and the peak infestation was noticed at 19 th standard meteorological week (May) *i.e.* at six weeks after transplanting with 24 mines plant $^{-1}$.

4.1.4.2 Correlation with Weather Parameters

The correlation between weather parameters and number of mines plant^{-1} caused by *L. trifolii* is presented in Table 12.

There was a significant negative correlation observed between maximum temperature and number of mines plant^{-1} with a correlation coefficient of -0.620 which exhibited a moderate downhill relationship. The number of mines plant^{-1} also showed a significant negative relationship with minimum temperature and the correlation coefficient was recorded as -0.822 which denoted a strong linear relationship. However, morning and evening relative humidity showed a positive non-significant relationship with number of mines plant^{-1}. Wind velocity, sunshine hours and rainfall revealed non-significant negative relationship with number of mines plant^{-1}.

Table 11. Incidence of American serpentine leaf miner, *L. trifolii* in tomato

Sl. No	Month	Weeks after transplanting	Standard meteorological week	Number of mines plant^{-1}
1	April	1	14	1.27
2	April	2	15	1.80
3	April	3	16	2.53
4	April	4	17	4.27
5	April-May	5	18	16.53
6	May	6	19	24.00
7	May	7	20	19.80
8	May	8	21	22.46
9	May- June	9	22	20.26
10	June	10	23	19.58
11	June	11	24	16.83
12	June	12	25	18.53

Table 12. Correlation of *L. trifolii* incidence with weather parameters

Weather parameters	Correlation coefficient	Level of significance at 5%
Maximum Temperature (^{0}c)	-0.620	Significant
Minimum Temperature (^{0}c)	-0.822	Significant
Relative Humidity (Morning)	0.209	Non-significant
Relative Humidity (Evening)	0.487	Non-significant
Wind velocity (km/ hr)	-0.218	Non-significant
Sunshine (hours)	-0.531	Non-significant
Rainfall (mm)	0.532	Non-significant

4.2 EVALUATION OF VARIETIES FOR FIELD TOLERANCE TO *L. trifolii.*

4.2.1 Incidence of *L. trifolli* on Different Tomato Cultivars (One Month After Transplanting)

Incidence of *L. trifolii* on various tomato cultivars at one month after transplanting is depicted in Table 13

4.2.1.1 Leaf Damage

The percentage leaf damage caused by *L. trifolii* on various tomato cultivars differed significantly. The leaf damage ranged from 10.12 to 66.20 per cent. Among the 15 cultivars, Arka Abha was more tolerant to *L. trifolii* infestation with lowest leaf damage of 10.12 per cent, which was significantly different from all other cultivars. *L. trifolii* showed less preference to Anagha with a leaf damage of 15.50 per cent which was statistically on par with varieties Arka Vikas (16.13), Pusa Ruby (17.45), Akshaya (17.97), Arka Meghali (18.62), Hissar Lalith (19.69) and accession LE 20 (16.78). Manulekshmi was significantly different from other varieties with a leaf damage of 29.17 per cent whereas Arka Alok suffered a leaf damage of 22.85 per cent. Highest damage was observed in hybrid Swaraksha with a percentage leaf damage of 66.20 which was significantly different from other cultivars. Percentage leaf damage on Hybrids *viz.,* NS-538 (60.67), Arka Samrat (59.44) and Arka Rakshak (58.40) were statistically on par with variety Vellayani Vijai (57.45).

4.2.1.2 Number of Mines Plant^{-1}

The number of mines plant^{-1} exhibited a significant difference among the fifteen tomato cultivars screened for field tolerance to *L. trifolii.* The number of mines plant^{-1} varied from 6.56 to 138.99. Lowest number of mines plant^{-1} was recorded in Arka Abha (6.56) followed by Arka Vikas (9.44) which were statistically on par. Maximum number of mines plant^{-1} was observed in hybrid NS-538 (138.99) which was significantly different from all other varieties. Second highest infestation was recorded in hybrid Arka Rakshak with 94.88 mines plant^{-1} which was statistically on par with Arka Samrat (94.33) and Swarkasha (83.50 ^{1}). Manulekshmi recorded 24.22 mines plant^{-1} which was statistically on par with varieties Anagha (22.22), Hissar Lalith

Table 13. Incidence of *L. trifolii* on different tomato cultivars (one month after transplanting)

Cultivars	Leaf damage (percentage)	Number of mines plant^{-1}	Number of larvae plant^{-1}	Leaf area (cm^2)	Length width ratio of leaf
Vellayani Vijai	57.45	66.55 (8.14)	3.22 (1.92)	579.77	1.48
Akshaya	17.97	15.99 (3.99)	0.78 (1.09)	500.40	1.55
Manulekshmi	29.17	24.22 (4.92)	0.55 (1.02)	557.33	1.36
Anagha	15.50	22.22 (4.69)	0.55 (1.02)	440.43	1.57
LE 20	16.78	16.78 (4.08)	0.55 (1.03)	535.20	1.40
Pusa Ruby	17.45	17.22 (4.12)	0.66 (1.08)	530.90	1.55
Swaraksha	66.20	83.50 (9.13)	4.67 (2.26)	693.07	1.43
NS-538	60.67	138.99 (11.75)	8.55 (3.00)	695.40	1.39
Arka Abha	10.12	6.56 (2.56)	0.11 (0.77)	518.70	1.61
Arka Meghali	18.62	12.44 (3.48)	1.11 (1.25)	536.63	1.59
Arka Alok	22.85	16.66 (4.08)	0.33 (0.91)	643.03	1.42
Arka Vikas	16.13	9.44 (3.08)	0.44 (0.96)	619.99	1.55
Arka Rakshak	58.40	94.88 (9.74)	5.33 (2.42)	891.33	1.39
Arka Samrat	59.44	94.33 (9.70)	4.78 (2.28)	845.90	1.22
Hissar Lalith	19.69	17.78 (4.18)	0.44 (0.95)	475.43	1.53
CD (0.05)	5.179	0.899	0.338	43.027	0.172

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed values

(17.78), Pusa Ruby (17.22), Arka Alok (16.66) and accession LE 20 (16.78). Arka Vikas recorded second lowest number of mines plant^{-1} (9.44) which was statistically on par with Arka Meghali (12.44).

4.2.1.3 Number of Larvae Plant^{-1}

A significant difference was observed in the number of larvae plant $^{-1}$ among the different cultivars of tomato screened against *L. trifolii.* Number of larvae present on the plants varied from 0.11 to 8.55. Lowest number of larvae plant $^{-1}$ was reported from Arka Abha (0.11) which was on par with Arka Alok (0.33), Hissar Lalith (0.44), Arka Vikas (0.44), Manulekshmi (0.55), Anagha (0.55), LE 20 (0.55), Pusa ruby (0.66) and Aksahya (0.78). Maximum number of larvae were recorded in hybrid NS - 538 (8.55). It was followed by Arka Rakshak (5.33), Arka Samrat (4.78) and Swarkasha (4.67) which were statistically on par .

4.2.1.4 Biometric Characters

Among the fifteen tomato cultivars, highest leaf area was observed in Arka Rakshak (891.33 cm^2) which was significantly superior to other cultivars. Lowest leaf area was observed in Anagha (440.33 cm^2) which was on par with Hissar Lalith (475.43 cm^2). It was followed by Akshaya (500.40 cm^2), Arka Abha (518.70 cm^2), Pusa Ruby (530.90 cm^2), LE 20 (535.20 cm^2) and Arka Meghali (536.63 cm^2) which were statistically on par.

Length width ratio of leaf was observed to be highest in Arka Abha (1.61) followed by Arka Meghali (1.59). Lowest Length width ratio was observed in Arka Samrat (1.22) which was on par with Manulekshmi (1.36), Arka Rakshak (1.39) and NS- 538 (1.39). It was followed by LE 20 (1.40), Arka Alok (1.42), Swaraksha (1.43), Vellayani Vijai (1.48), Hissar Lalith (1.53), Arka Vikas (1.54), Pusa Ruby (1.55) Akshaya (1.55) and Anagha (1.57) which were statistically on par.

4.2.2. Incidence of *L. trifolli* on Different Tomato Cultivars (Two Months After Transplanting)

Incidence of *L. trifolii* on various tomato cultivars at two months after transplanting is depicted in Table 14.

4.2.2.1 Leaf Damage (Percentage)

Tomato cultivars were differed significantly in percentage leaf damage caused by *L. trifolii* and it ranged from 14.21 to 66.26 per cent. Arka Abha recorded the lowest percentage leaf damage (14.21) which was on par with Anagha (15.11), Akshaya (17.53), LE 20 (17.61), Pusa Ruby (18.45), Arka Meghali (18.72) and Arka Vikas (20.57). Hybrid NS-538 was severely damaged by *L. trifolii* with a leaf damage percentage of 66.26 which was on par with hybrid Swaraksha with a leaf damage of 66.09 per cent. It was followed by Arka Rakshak (51.65) and Arka Samrat (48.69) which were statistically on par. Vellayani Vijai showed a leaf damage of 41.46 per cent, which was significantly different from all other cultivars. *L. trifolii* caused leaf damage of 26.45 per cent in Manulekshmi which was statistically on par with Hissar Lalith (25.88) and Arka Alok(23.18).

4.2.2.2 Number of Mines Plant^{-1}

All cultivars were significantly differed in number of mines plant^{-1}. It ranged from 8.22 to 153.44 mines plant^{-1}. Arka Abha recorded the lowest number of mines plant^{-1} (8.22) followed by LE 20 (13.33) and Arka Meghali (13.77) which were statistically on par. Maximum number of mines plant^{-1} was recorded in NS-538 (153.44) which was significantly higher to all other cultivars. It was followed by hybrid Arka Rakshak (119.11) and Arka Samrat (107.77) and were statistically on par. However Hybrid Swaraksha was significantly different from all other cultivars which recorded 85.44 mines plant^{-1}. Pusa Ruby recorded 27.33 mines plant^{-1} which was statistically on par with Hissar Lalith (24.55), Anagha (29.44), Manulekshmi (31.33) and Akshaya (36.55). Vellayani Vijai was preferred by *L. trifolii* which caused 68.22 mines plant^{-1} and significantly different from all other treatments.

Table 14. Incidence of *L. trifolii* on different tomato cultivars (2 months after transplanting)

Cultivars	Leaf damage (percentage)	Number of mines plant^{-1}	Number of larvae plant^{-1}	Leaf area (cm^2)	Length width ratio of leaf
Vellayani Vijai	41.46	68.22 (8.23)	4.27 (2.18)	699.87	1.56
Akshaya	17.53	36.55 (6.04)	1.11 (1.27)	592.80	1.54
Manulekshmi	26.45	31.33 (5.58)	1.44 (1.35)	613.50	1.39
Anagha	15.11	29.44 (5.40)	0.77 (1.12)	513.53	1.54
LE 20	17.61	13.33 (3.64)	0.33 (0.89)	572.90	1.48
Pusa Ruby	18.45	27.33 (5.20)	0.33 (0.89)	573.07	1.51
Swaraksha	66.09	85.44 (9.23)	5.78 (2.49)	854.17	1.49
NS-538	66.26	153.44 (12.34)	8.99 (3.08)	891.91	1.45
Arka Abha	14.21	8.22 (2.85)	0.22 (0.84)	509.47	1.67
Arka Meghali	18.72	13.77 (3.70)	0.55 (0.99)	557.80	1.59
Arka Alok	23.18	16.89 (4.07)	0.33 (0.91)	712.98	1.44
Arka Vikas	20.57	15.99 (3.95)	0.33 (0.89)	724.53	1.46
Arka Rakshak	51.65	119.11 (10.91)	6.78 (2.69)	973.20	1.47
Arka Samrat	48.69	107.77 (10.36)	6.89 (2.70)	967.40	1.30
Hissar Lalith	25.88	24.55 (4.95)	0.55 (1.02)	632.30	1.37
CD(0.05)	6.519	0.995	0.403	46.557	0.153

*Figures in parenthesis are $\sqrt{x+0.5}$ transformed values

4.2.2.3 Number of Larvae Plant^{-1}

There was a significant difference in number of larvae plant^{-1} among the fifteen tomato cultivars. Arka Abha recorded lowest number of larvae plant^{-1} (0.22) which was statistically on par with cultivars Arka Vikas (0.33), Pusa Ruby (0.33), LE 20 (0.33), Arka Alok (0.33), Arka Meghali (0.55), Hissar Lalith (0.55) and Anagha (0.77). Maximum number of larvae plant^{-1} was observed in hybrid NS 538 (8.99) which was statistically on par with Arka Samrat (6.89) and Arka Rakshak (6.78). Higher larval population was recorded in Vellayani Vijai (4.27 larvae plant^{-1}) which was statistically on par with Swaraksha (5.78).

4.2.2.4. Biometric Characters

Arka Rakshak and Arka Samrat possessed highest leaf area among the cultivars and found statistically on par (973.2 cm^2 and 967.4 cm^2 respectively). It was followed by NS-538 (891.91 cm^2) and Swaraksha (854.17 cm^2) which were also statistically on par. Lowest leaf area was observed in Arka Abha (509.47 cm^2) which was on par with Anagha (513.53 cm^2). It was followed by Arka Meghali (557.80 cm^2), LE 20 (572.90 cm^2), Pusa Ruby (573.07 cm^2) and Akshaya (592.80 cm^2) which were also statistically on par.

Length width ratio of leaves was recorded the highest in Arka Abha (1.67) followed by varieties Arka Meghali (1.59), Vellayani Vijai (1.56), Anagha (1.54) and Akshaya (1.54) which were statistically on par. The lowest length width ratio of leaves was observed in Arka Samrat (1.30) which was statistically on par with Hissar Lalith (1.37), Manulekshmi (1.39), Arka Alok (1.44) and NS-538(1.45).

Among the 15 tomato cultivars, Swaraksha (122.8 cm) was the tallest cultivar followed by Manulekshmi (117.78 cm) and Arka Samrat (114.33 cm) which were statistically on par. Hissar Lalith was the shortest with 73.33 cm plant height which was on par with Vellayani Vijai (82.77 cm).

Among tomato cultivars evaluated, Anagha possessed maximum number of branches plant $^{-1}$ (6.89) followed by Arka Vikas (6.56), Akshaya (6.34), Pusa ruby (6.22) and LE 20 (6.00) which were statistically on par while Arka Samrat recorded 97 lowest number of branches plant $^{-1}$ (3.00). It was followed by NS-538 (3.33), Arka Rakshak (3.33) and Swaraksha (4.00) and were statistically on par.

4.2.3. Yield (kg Plant^{-1})

The weight of fruits and number of fruits plant^{-1} are presented in Table 15.

On examining the yield obtained from various cultivars, hybrid NS-538 recorded higher yield of 0.65 kg plant^{-1} and was significantly different from other cultivars, followed by Swaraksha (0.53) and Arka Rakshak (0.48). Among the varieties, the highest yield was recorded from Arka Alok (0.46 kg plant^{-1}) which was significantly different from other cultivars. The lowest yield was recorded from Anagha (0.29 kg plant^{-1}) which was on par with LE 20 (0.30) and Hissar Lalith (0.29). Vellayani Vijai recorded a yield of 0.44 kg plant^{-1} which was statistically on par with Arka Samrat (0.44) and Arka Vikas (0.43).

Number of fruits plant^{-1} also exhibited significant difference with each other, in which maximum number of fruits plant^{-1} was recorded from Vellayani Vijai (16.11) and Hissar Lalith (6.11) produced the lowest number of fruits plant^{-1}

4.2.4. Classification of Tomato Cultivars Based on Tolerance

The details on classification of cultivars based on tolerance are presented in Table 16.

Among the 15 cultivars, hybrids, Swaraksha and NS-538 were included under the category highly susceptible based on the mean percentage leaf damage (66.15 and 63.47 respectively). Hybrids, Arka Rakshak, Arka Samrat and variety Vellayani Vijai were classified as susceptible with mean leaf damage percentage of 55.03, 54.07, and 49.46 respectively. Three varieties *viz.,* Manulekshmi (27.81), Arka Alok (23.02) and Hissar Lalith (22.79) were contained in the category moderately tolerant with lower mean leaf damage percentage. Seven cultivars were recorded as tolerant which were Arka Abha, Arka Meghali, Arka Vikas, Pusa Ruby, Anagha, Akshaya and LE 20 with a damage score of one and mean leaf damage percentage of 12.17 to 18.67.

Table 15. Biometric characters and yield of tomato cultivars evaluated against *L.trifolii*

Cultivars	Plant height (cm)	Number of branches plant^{-1}	Yield (kg plant^{-1})	Number of fruits plant^{-1}
Vellayani Vijai	82.77	5.22	0.44	16.11
Akshaya	103.33	6.34	0.34	11.11
Manulekshmi	117.78	5.44	0.31	6.33
Anagha	104.99	6.89	0.29	6.11
LE 20	105.886	6.00	0.30	9.33
Pusa Ruby	93.56	6.22	0.39	6.22
Swaraksha	96.11	4.00	0.53	7.33
NS-538	122.78	3.33	0.65	9.33
Arka Abha	87.99	5.22	0.32	7.00
Arka Meghali	108.33	4.89	0.33	6.11
Arka Alok	100.55	4.89	0.46	6.56
Arka Vikas	93.89	6.56	0.43	6.44
Arka Rakshak	107.77	3.33	0.48	7.55
Arka Samrat	114.33	3.00	0.43	6.66
Hissar Lalith	73.33	5.22	0.30	6.11
CD (0.05)	9.714	1.353	0.012	1.823

Table 16. Classification of tomato cultivars based on tolerance

Sl.No.	Cultivars	Mean leaf damage (Percentage)	Damage score	Rating index
1	Vellayani Vijai	49.46	3	Susceptible
2	Akshaya	17.75	1	Tolerant
3	Manulekshmi	27.81	2	Moderately tolerant
4	Anagha	15.31	1	Tolerant
5	LE 20	17.20	1	Tolerant
6	Pusa Ruby	17.95	1	Tolerant
7	Swaraksha	66.15	4	Highly susceptible
8	NS-538	63.47	4	Highly susceptible
9	Arka Abha	12.17	1	Tolerant
10	Arka Meghali	18.67	1	Tolerant
11	Arka Alok	23.02	2	Moderately tolerant
12	Arka Vikas	18.35	1	Tolerant
13	Arka Rakshak	55.03	3	Susceptible
14	Arka Samrat	54.07	3	Susceptible
15	Hissar Lalith	22.79	2	Moderately tolerant

4.2.5. Correlation Co-efficient of Different Independent and Dependent Variables

The details are included in Table 17

On analyzing the correlation between leaf damage (percentage) and leaf area, a correlation coefficient of 0.837 was obtained which indicated a significant strong positive relationship. As the leaf area increased, an increase in leaf damage caused by *L. trifolii* was also observed. The regression equation obtained was $Y= -42.195 + 0.114X$, where Y is the leaf damage (percentage) and X is the leaf area. This equation explained that with every one square cm increase in leaf area, there was an increase in leaf damage (percentage) by 0.114. Length width ratio revealed a negative significant moderate relationship with percentage leaf damage with a correlation coefficient of -0.547. When length width ratio of leaf was increased there was a decrease in percentage leaf damage. The regression equation obtained was $Y= 199.79 - 113.67 X$, where Y is the leaf damage and X is the length width ratio of leaf. This equation explained that with every one unit increase in length width ratio, there was a decrease of 113.67 per cent in leaf damage.

Leaf area showed a positive significant strong correlation with number of mines plant^{-1} with correlation coefficient of 0.822. The regression equation obtained was $Y= -4.964+ 0.071X$ which signified that every one square cm increase in leaf area, there was a 0.071 increase in number of mines plant^{-1}. Length width ratio of leaf showed a significant negative correlation with number of mines plant^{-1} with a correlation coefficient of -0.562. The regression equation obtained was $Y= 32.415- 17.795 X$. The regression equation revealed that one unit increase in length width ratio resulted in reduction of number of mines to the tune of 17.795.

Correlation of number of larvae plant^{-1} with leaf area also revealed a significant positive strong relationship and the correlation coefficient was 0.833. The regression equation was $Y=-1.363 + 0.004 X$. It explained that with a unit increase in leaf area there was 0.004 unit increase in number of larvae plant^{-1}. There was a non-significant negative correlation observed in number of live larvae plant^{-1} with length width ratio.

Table17. Correlation co-efficient of different independent and dependent variables

Sl.No .	Correlation between independent and dependent variable	Correlation coefficient	Level of significance at 5%	Regression equation
1	Leaf area v/s leaf damage (percentage)	0.837	Significant	Y= -42.195 + 0.114 X
2	Length width ratio of leaf v/s leaf damage (percentage)	-0.547	Significant	Y= 199.79 – 113.67 X
3	Leaf area v/s number of mines plant^{-1}	0.822	Significant	Y= -4.964 + 0.071 X
4	Length width ratio of leaf v/s number of mines plant^{-1}	-0.562	Significant	Y= 32.415 – 17.795 X
5	Leaf area v/s number of larva plant^{-1}	0.833	Significant	Y= -1.363 + 0.004 X
6	Length width ratio of leaf v/s number of larva plant^{-1}	-0.507	Non-significant	-

4.3 MANAGEMENT OF *L. trifolii*

4.3.1. Leaf Damage (Percentage)

The data on effect of treatments on leaf damage (percentage) caused by *L. trifolii* at 5, 15, 25, 35 days after sprayings are presented in Table 18.

The percentage damage ranged from 9.34 to 47.74 at 5 days after spraying. All the treatments were significantly superior to untreated check with 47.44 per cent leaf damage. The lowest leaf damage of 9.34 per cent was recorded in chlorantraniliprole 18.5 SC 0.006 % at 20 days interval treated plants followed by chlorantraniliprole 18.5 SC 0.006 % at 10 days interval treated plants (9.95) and were statistically on par. The second best treatment was flubendiamide 20 WG 0.005 % at 20 days interval followed by flubendiamide 20 WG 0.005 % at 10 days interval with percentage leaf damage of 14.03 and 14.81 respectively and were statistically on par. Among the various non chemicals treated, the lowest leaf damage of 18.18 per cent was observed in fish amino acid 0.5 % at 10 days interval treated plants followed by fish amino acid 0.5 % at 20 days interval with a percentage leaf damage of 18.82 and these treatments were on par with neem seed kernel extract 5 % at 10 days interval (19.15) and neem seed kernel extract 5 % at 20 days interval (19.23). Plants treated with oxuron 0.5 % at 10 days interval (23.10) was on par with oxuron 0.5 % at 20 days interval with leaf damage of 23.48 per cent which were also on par with neem oil 2.5 % at 10 days interval (25.71). Higher leaf damage was observed in plants treated with neem oil 2.5 % at 20 days interval (26.15 per cent) which was statistically on par with neem oil 2.5 % at 10 days interval.

Observations at 15 days after spraying showed that all the treatments were significantly superior to untreated check in leaf damage caused by *L. trifolii* (40.56 per cent). The percentage leaf damage varied from 5.32 to 40.56. The lowest percentage of leaf damage was observed in treatment with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval (5.32) which was significantly superior to all other treatments. The second best treatment was chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with leaf damage of 9.47 per cent which was significantly different from all other treatments.

Table 18. Effect of treatments on leaf damage caused by *L. trifolii* in tomato

Treatments	Leaf damage (Percentage)			
	5 DAS	15 DAS	25 DAS	35 DAS
Neem oil 2.5 % @ 10 days interval	25.71	18.41	19.42	14.61
Neem Seed Kernel Extract 5 % @ 10 days interval	19.15	14.63	14.49	13.56
Oxuron 0.5 % @ 10 days interval	23.10	17.87	20.02	14.63
Fish amino acid 0.5 % 10 days interval	18.18	13.70	12.88	10.40
Flubendiamide 20 WG 0.005 % @10 days interval	14.81	12.99	12.25	10.69
Chlorantraniliprole 18.5 SC 0.006 % @ 10 days interval	9.95	5.32	2.98	1.52
Neem oil 2.5 % @ 20 days interval	26.15	31.20	21.11	22.87
Neem Seed Kernel Extract 5 % @ 20 days interval	19.23	20.30	16.15	17.32
Oxuron 0.5 % @ 20 days interval	23.48	26.59	22.12	23.49
Fish amino acid 0.5 % @ 20 days interval	18.82	18.51	15.72	16.18
Flubendiamide 20 WG 0.005% @ 20 days interval	14.03	17.58	13.73	14.54
Chlorantraniliprole 18.5 SC 0.006 % @ 20 days interval	9.34	9.47	5.64	6.11
Untreated check	47.44	40.56	39.44	37.25
CD (0.05)	2.646	3.156	3.006	4.213

*DAS- Days after spraying

Among the non-chemicals, plants treated with fish amino acid 0.5 % at 10 days interval was the best treatment with leaf damage of 13.70 per cent followed by neem seed kernel extract 5 % at 10 days interval (14.63) which were on par. Plants treated with oxuron 0.5 % at 10 days interval treated plants showed a leaf damage of 17.87 per cent which was statistically on par with neem oil 2.5 % at 10 days interval (18.41 %), fish amino acid 0.5 % at 20 days interval (18.51 per cent) and neem seed kernel extract 5 % at 20 days interval (19.23 per cent). Higher leaf damage was observed in plants treated with neem oil 2.5 % at 20 days interval (31.20 per cent) followed by oxuron 0.5 % at 20 days interval with leaf damage of 26.59 per cent .

On comparison, untreated check exhibited significant difference from all other treatments at 25 days after spraying. Leaf damage ranged from 2.98 to 39.44 per cent. Percentage leaf damage was observed to be minimum in plots treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval with leaf damage of 2.98 followed by chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with 5.64 per cent leaf damage. Oxuron 0.5 % at 20 days interval was the least effective treatment with higher leaf damage of 22.12 per cent. It was also statistically on par with neem oil 2.5% at 20 days interval, oxuron 0.5 % at 10 days interval and neem oil 2.5 % at 10 days interval with leaf damage of 21.11, 20.02 and 19.42 per cent respectively. Among the non-chemicals, fish amino acid 0.5 % at 10 days interval was the best treatment with less leaf damage of 12.88 per cent. It was on par with neem seed kernel extract 5 % at 10 days interval (14.49 per cent).

Similar trend was also observed at 35 days after spraying also. All the treatments were significantly differed in the percentage leaf damage caused by *L. trifolii*. The leaf damage varied from 1.52 to 37.25 per cent. Chlorantraniliprole 18.5 SC 0.006 % at 10 days interval was significantly superior treatment with lowest leaf damage of 1.52 per cent followed by chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with 6.11 per cent leaf damage. Oxuron 0.5 % at 20 days interval was the least effective treatment with leaf damage of 23.49 per cent which was on par with neem oil 2.5 % at 20 days interval with leaf damage of 22.87 per cent even though these were superior to untreated check with 37.25 per cent leaf damage. Among the non-chemicals, fish amino acid 0.5 % at 10 days interval treated plots recorded less leaf damage of 10.40 per cent which was on par with neem seed kernel extract 5 % at 10 days interval (13.56 per cent) and neem oil 2.5 % at 10 days interval (14.61 per cent).

4.3.2. Number of Mines Plant $^{-1}$

The data on the effect of various treatments on number of mines plant^{-1} caused by *L. trifolii* at 5, 15, 25, 35 days after spraying are depicted in Table 19.

The number of mines plant^{-1} ranged from 0.58 to 9.25 at 5 days after spraying. Lowest number of mines plant^{-1} was observed in chlorantraniliprole 18.5 SC 0.006 % at 20 days interval treated plants (0.58) followed by chlorantraniliprole 18.5 SC 0.006 % at 10 days interval treated plants (0.75) which were statistically on par. Among the non-chemicals, lowest number of mines plant^{-1} was recorded in plants treated with fish amino acid 0.5 % at 10 days interval (2.42) followed by fish amino acid 0.5 % at 20 days interval treated plants with 2.75 mines plant $^{-1}$. These treatments were on par with neem seed kernel extract 5 % at 20 days interval (3.50 mines plant^{-1}) and neem seed kernel extract 5 % at 20 days interval (3.08 mines plant $^{-1}$). Plants treated with oxuron 0.5 % at 10 days interval (5.67) and oxuron 0.5 % at 20 days interval (5.50) recorded the highest number of mines plant^{-1} with the exception of untreated check with 9.25 mines plant $^{-1}$.

Efficacy of various treatments at 15 days after spraying also exhibited significant difference on comparison with the untreated check (17.83 mines plant $^{-1}$). Significantly lowest mines plant^{-1} was observed in plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval (0.67) which was superior with other treatments. It was followed by chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with 3.00 mines plant $^{-1}$. Plants treated with oxuron 0.5 % at 20 days interval recorded more number of mines plant^{-1} (11.33) which was on par with neem oil 2.5 % at 20 days interval (10.25). Higher number of mines plant $^{-1}$ was also recorded in plants treated with oxuron 0.5 % at 10 days interval (7.83) which was on par with neem seed kernel extract 5 % at 20 days interval (6.75) and neem oil 2.5 % at 10 days interval (6.5). Among the non-chemicals, plants treated with fish amino acid 0.5 % at 10 days interval was the most effective treatment with 5.00 mines plant $^{-1}$ which was statistically on par

Table 19. Effect of treatments on number of mines plant^{-1} caused by *L. trifolii* in tomato.

Treatments	Number of mines plant^{-1}			
	5 DAS	15 DAS	25 DAS	35 DAS
Neem oil 2.5 % @ 10 days interval	3.92 (1.95)	6.5 (2.54)	15.95 (3.9)	16.25 (4.09)
Neem Seed Kernel Extract 5 % @ 10 days interval	3.08 (1.74)	5.17 (2.28)	10.33 (3.20)	14.08 (3.81)
Oxuron 0.5 % @ 10 days interval	5.67 (2.38)	7.83 (2.78)	16.92 (4.08)	20.50 (4.59)
Fish amino acid 0.5 % @ 10 days interval	2.42 (1.55)	5.00 (2.24)	8.75 (2.96)	13.83 (3.74)
Flubendiamide 20 WG 0.005% @10 days interval	2.00 (1.41)	4.67 (2.16)	6.92 (2.63)	13.75 (3.77)
Chlorantraniliprole 18.5 SC 0.006 % @ 10 days interval	0.75 (0.83)	0.67 (0.81)	2.17 (1.47)	1.83 (1.43)
Neem oil 2.5 % @ 20 days interval	3.75 (1.94)	10.25 (3.20)	16.85 (4.11)	23.17 (4.87)
Neem Seed Kernel Extract 5 % @ 20 days interval	3.50 (1.73	6.75 (2.60)	10.58 (3.25)	17.67 (4.25)
Oxuron 0.5 % @ 20 days interval	5.50 (2.34)	11.33 (3.36)	21.02 (4.58)	23.67 (4.92)
Fish amino acid 0.5 % @ 20 days interval	2.75 (1.65)	5.67 (2.38)	10.58 (3.25)	16.42 (4.11)
Flubendiamide 20 WG 0.005% @ 20 days interval	1.92 (1.39)	5.33 (2.30)	9.50 (3.07)	14.92 (3.91)
Chlorantraniliprole 18.5 SC 0.006 % @ 20 days interval	0.58 (0.76)	3.00 (1.72)	4.33 (2.07)	4.75 (2.28)
Untreated check	9.25 (3.04)	17.83 (4.21)	47.67 (6.91)	47.5 (6.92)
CD (0.05)	0.411	0.326	0.474	0.600

*DAS-Days after spraying

**Figures in parenthesis are √x+0.5 transformed values with neem seed kernel extract 5 % at 10 days interval (5.17). It was also on par with plants treated with fish amino acid 0.5 % at 20 days interval (5.67 mines plant^{-1}).

At 25 days after spraying, the number of mines plant^{-1} ranged from 2.17 to 47.67. Plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval was significantly superior to all other treatments with 2.17 mines plant $^{-1}$. A significantly lower number of mines plant^{-1} was also recorded from plants treated with chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with 4.33 mines plant $^{-1}$. Plants treated with oxuron 0.5 % at 20 days interval recorded 21.02 mines plant $^{-1}$. It was followed by neem oil 2.5 % at 20 days interval (16.85 mines plant^{-1}), oxuron 0.5 % at 10 days interval (16.92 mines plant $^{-1}$) and neem oil 2.5 % at 10 days interval (16.85 mines plant $^{-1}$) were statistically on par. Plants treated with fish amino acid 0.5 % at 10 days interval showed least number of mines plant $^{-1}$ (8.75) among the tested non-chemicals, which was on par with neem seed kernel extract 5 % at 10 days interval (10.33), neem seed kernel extract 5 % at 20 days interval (10.58) and fish amino acid 0.5 % at 20 days interval (10.58).

Similar trend was also observed at 35 days after spraying also. All the treatments were significantly differed from the untreated check. Lowest number of mines plant $^{-1}$ was observed in plots treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval which was significantly different from all other treatments with 1.83 mines plant $^{-1}$. Chlorantraniliprole 18.5 SC 0.006 % at 20 days interval was also recorded lesser number of mines plant $^{-1}$ (4.75). Out of the various non-chemicals tested, plants treated with fish amino acid 0.5 % at 10 days interval recorded lowest number of mines (13.83 mines plant $^{-1}$) which was significantly on par with neem seed kernel extract 5 % at 10 days interval (14.08), neem oil 2.5 % at 10 days interval (16.25), fish amino acid 0.5 % at 20 days interval (16.42) and neem seed kernel extract 5 % at 20 days interval (17.67). Least effective treatment in reducing number of mines plant $^{-1}$ was plants treated with oxuron 0.5 % at 20 days interval (23.67) followed by neem oil 2.5 % at 20 days interval (23.17) and oxuron 0.5 % at 10 days interval (20.50) which were statistically on par.

4.3.3. Number of Larvae Plant $^{-1}$

Effect of treatments on number of *L. trifolii* larvae plant^{-1} was tabulated and presented in Table 20.

The number of larvae plant^{-1} varied from 0.08 to 1.92 at 5 days after spraying. Maximum number of larvae plant^{-1} was observed in untreated check (1.92) while minimum number of larvae plant^{-1} was observed in plants treated with chlorantraniiliprole18.5 SC 0.03 % at 10 days interval (0.08) and chlorantraniliprole 0.006 % at 20 days interval (0.08) which were on par. Among the non-chemicals, lowest number of larvae plant $^{-1}$ was recorded in treatment with fish amino acid 0.5 % at 10 days interval (0.50) and fish amino acid 0.5 % at 20 days interval (0.50) which were statistically on par and in turn also on par with neem seed kernel extract 5 % at 20 days interval (0.58), neem seed kernel extract 5 % at 10 days interval (0.67), neem oil 2.5 % at 20 days interval (0.67) and neem oil 2.5 % at 10 days interval (0.67). Oxuron 0.5 % at 20 days interval was least effective in reducing number of larvae plant^{-1}(1.00) followed by oxuron 0.5 % at 10 days interval (1.00) which were statistically on par.

There was a significant difference observed in number of larvae plant $^{-1}$ at 15 days after spraying with maximum number of larvae recorded from untreated check (2.92). Absolute reduction of larvae plant^{-1} was detected from plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval. It was followed by plants treated with chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with 0.08 larvae plant $^{-1}$ which were statistically on par. Out of the non-chemicals evaluated against *L. trifolii*, plants treated with fish amino acid 0.5 % at 10 days interval recorded lowest number of larvae plant $^{-1}$ (0.42) which was on par with neem seed kernel extract 5 % at 10 days interval (0.42), fish amino acid 0.5 % at 20 days interval (0.58), and neem oil 2.5 % at 10 days interval (0.75). Comparatively higher number of larvae plant $^{-1}$ was observed in plants treated with oxuron 0.5 % at 20 days interval (1.58) and neem oil 2.5% at 20 days interval (1.50) which were on par. It was followed by plants treated with oxuron 0.5 % at 10 days interval (0.83 larvae plant $^{-1}$) and neem seed kernel extract 5 % at 20 days interval (0.83) and were statistically on par.

Table 20. Effect of treatments on number of *L.trifolii* larvae plant $^{-1}$ in tomato.

	Number of larvae plant^{-1}			
Treatments	5 DAS	15DAS	25DAS	35DAS
Neem oil 2.5 % @ 10 days interval	0.67 (1.08)	0.75 (1.11)	2.00 (1.57)	1.58 (1.45)
Neem Seed Kernel Extract 5 % @ 10 days interval	0.67 1.08	0.50 (0.99)	1.25 (1.32)	1.00 (1.22)
Oxuron 0.5 % @ 10 days interval	1.00 (1.22)	0.83 (1.16)	2.92 (1.84)	2.83 (1.82)
Fish amino acid 0.5 % @10 days interval	0.50 1.0	0.42 (0.95)	0.83 (1.16)	0.58 (1.03)
Flubendiamide 20 WG 0.005 % @10 days interval	0.58 (1.03)	0.58 (1.03)	1.50 (1.40)	1.33 (1.34)
Chlorantraniliprole 18.5 SC 0.006 % @ 10 days interval	0.08 (0.76)	0.00 (0.70)	0 (0.70)	0 (0.70)
Neem oil 2.5 % @ 20 days interval	0.67 (1.08)	1.50 (1.41)	2.08 (1.60)	2.25 (1.66)
Neem Seed Kernel Extract 5 % @ 20 days interval	0.58 (1.03)	0.83 (1.16)	1.75 (1.49)	1.42 (1.39)
Oxuron 0. 5% @ 20 days interval	1.00 (1.22)	1.58 (1.45)	2.92 (1.84)	2.83 (1.82)
Fish amino acid 0.5 % @ 20 days interval	0.50 (0.99)	0.58 (1.01)	0.92 (1.18)	1.00 (1.22)
Flubendiamide 20 WG 0.005 % @ 20 days interval	0.58 (1.03)	0.67 (1.08)	1.58 (1.45)	1.58 (1.42)
Chlorantraniliprole 18.5 SC 0.006 % @ 20 days interval	0.08 (0.76)	0.08 (0.76)	0 (0.70)	0 (0.70)
Untreated check	1.92 (1.55)	2.92 (1.84)	7.08 (2.75)	5.92 (2.53)
CD (0.05)	0.189	0.169	0.220	0.253

*DAS- days after spraying

** Figures in parenthesis are $\sqrt{x+0.5}$ transformed values

At 25 days after spraying, no larva was observed in plants treated with cholrantraniliprole 18.5 SC 0.006 % at 10 days interval and chlorantraniliprole 18.5 SC 0.006 % at 20 days interval. Remarkable reduction in number of larvae plant^{-1} was observed in plants treated with fish amino acid 0.5 % at 10 days interval (0.83) followed by fish amino acid 0.5 % at 20 days interval (0.92) and were on par with neem seed kernel extract 5 % at 10 days interval with 1.25 larvae plant $^{-1}$. Higher larval population plant^{-1} was observed in plants treated with oxuron 0.5 % at 10 days interval (2.92) followed by oxuron 0.5% at 20 days interval (2.92) and untreated check (7.08). Plants treated with flubendiamide 20 WG 0.005 % at 10 days interval recorded a larval population of 1.50 whereas flubendiamide 20 WG 0.005 % at 20 days recorded 1.58 larvae plant $^{-1}$. These treatments were equally effective as neem seed kernel extract 5 % at 20 days interval (1.75 larvae plant $^{-1}$), neem oil 2.5 % at 10 days interval (2.00 larvae plant $^{-1}$) and neem oil 2.5 % at 20 days interval (2.08 larvae plant $^{-1}$) in reduction of larval population on tomato.

Significant difference was observed among the treatments in reduction of number of larvae plant $^{-1}$ at 35 days after spraying also. The larval population ranged from 0 to 5.92. Absolute reduction of larval population was observed in plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval and chlorantraniliprole 18.5 SC 0.006 % at 20 days interval. Among the tested non-chemicals, significant reduction of number of larvae was observed in plants treated with fish amino acid 0.5 % at 10 days interval treated plants with 0.58 larvae plant $^{-1}$. It was on par with neem seed kernel extract 5 % at 10 days interval and fish amino acid 0.5 % at 20 days interval with larval population of 1.00 for each treatment. Higher larval incidence was noticed in plants treated with oxuron 0.5 % at 10 days interval followed by oxuron 0.5 % at 20 days interval and neem oil 2.5 % at 20 days interval with 2.83, 2.83 and 2.25 larvae plant^{-1} respectively. Flubendiamide 20 WG 0.005 % at 10 days interval treated plants recorded 1.33 larvae plant $^{-1}$ whereas flubendiamide 20 WG 0.005 % at 20 days interval recorded 1.58 larvae plant $^{-1}$ which were on par with neem seed kernel extract 5 % at 10 days interval with 1.00 larvae plant^{-1} and neem oil 2.5 % at 10 days interval (1.58 larvae plant $^{-1}$).

Table 21. Effect of treatments on yield of tomato

Treatments	Number of fruits plant $^{-1}$	Yield (kg plant^{-1})	Benefit cost ratio
Neem oil 2.5 % @10 days interval	18.00	0.378	0.80
Neem Seed Kernel Extract 5 % @10 days interval	20.17	0.443	1.18
Oxuron 0.5 % @10 days interval	19.08	0.377	1.02
Fish amino acid 0.5 % @ 10 days interval	18.25	0.473	1.39
Flubendiamide 20 WG 0.005 %@10 days interval	18.83	0.472	1.21
Chlorantraniliprole 18.5 SC 0.006 % @ 10 days interval	19.67	0.566	1.4
Neem oil 2.5 % @ 20 days interval	17.83	0.374	0.95
Neem Seed Kernel Extract 5 % @ 20 days interval	18.00	0.436	1.28
Oxuron 0.5 % @ 20 days interval	18.75	0.376	1.11
Fish amino acid 0.5 % @ 20 days interval	20.58	0.446	1.40
Flubendiamide 20 WG 0.005 % @ 20 days interval	19.00	0.454	1.3
Chlorantraniliprole 18.5 SC 0.006 % @ 20 days interval	19.42	0.546	1.53
Untreated check	18.00	0.296	
CD(0.05)	NS	0.064	

4.3.4. Yield (kg Plant^{-1})

Effect of treatments on weight of fruits and number of fruits of tomato infested by *L. trifolii* is presented on Table 21.

Number of fruits plant^{-1} recorded from various treatments exhibited no significant difference.

A significant difference was observed in weight of fruits plant^{-1} recorded from various treatments. The highest yield was recorded from plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval (0.57 kg plant^{-1}) which was on par with chlorantraniliprole 18.5 SC 0.006 % at 20 days interval (0.55 kg plant^{-1}). The lowest yield was reported in untreated check (0.30 kg plant^{-1}) which was significantly different from all other treatments. Among the non chemicals, maximum yield was recorded from plants treated with fish amino acid 0.5 % at 10 days interval (0.47 kg plant^{-1}) followed by fish amino acid 0.5 % at 20 days interval (0.45 kg plant^{-1}) which were on par. It was also on par with NSKE 5 % at 10 days interval and NSKE 5 % at 20 days interval with fruit yield of 0.443 kg plant^{-1} and 0.44 kg plant^{-1} respectively. Comparatively lower yield was recorded in plants treated with oxuron 0.5 % at 20 days interval (0.38 kg plant^{-1}) treated plants which was on par with neem oil 2.5 % at 20 days interval (0.374 kg plant^{-1}), oxuron 0.5 % at 10 days interval (0.38 kg plant^{-1}), neem oil 2.5 % at 10 days interval (0.38 kg plant^{-1}). Flubendiamide 20 WG 0.005 % at 10 days interval recorded 0.47 kg plant^{-1} whereas flubendiamide 20 WG 0.005 % at 20 days interval recorded 0.45 kg plant^{-1}and were on par. It was also statistically on par with neem seed kernel extract 5 % at 10 days interval treated plots with yield of 0.47 kg plant^{-1}. On comparing the benefit cost ratio, the highest was observed in chlorantraniliprole 18.5 SC 0.006 % at 20 days interval treated plants (1.53) followed by plants treated with fish amino acid 0.5 % at 20 days interval (1.40) and chlorantraniliprole 18.5 SC 0.006 % at 10 days interval (1.40).

Discussion

5. DISCUSSION

Tomato, apple of paradise, is one of the most popular vegetable crops in the world next to potato. Out of the various factors, insect pest infestation plays a significant role in diminishing the productivity of tomato crop. Among the various pests in tomato, American serpentine leaf miner, *L. trifolii* is an economically important invasive pest which invaded to India along with chrysanthemum planting materials (Viraktamath *et al.,* 1993). Factors like short life cycle, high reproductive potential, concealed larval stages and resistance to insecticides makes the management of *L. trifolii* difficult (Pawar and Patil, 2013).

In this scenario, host plant resistance can be considered as the first step in insect pest management. Natural enemies also played an important role in reduction of population of *L. trifolii* in field situations. Besides, botanicals and green labeled insecticides can be promoted in order to overcome the harmful effects of synthetic, highly toxic insecticides.

The present study aims to evaluate field tolerance of tomato cultivars to *L. trifolii* and to evolve an effective method for the management of *L. trifolii* in tomato.

5.1 PESTS OF TOMATO

Important insect pests of tomato recorded from Instructional Farm, College of Agriculture, Vellayani at both vegetative and reproductive stages were *L. trifolii, S. litura, A. signata, H. vigintioctopunctata, A. trachoides* and *P. solenopsis*. *H. armigera* and *A. dispersus* were observed at reproductive stage of the crop while *L. vittata, Saissetia* sp. and *M. persicae* were noted only at vegetative stage of the crop. Similarly, insect pest complex of tomato was recorded from different places (Reddy and Kumar, 2004; Naik *et al.,* 2005; Kumar, 2014; Mandloi *et al.*, 2015). Kousika *et al.* (2015) also reported that tomato crop was severely damaged by *H. armigera, S. litura* and *L. trifolii* in Tamil Nadu.

Among the pests, solanum whitefly, *A. trachoides* is recorded for the first time in tomato from Kerala. It was previously reported from Karnataka on *Duranta* sp. and *Capsicum annuum*. Severe infestation resulted in drying of leaves and development of sooty mould on the leaves (Ramanujam *et al.* 2014; Dubey and Sundararaj, 2015).

Tomato fruit borer, *H. armigera* caused a leaf damage of 10.16 per cent and fruit damage of 13.86 per cent at reproductive stage of the crop. Singh and Singh (1977) reported higher fruit damage of 50 to 60 per cent in tomato in Punjab. Higher incidence of fruit borer at reproductive stage of the crop was also reported in Madhya Pradesh (Mandloi *et al.*, 2015). The lower damage in the present study may be due to the activity of natural enemies. Spiralling whitefly caused higher leaf damage at reproductive stage of the crop (23.13 per cent). This may be due to the wide host range of the pest coupled with high temperature and relative humidity of the season.

Natural enemies are entities, which maintain their population, once they are established in an ecosystem and able to maintain the pest population below damaging levels (Pimental, 1991). Important predators recorded from tomato pests were *N. tenuis*, *A. puttarudriahi*, *C. transversalis* and a predatory midge. *N. tenuis*, a mirid bug was observed as a predator of *A. trachoides* and it is recorded for the first time from Kerala. Studies conducted by Calvo *et al.* (2009) and Zappala *et al.* (2013) confirmed the predatory nature of *N. tenuis*, on whitefly species *B. tabaci* in sweet potato and tomato respectively.

Coccinellid beetles played a predominant role in reduction of sucking pest complexes due to their voracious feeding nature and predaceous behavior of both adult and grub, which dominated over the pest population in crops (Rekha *et al.*, 2009). *C. transversalis* was observed as a predator of aphids, *M. persicae* on tomato. Similar results were also reported by Rekha, *et al.* (2009) from Tamil Nadu. Coccinellid, *A. puttarudriahi* was recorded as a predator of solanum whitefly *A. trachoides*. Ramanujam *et al.* (2014) reported the predatory nature of *A. puttarudriahi* on solanum whitefly in pepper.

Cecidomyiids were considered as the most promising predators of mealy bug colonies (Carter, 1944). A midge predator was recorded from mealy bug *P. solenopsis* in tomato from the present study. Hayon *et al.* (2016) reported that predatory gall midges fed actively on eggs, nymphs and adults of mealy bugs.

Fourteen species of spiders were observed from tomato plants at Instructional Farm, Vellayani. Major ecological guild observed was orb web weavers, in which family araneidae exhibited maximum species diversity. Manu (2005) reported that family araneidae was the most abundant family in vegetable ecosystem while hunter guild was the predominant ecological guild. Difference observed in the present study may be due to changes in host plant and pest species. The other important families observed from tomato plants were oxyopidae, thomisidae and tetragnathidae which were also recorded by Manu (2005) from vegetable ecosystem.

In the present study, three hymenopterans (eulophidae and braconidae) were recorded as parasitoids of *L. trifolii* in tomato. Reji (2002) reported *Chrysonotomyia rexia* Narendran as predominant parasitoid on *L. trifolii* in cowpea. In the present study, *Neochrysocharis* sp. was recorded as the abundant species in tomato. The variation in abundance of a species may be due to the changes in host crop and season. This view was supported by the findings of Johnson and Hara (1987). The predominance of *Neochrysocharis* sp. as parasitoid of *L. trifolii* was also reported by Saito *et al.* (1996) in Japan. Sharma *et al.* (2011) also recorded the prevalence of *Neochrysocharis* sp. in Himachal Pradesh.

Opius sp. was recorded as a parasitoid of *L. trifolii* in tomato from the present study. The incidence of *Opius* sp. on leaf miner was also pointed out by Sharma *et al.* (2011) from Himachal Pradesh. *Neochrysocharis* sp. and *Opius* sp. are recorded for the first time as parasitoids of *L. trifolii* from Kerala. Presence of new parasitoid communities revealed the importance of conservation of parasitoids in tomato ecosystem.

Liriomyza spp. is a polyphagous leaf miner distributed all around the world as a pest of vegetables, ornamentals, fiber crops, fodder crops and weeds. In order to identify the host plants of *Liriomyza* spp., a study was conducted at Instruction Farm, College of Agriculture, Vellayani. Forty one plants under 19 families were recorded as hosts of *Liriomyza* spp., which included vegetables, ornamentals, and weeds. Wide host range of *Liriomyza* spp. was reported from various parts of the world (Stegmaier, 1966; Spencer, 1981; Saradhi and Patnaik, 2004; Smitha, 2004).

Cucurbitaceae was the dominant family of vegetables infested by leaf miners whereas asteraceae recorded maximum number of hosts infested by *Liriomyza* spp. among the ornamentals and weeds. The finding of Bogran (2005) was in conformity with the present results, such that asteraceae and cucurbitaceae families were severely infested by the agromyzid leaf miners.

The study on host range of *Liriomyza* spp. ensured the polyphagous nature of leaf miner which emphasized the severity of damage. Wide host range indicated the successful establishment of serpentine leaf miner. Infestation of leaf miner is noticed even in the seedling stage of the crop due to this wide host range. Pest may be present throughout the year in any of the host plants. The role of weed hosts was also mentioned in the findings of Schuster *et al.* (1991) and Reji (2002).

The leaf miner infestation was observed throughout the crop period in tomato. The peak infestation was recorded at six weeks after transplanting and persisted till the harvesting stage. Mandloi *et al.* (2015) also ensured the presence of leaf miner throughout the crop growth stage.

In the present study, maximum temperature and minimum temperature exhibited a significant negative correlation with mean number of mines plant^{-1}.

Chakraborty (2011) also observed a significant negative correlation of maximum and minimum temperature with leaf miner incidence. Similar results were reported by Variya and Bhut (2014) on tomato in Gujarat. Mandloi *et al.* (2015) also recorded that minimum temperature exhibited a significant negative correlation with number of mines in Madhya Pradesh.

Relative humidity and rainfall exhibited a positive correlation with number of mines plant^{-1} whereas sunshine hours and wind velocity expressed negative association. Choudary and Rosaiah (2000) reported that sunshine hours exhibited a negative correlation with leaf miner incidence.

5.2 EVALUATION OF VARIETIES FOR FIELD TOLERANCE TO *L. trifolii*

Host plant resistance is considered as the first line of defense against pest species in an agro ecosystem. Being a cultural control tactic, host plant resistance was considered as an economically and environmentally safe alternative which enhance the effects of biological control strategies and upgrade the performance of pesticide applications for the management of major pests of crops (Teets, 1994). It is considered as the preliminary step in integrated pest management to ensure the suppression of pest population. Based on these facts, fifteen tomato cultivars were screened for their field tolerance to *L. trifolii* at Instructional Farm, Vellayani. Hybrids, released varieties and accessions were included in the present study for identification of tolerant cultivars.

Among the tested cultivars, lowest mean leaf damage (percentage) was observed in Arka Abha (12.17) whereas highest leaf damage was recorded from hybrid Swarkasha (66.15 per cent) (Fig.1). Hybrid cultivars *viz.,* NS-538 (63.47 per cent), Arka Rakshak (55.03 per cent) and Arka Samrat (54.07 per cent) recorded higher mean leaf damage compared to other cultivars which signified the higher susceptibility of hybrid cultivars to leaf miner infestation. Tandon and Bakthavatsalan (2002) recorded similar observations which revealed the higher susceptibility of hybrids in terms of mean leaf damage (percentage) to *L. trifolii.*

Arka Abha recorded lowest mean number of mines plant^{-1} (7.39) followed by Arka Vikas (12.72) and Arka Meghali (13.11) whereas highest number of mines plant^{-1} was observed in NS-538 (146.22) (Fig.2). Arka Rakshak (106.99), Arka Samrat (101.05) and Swaraksha (84.47) also recorded higher number of mines plant^{-1}.

The mean larval population plant^{-1} was also recorded lowest in Arka Abha (0.17) followed by Arka Alok (0.33) and accession LE 20 (0.44) while highest mean larval population was observed in NS- 538 (8.77) (Fig.3). Classification of varieties to different categories based on mean leaf damage caused by *L. trifolii* disclosed that hybrids were included under the category highly susceptible or susceptible group (Table 16). Choudhary and Rosaiah (2000) also concluded that hybrids were more susceptible to leaf miner incidence in West Bengal than that of open pollinated varieties. Similar results were also reported by Lasker and Ghosh (2005).

All other varieties and accessions *viz.,* Arka Abha, Arka Meghali, Arka Vikas, Pusa Ruby, Anagha, Akshaya, LE 20, Manulekshmi, Arka Alok and Hissar Lalith were included under tolerant or moderately tolerant group except Vellayani Vijai which was included under susceptible category (Table.16). Lasker and Ghosh (2005) ; Naik *et al.*(2005) and Rai *et al.* (2013) also included Pusa ruby under less susceptible or resistant category and hybrids as most susceptible groups.

Among the fifteen cultivars Arka Abha was recorded as the least preferred cultivar with least leaf damage, number of mines plant^{-1} and number of larvae plant^{-1}. Less susceptibly of the cultivar may be owing to the factors like decreased ovipositional preference of the adult which occurred as a result of presence of deterrent chemicals or due to specific plant characters (Erb *et al.,* 1993). The reduction in larval population and number of mines may be due to antibiosis effect which prevented the hatching of eggs or obstructed the larval development.

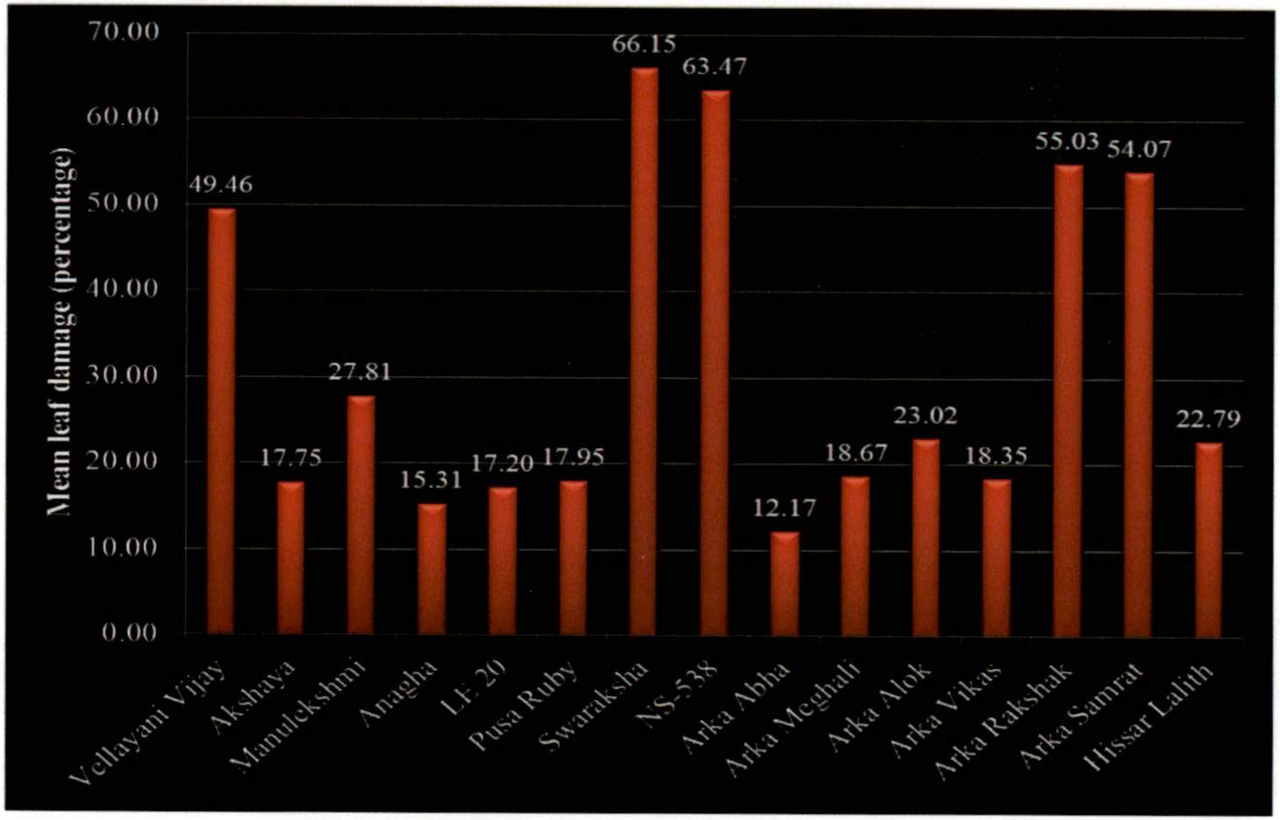


Fig. 1. Incidence of *L. trifolii* on different tomato cultivars (Mean percentage leaf damage)

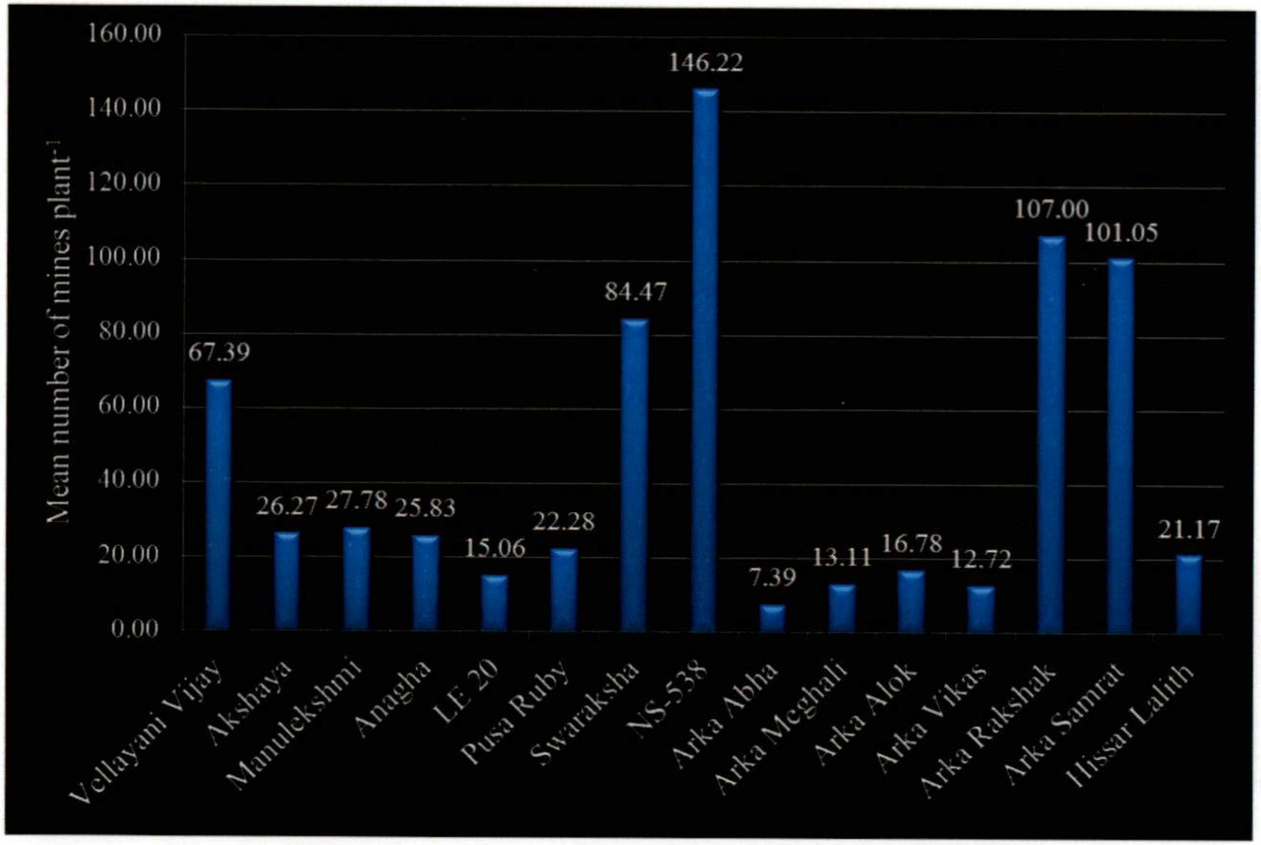


Fig. 2. Incidence of *L. trifolli* on different tomato cultivars (Mean number of mines $plant^{-1}$)

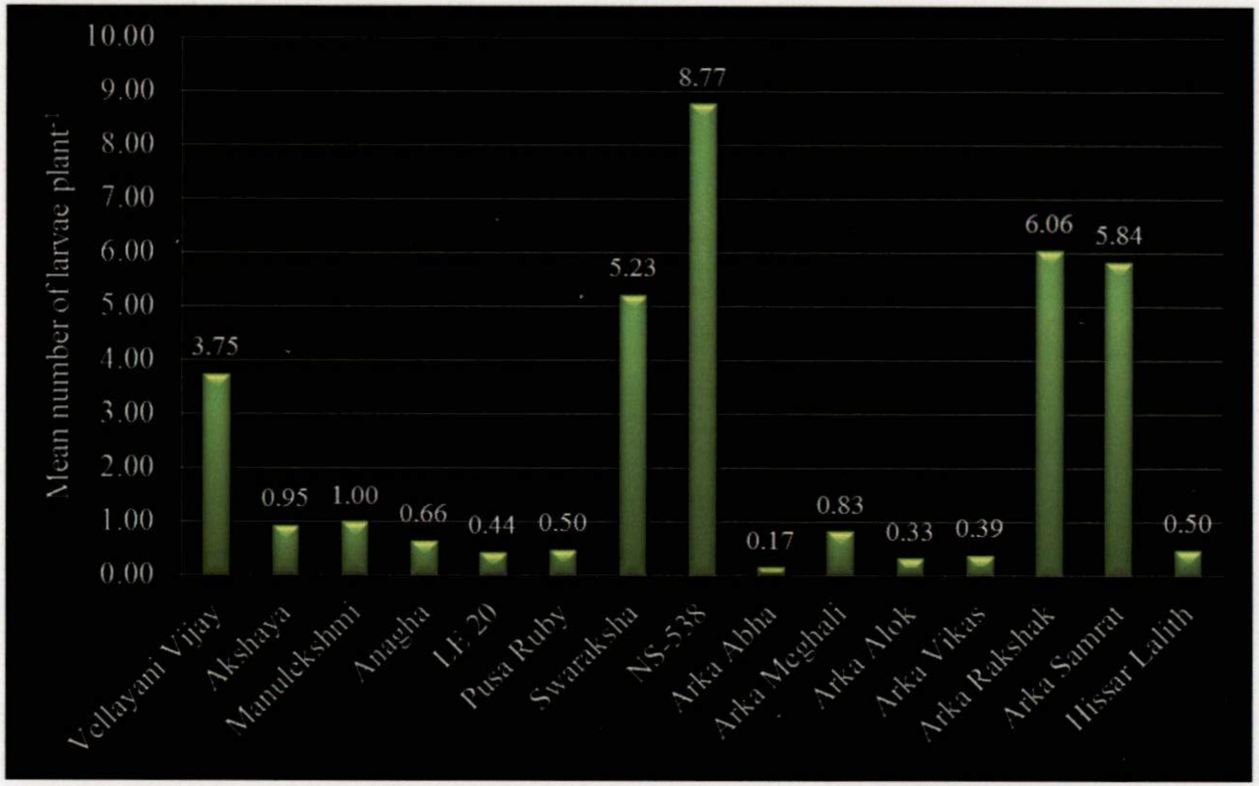


Fig. 3. Incidence of *L. trifolii* on different tomato cultivars (Mean number of larvae plant^{-1})

Higher susceptibility of hybrids may be due to their nutritional quality, or morphological characteristics of leaves. Varietal preference of leaf miner mainly attributed to the differences in nutritional qualities of the cultivars or morphological structures like presence of trichomes in the plant which prevented the oviposition and mining of *L. trfolii* (Fery and Kennedy, 1987; Carr and Ubanks, 2002). Fernandes *et al.* (2012) also reported that presence of hydrocarbon compounds in leaves precluded leaf miners from tomato.

Leaf area exhibited a significant strong positive correlation with mean leaf damage (percentage), number of mines plant^{-1} and number of larvae plant^{-1}. Hybrid cultivars recorded higher leaf area which leads to higher mean leaf damage percentage, number of mines plant^{-1} and number of larvae plant^{-1}. When there was more leaf area, adult fly got more space for oviposition and larval stages were acquainted with more space for mining. Larvae of leaf miner were unable to shift their position from one leaf to another. So increased leaf area reduced the competition of *L. trifolii* maggots for nutrients and space which resulted in higher infestation. Length width ratio expressed a significant negative correlation with mean leaf damage (percentage) and number of mines plant^{-1}. When the length width ratio of leaf increased, there was reduction of space for mine expansion and oviposition. Arka Abha possessed highest mean length width ratio of leaf (1.64) and it recorded least mean leaf damage (12.17 per cent) and number of mines plant^{-1} (7.39) indicated the non-preference of the cultivar by *L. trifolii.* Similarly Sahu and Shaw (2006) reported the relation between leaf area, length width ratio and leaf damage in tomato cultivars against *L. trifolii* in Raipur.

The highest yield was recorded from hybrid NS-538 (0.649 kg plant^{-1}) followed by Swaraksha (0.526 kg plant^{-1}) and Arka Rakshak (0.476 kg plant^{-1}) whereas lowest yield was recorded from Anagha (0.285 kg plant^{-1}). Higher yield is a basic criterion of acceptability of hybrids and it is emphasized in breeding programmes. Even though leaf miner infestation was high in hybrids, the yield recorded by the hybrids was higher than other tolerant varieties. This may be due to the increased hybrid vigour of the plants contributing to the number of leaves, size of leaves, number of flowers, etc. Considering the cost involved in the purchase of hybrid seeds, high cost of cultivation operations and high susceptibility to leaf miners render the recommendation of hybrids in *L. trifolii* endemic areas.

5.3 MANAGEMENT OF *L. trifolii*

Four non-chemicals and two green labeled chemicals at two different intervals were evaluated for their efficacy to manage *L. trifolii* in tomato. All the treatments were superior in checking *L. trifolii* infestation in tomato compared to untreated check. Among this, plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval was recorded as the superior treatment for management of *L. trifolii.* Application of chlorantraniliprole SC 0.006 % at 20 days interval also exhibited higher percentage reduction in mean leaf damage caused by *L. trifolii* which was statistically on par with chlorantraniliprole SC 0.03% at 10 days interval (Fig 4.).

The highest percentage reduction in mines plant^{-1} and larval population was also recorded from chlorantraniliprole 18.5 SC 0.006 % at 10 days interval treated plants followed by chlorantraniliprole 18.5 SC 0.006 % at 20 days interval treated plants (Fig 5. and Fig 6.). Both treatments showed cent per cent reduction in larval population of *L. trifolii* at 25 and 35 days after spraying. Kousika *et al.* (2015) recorded the superiority of chlorantraniliprole 30 g a.i. ha^{-1} in reducing the leaf damage and leaf miner population in tomato. Similar findings were also made by Thamilarasi (2016) in cowpea and salad cucumber who recorded complete absence of larval stages at 15 days after spraying.

Flubendiamide 20 WG 0.005 % at 10 days interval was also recorded to have substantial percentage reduction in leaf damage (71.30), number of mines plant^{-1} (71.05) and larval population (77.53) over untreated check. Jyotsana *et al.* (2013) also validated the efficacy of flubendiamide 60 g a.i. ha^{-1}, who recorded a percentage larval mortality of 61.92 per cent in gherkin.

The highest percentage reduction in mean leaf damage (95.92), mines plant^{-1} (96.15) and cent per cent reduction in larval population over untreated check was recorded from green labeled chemical chlorantraniliprole. Remarkable reduction in pest infestation may be due to the toxicity of pesticide deposit which render the ovipositional preference of adults or hindered the larval development. It signified the importance of anthranilic diamide group as an effective substitution for conventional highly toxic chemicals which were ineffective due to resistance development.

Among the nonchemicals, plants treated with fish amino acid 0.5 % at 10 days interval recorded highest percentage reduction in leaf damage (72.08), number of mines plant^{-1} (70.88) and number of larvae plant^{-1} (90.20) over untreated check. No previous reports were available to verify this finding. NSKE 5 % also recorded similar trend in percentage reduction of leaf damage (63.6), number of mines plant^{-1} (70.36) and number of larvae plant^{-1} (83.11) over untreated check (Fig.4, 5 and 6). This may be due to the repellent action of neem which may act as an ovipositional deterrent. Higher efficacy of NSKE against *L. trifolii* was previously recorded in tomato, cowpea and cucumber (Ramesh and Ukey, 2007; Ganapathy *et al.* 2010; Pawar and Patil, 2013; Chavan *et al.* 2015).

Plants treated with neem oil 2.5 % at 20 days interval was less effective in reducing leaf miner infestation in tomato. Similarly, Chavan *et al.* (2015) recorded that neem oil 0.5 % was not effective in reducing live mines after second and third spray in Maharashtra. However, present findings were contradictory to the results of Reji (2002); Ramesh and Ukey (2007). The differences observed in the present study may be due to the less persistence of neem oil in treated plants.

Similar trend was also observed in yield. Chlorantraniliprole 0.006 % at 10 days interval treated plots recorded 91.21 per cent increase in yield which was statistically on par with chlorantraniliprole 0.006 % at 20 days interval which recorded 84.46 per cent yield increase over untreated check (Fig. 7). Likewise, higher yield was also recorded from bitter gourd plants treated with

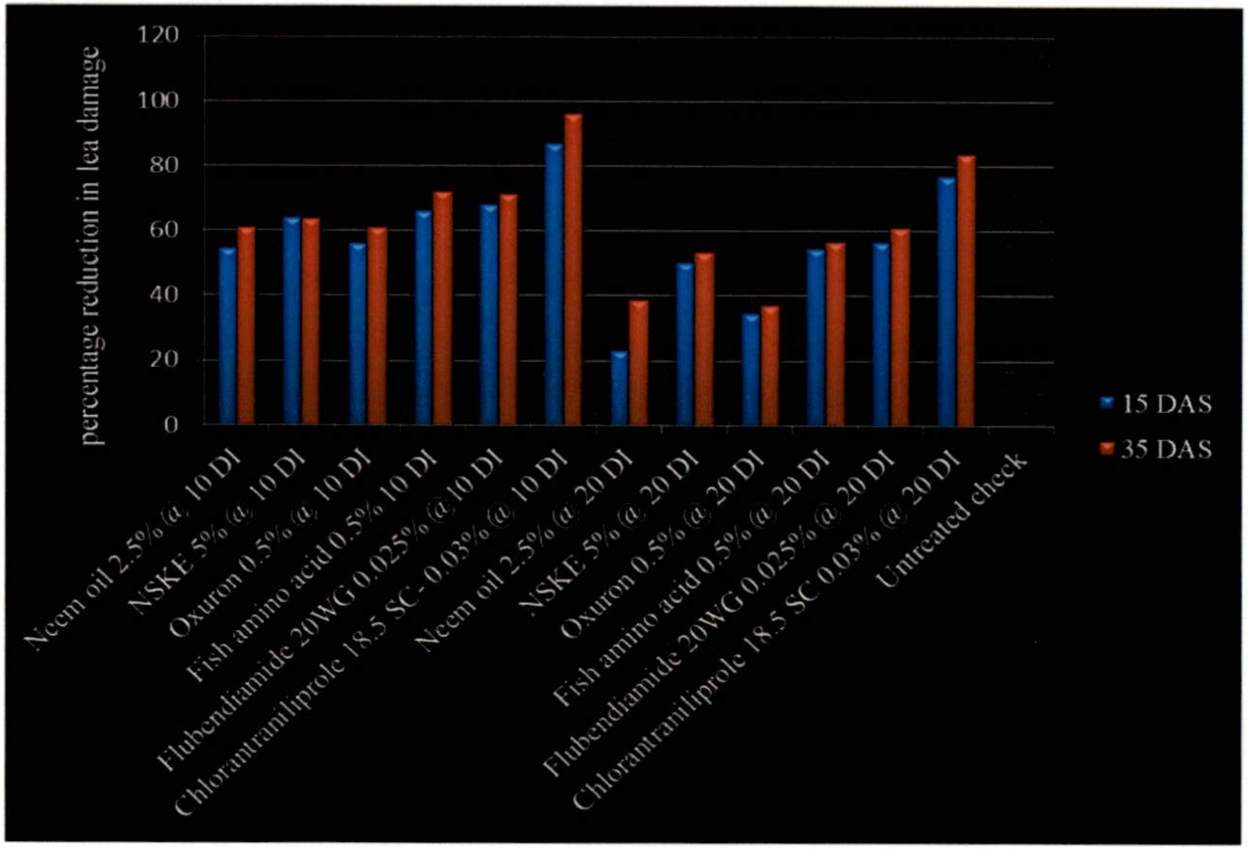


Fig. 4. Percentage reduction in mean leaf damage caused by *L. trifolii* over untreated check

*DI- Days Interval

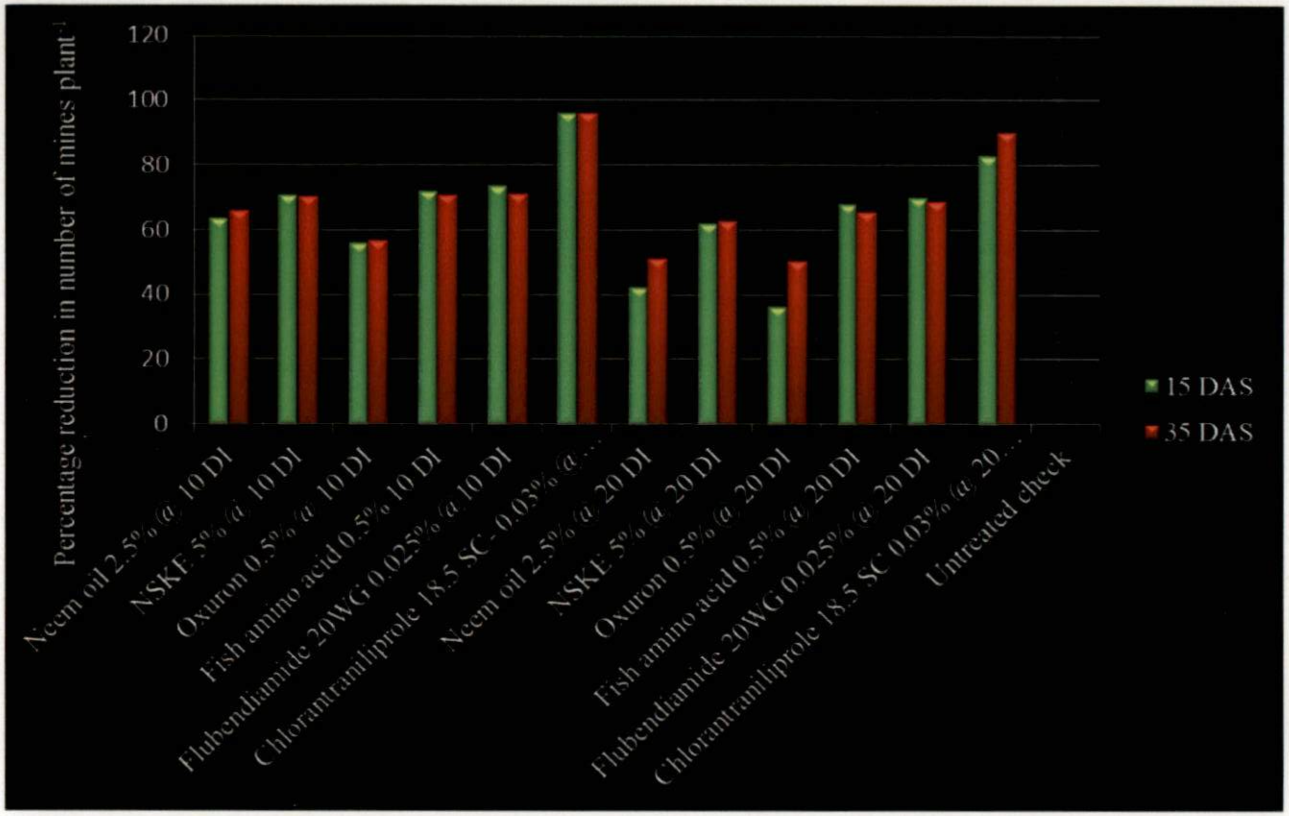


Fig. 5. Percentage reduction in mean number of mines plant^{-1} over untreated check

*DI- Days Interval

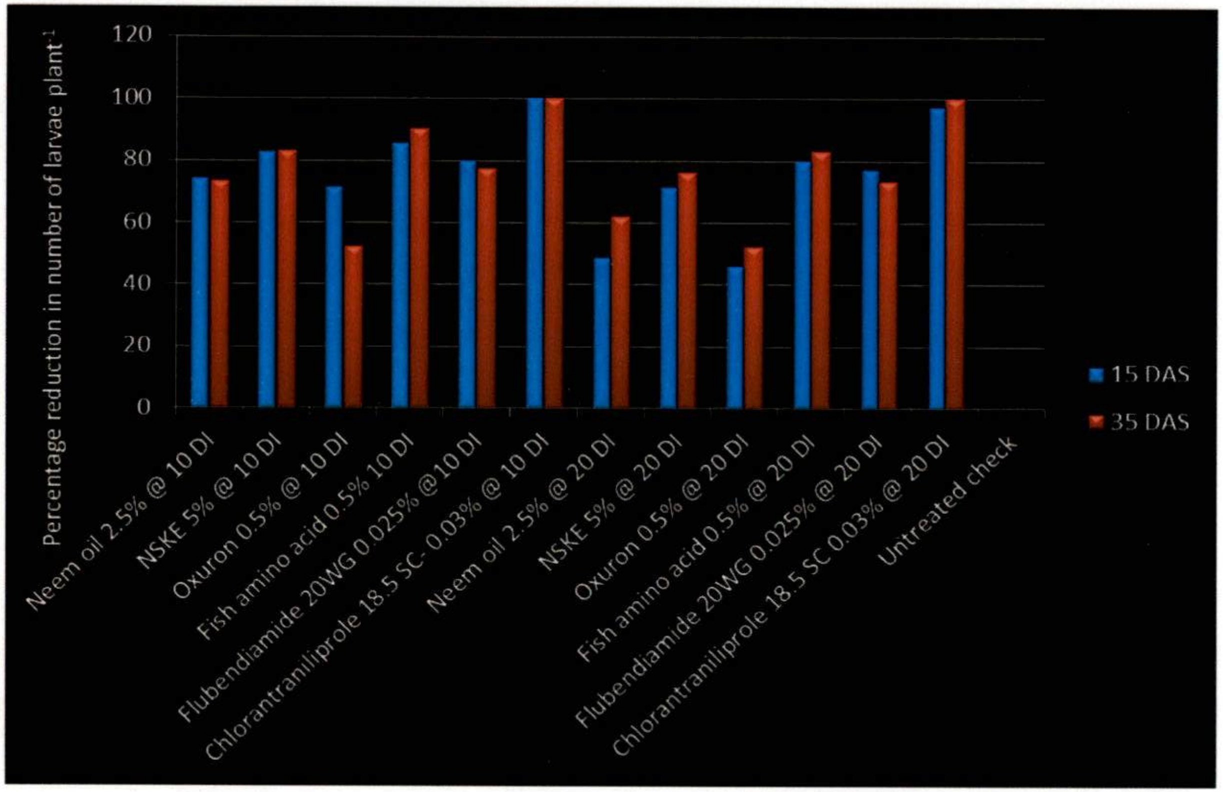


Fig.6. Percentage reduction in mean number of larvae $plant^{-1}$ over untreated check.

*DI- Days Interval

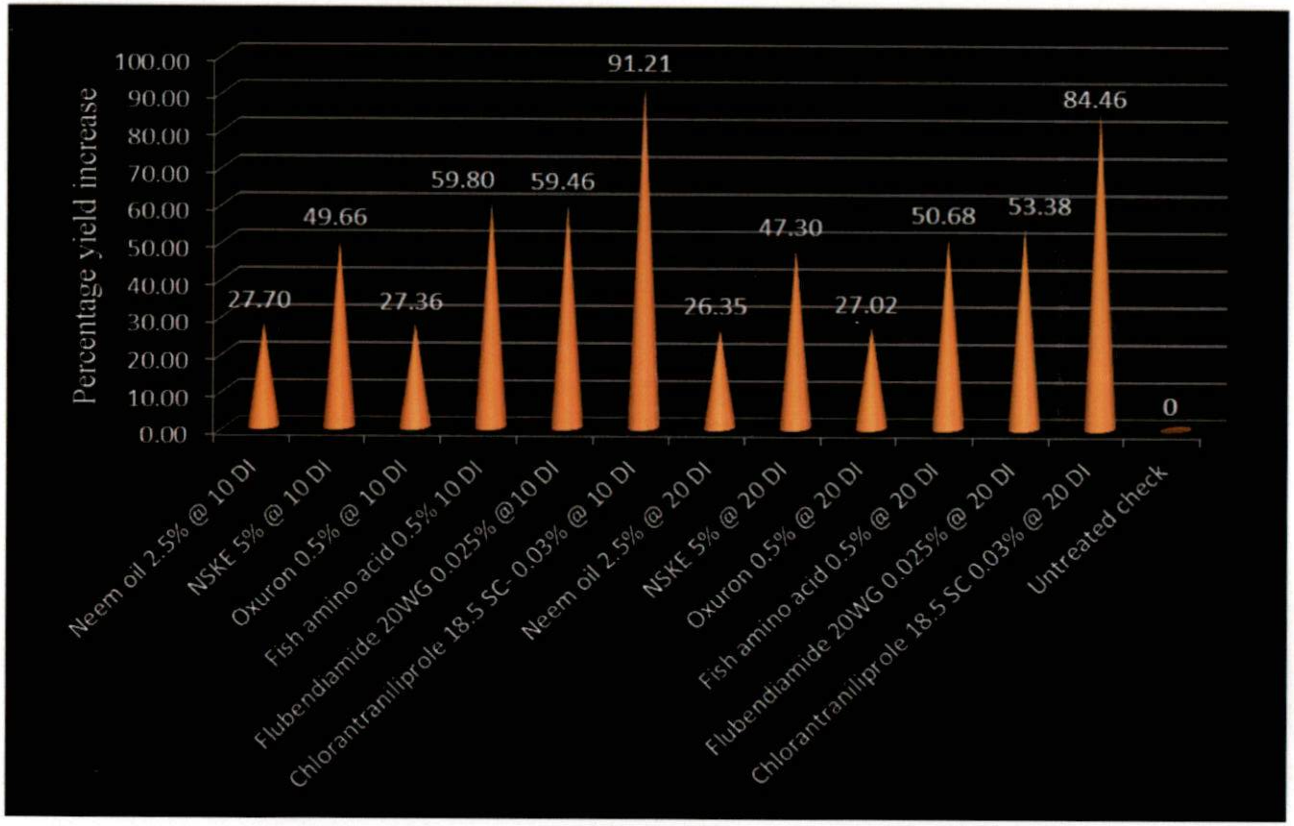


Fig. 7. Percentage yield increase over untreated check

*DI- Days Interval

chlorantraniliprole 0.006 % against *L. trifolii* (Bharathi *et al.*, 2011). Among the non-chemicals, highest yield increase was recorded in plants treated with fish amino acid 0.5 % at 10 days interval (59.80 per cent) which was statically on par with fish amino acid 0.5 % at 20 days interval (50.68 per cent), NSKE 5 % at 10 days interval (49.66 per cent) and NSKE 5 % at 20 days interval (47.30 per cent) over untreated check. Ramesh and Ukey, (2007) also observed that NSKE 5 % recorded 93.17 per cent yield increase over untreated check which indicated the superiority of the treatment.

The present study revealed that tomato was ravaged by many pests both at vegetative and reproductive stage of the crop. Report of new pest on tomato may aggravate the situation by induction of more damage on the host plant whereas reports of new predators may alleviate the surge of pest population in Kerala. American serpentine leaf miner *L. trifolii* was observed as a major pest of tomato and its wide host range indicated the severity of the pest. Record of new parasitoids highlighted the importance of conservation of natural enemies and avoidance of toxic chemicals in tomato ecosystem.

Concept of host plant resistance can be effectively incorporated in the integrated management programme of *L. trifolii*. Tolerant cultivars *viz.*, Arka Abha, Arka Meghali, Arka Vikas, Pusa Ruby, Anagha, Akshaya and LE 20 can be used in endemic areas. In addition to this, application of non-chemicals like fish amino acid 0.5 % or NSKE 5 % at 20 days interval can be included in organic farming practices. In pest prone areas, green labeled chemical, chlorantraniliprole 18.5 SC 0.006 % at 20 days interval can be recommended for the effective management of *L. trifolii* in tomato.

Summary

6. SUMMARY

Tomato, the second most popular vegetable crop in the world, is devastated by more than hundred pests every year (Taleker *et al*., 1983). Out of the numerous pests, American serpentine leaf miner *L. trifolii,* an invasive polyphagous pest, is considered as an important one which has established at various agro ecosystems in India after its introduction in 1991 (Viraktamath *et al.*, 1993). Wide host range along with short life span, high reproductive potential, concealed larval stages and resistant populations made the management of *L. trifolii,* a strenuous task (Pawar and Patil, 2013). In this scenario, conservation of natural enemy population, utilization of resistant cultivars and ecofriendly pest management options can be incorporated in the IPM of *L. trifolii.*

With this view, an experiment was conducted at College of Agriculture, Vellayani to identify field tolerance of tomato cultivars against American serpentine leaf miner and to evolve an effective method for its management.

- The important pests observed in tomato ecosystem were American serpentine leaf miner *L. trifolii*, tomato fruit borer *H. armigera*, tobacco caterpillar *S. litura*, green semilooper *A. signata*, leaf beetle *L. vittata*, hadda beetle *H. vigintioctopunctata,* solanum whitefly *A. trachoides*, spiralling whitefly *A. dispersus*, mealy bug *P. solenopsis*, scale insect *Saissetia* sp. and aphid *Myzus persicae.*

- Among the pests, solanum whitefly, *A. trachoides* is recorded for the first time in tomato from Kerala.

- The important predators recorded were mirid bug *N. tenuis*, lady bird beetles, *A. puttarudriahi*, *C. transversalis* and a midge predator. In this, *N. tenuis* is recorded for the first time as a predator of *A. trachoides* from Kerala.

- Fourteen species of spiders under three ecological guilds were observed, in which orb web weavers were predominant in tomato plants. Family areanidae exhibited maximum species diversity. Other ecological guilds recorded from tomato ecosystem were stalkers and ambushers.

- Three parasitoids under two hymenopteran families *viz.,* eulophidae and braconidae were recorded from *L. trifolii. Neochrysocharis* sp., a larval parasitoid was the most abundant species which was recorded for the first time from Kerala. Another larval-pupal parasitoid, *Opius* sp. was also recorded for the first time in Kerala.

- Forty one plants including twenty two species of vegetables, ten species of ornamentals and nine species of weeds were observed as host plants of *Liriomyza* spp. Wide host range indicated the severity of pest species in the study area.

- Among the tested fifteen tomato cultivars, Arka Abha was the least preferred variety by the pest which recorded least leaf damage (10.12 per cent), number of mines plant^{-1} (6.56) and number of larvae plant $^{-1}$ (0.11) . Hybrid cultivars were observed to be highly susceptible to the leaf miner infestation.

- Tomato cultivars were classified in to various categories based on mean leaf damage (percentage) caused by *L. trifolii* infestation. Seven cultivars were recorded as tolerant which were Arka Abha, Arka Meghali, Arka Vikas, Pusa Ruby, Anagha, Akshaya and LE 20. Three varieties *viz.,* Manulekshmi, Arka Alok and Hissar Lalith were included in the category moderately tolerant. Swaraksha and NS-538 were categorized as highly susceptible whereas Arka Rakshak, Arka Samrat and Vellayani Vijay were classified as susceptible.

- Leaf area exhibited a significant strong positive correlation with mean leaf damage (percentage), number of mines plant^{-1} and number of larvae plant^{-1}. Length width ratio revealed a significant negative relationship with leaf damage (percentage) and number of mines plant^{-1}.

- Among the tested green labeled insecticides and non-chemicals, chlorantraniliprole 18.5 SC 0.006 % at 10 days interval was recorded as the best treatment with less leaf damage (1.52 per cent), number of mines plant^{-1} (1.83) and number of larvae plant^{-1} (0.00) followed by chlorantraniliprole 18.5 SC 0.006 % at 20 days interval with leaf damage of 6.11 per cent, 4.75 mines plant^{-1} without any larva in the treated plants.

- Highest yield was recorded from the plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval (0.566 kg plant^{-1}) which was statistically on par with chlorantraniliprole 18.5 SC 0.006 % at 20 days interval (0.546 kg plant^{-1}).

- Among the non-chemicals, plants treated with fish amino acid 0.5 % at 10 days interval was observed with least leaf damage (10. 40 per cent), number of mines plant^{-1} (13.83) and number of larvae plant $^{-1}$ (0.58). This treatment recorded a fruit yield of 0.473 kg plant $^{-1}$ which was statistically on par with fish amino acid 0.5% at 20 days interval (0.446 kg plant^{-1}), NSKE 5 % at 10 days interval (0.443 kg plant^{-1}) and NSKE 5 % at 20 days interval (0.436 kg plant^{-1}).

- Based on the present study, chlorantraniliprole 18.5 SC 0.006 % at 20 days interval can be recommended for the effective management of *L. trifolii* in tomato.

- In the present scenario of organic farming, fish amino acid 0.5 % at 20 days interval or NSKE 5 % at 20 days interval can be recommended for the management of *L. trifolii* in tomato.

The results obtained from the present study highlighted the importance of natural enemy conservation, utilization of tolerant cultivars and use of safe chemicals and non-chemicals for the management of *L. trifolii* in tomato ecosystem.

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MANAGEMENT OF AMERICAN SERPENTINE LEAF MINER *Liriomyza trifolii* (Burgess) Dietars IN TOMATO

by

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ABSTRACT

The study on "Management of American serpentine leaf miner *Liriomyza trifolii* (Burgess) Dietars in tomato" was conducted at College of Agriculture, Vellayani during 2015 to 2017 with the objectives to evaluate tomato varieties for field tolerance to *L. trifolii* and to evolve effective methods for its management. A total of 15 cultivars were screened for the field tolerance to *L. trifolii* and four non chemicals *viz.,* neem oil 2.5 %, NSKE 5 %, oxuron 0.5 %, fish amino acid 0.5 % and two green labeled chemicals, flubendiamide 20 WG 0.005 % and chlorantraniliprole 18.5 SC 0.006 % at two different intervals were tested against *L. trifolii.*

The important pests observed were American serpentine leaf miner *Liriomyza trifolii* Burgess, tomato fruit borer *Helicoverpa armigera* Hubner, tobacco caterpillar *Spodoptera litura* Fabricius, green semilooper *Argyrogramma signata* Fabricius, leaf beetle *Luperomorpha vittata* Duvivier, hadda beetle *Henosepilachna vigintioctopunctata* Fabricius, solanum whitefly *Aleurothrixus trachoides* (Back), spiralling whitefly *Aleurodicus dispersus* Russell, scale insect *Saissetia* sp. and aphids *Myzus persicae* Sulzer. Of this, *A. trachoides* was a new pest reported from Kerala.

Important predators recorded were mirid bug *Nesidiocoris tenuis* Reuter, lady bird beetles, *Axinoscymnus puttarudriahi* Kapur and Munshi, *Coccinella transversalis* Fabricius and a predatory midge. Fourteen species of spiders under three ecological guilds were observed, in which orb web weavers were predominant in tomato plants. Three parasitoids under two hymenopteran families *viz.,* eulophidae and braconidae were recorded from *L. trifolii.*

Forty one plants including twenty two species of vegetables, ten species of ornamentals and nine species of weeds were observed as host plants of *Liriomyza* spp.

Fifteen tomato cultivars were evaluated for the field tolerance to *L. trifolii.* Among the cultivars, Arka Abha recorded the least leaf damage (10.12 per cent), number of mines plant^{-1} (6.56) and number of larva plant $^{-1}$ (0.11). Arka Abha, Arka Meghali, Arka Vikas, Pusa Ruby, Anagha, Akshaya and LE 20 were recorded as tolerant cultivars whereas Manulekshmi, Arka Alok and Hissar Lalith were in the category of moderately tolerant and hybrids, Arka Rakshak, Arka Samrat and variety Vellayani Vijai were classified as susceptible ones. Hybrid Swaraksha and NS-538 were included under highly susceptible group.

Four non-chemicals and two green labeled insecticides at two different intervals were tested against *L. trifolii.* Among this, plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval was recorded as the best treatment with less leaf damage (1.52 per cent), number of mines plant^{-1} (1.83) and number of larvae plant^{-1} (0.00). Highest yield was also recorded from the plants treated with chlorantraniliprole 18.5 SC 0.006 % at 10 days interval (0.566 kg plant $^{-1}$) which was statistically on par with chlorantraniliprole 18.5 SC 0.006 % at 20 days interval (0.546 kg plant $^{-1}$). Among the non-chemicals, plants treated with fish amino acid 0.5 % at 10 days interval was observed with least leaf damage (10. 40 per cent), number of mines plant^{-1} (13.83) and number of larvae plant $^{-1}$ (0.58). This treatment recorded a fruit yield of 0.473 kg plant $^{-1}$ which was statistically on par with fish amino acid 0.5 % at 20 days interval, neem seed kernel extract 5 % at 10 days interval and neem seed kernel extract 5 % at 20 days interval.

Based on the results, use of tolerant cultivars along with the application of chlorantraniliprole 18.5 SC 0.006 % at 20 days interval (starting from one week after transplanting) can be recommended for the effective management of *L. trifolii* in tomato. In the present scenario of organic farming, fish amino acid 0.5 % at 20 days interval or neem seed kernel extract 5 % at 20 days interval (starting from one week after transplanting) can be recommended for the management of *L. trifolii* in tomato.

Appendices

Appendix I

Weather Parameters during April to July 2016

Standard Meteorological week No.	Temperature (^0C)		Relative humidity (%)		Wind velocity (km/hr.)	Sunshine hours	Rain (mm)	Evaporation (mm)
	Max.	Min.	Morning	Evening				
14	35.2	26.3	90.7	76.7	5.6	8.9	0.8	5.0
15	35.4	26.3	91.9	75.7	4.6	8.9	0.9	4.8
16	35.5	26.4	92.7	80.0	3.9	8.6	5.7	4.6
17	35.2	26.9	88.6	76.4	3.9	8.8	0	5.0
18	35.7	26.0	90.0	75.0	4.1	9.4	21.3	5.7
19	34.8	24.8	92.3	82.3	3.6	7.8	12.0	4.4
20	32.5	24.1	95.7	82.1	2.9	5.6	55.5	3.0
21	33.1	24.7	88.6	77.6	5.5	8.2	24.3	3.8
22	32.7	24.8	89.0	77.5	4.3	8.3	0	3.6
23	31.5	25.1	95.1	84.6	2.9	6.4	48.0	2.3
24	31.1	23.9	95.9	84.9	5.2	6.0	17.0	2.5
25	31.5	24.4	94.9	82.7	5	7.0	6.5	2.3