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Management of Vegetable Leaf Miner, *Liriomyza* Spp., (Diptera: Agromyzidae) in Vegetable Crops

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Abstract: Vegetables are considered high value crops based on their growing areas and productivity, even if they are affected by a variety of insect pests throughout the whole growing season. Leaf miner is an immature of an insect that lives inside and consumes the leaf tissues of vegetable plants. Adult females of leaf miner puncture the leaf with their ovipositor, forming tube pattern, and feed on the punctured parts. Host plants survey of leaf miner in Multan (Pakistan) area was conducted. Twenty host plants were found in 2017, whereas twenty-four host plants were found infested with *Liriomyza* spp. (Diptera) in 2022 i.e., watermelon (24% infestation), long melon (75%), pumpkin (71%), round gourd (67%), snake melon (70%), bitter gourd (50%), long gourd (89%), bottle gourd (93%), pointed gourd (80%), snap gourd (86%), ridge gourd (83%), cucumber (98%), mung bean (98%), eggplant (60%), *Petunia alba* (88%), *Zinnia elegies* (30%), cotton (10%), okra (5%), berseem (7%), tomato (89%), Pea (52%) and Canola (28%). No infestation of leaf miners was observed on potato, chilies, and sweet potatoes. Color attraction results in 2017 and 2022 showed that there was maximum attraction of tomato leaf miner towards yellow sticky cards as compared to blue sticky cards. Varietal preference of tomato crop showed that Baby red variety was the most preferred by leaf miner (*Liriomyza* spp.), and comparatively Sehar was the least preferred variety. Field efficacy of four different insecticides against leaf miner were also tested. Insecticidal effects attributed as percent reduction of leaf miner infestation that showed the highest reduction values were observed after 7 DOA for Spinetoram (76.98%), whereas Bifenthrin (57%). Deltaphos (43 %) was the least toxic insecticide against *Liriomyza* spp. Integrated approaches are recommended to manage vegetable leaf miner like application of yellow sticky traps, discouraging preferred host plants, application of insecticides with novel modes of actions like spintoram and spinosad for effective management.

Keywords: color preference; varietal preference; spintoram; spinosad

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1. Introduction

Vegetables cultivation is very important to reduce the poverty and to achieve the food security targets around the world [1].World Health Organization (WHO) recommends 73 kg of vegetables consumption per person annually, but its consumption in Pakistan is still limited i.e., 27.4 kg [2]. Based on cultivation area and production, vegetables are considered as minor crops in Pakistan [3].

Due to the increasing world population, the demand of tomato has also been increased. Tomato is an important crop which is used to make different pastes, ketchup, salad, and many other spicy eating items. Tomato fruits are nutraceutical food because it contains essential components like antioxidants, fiber, vitamin A, vitamin C and potassium [4]. Tomato is grown in different areas of Pakistan and available in domestic markets throughout the year [5]. There are number of insect pests attacking tomato crop from the emergence of seeds to the fruit harvesting. The main pests of tomato crop are aphids, fleas, beetles, leaf miners, and spider mites which attack mostly on young tomato plants [6]. Tomato leaf miner is one of the main insect pests of tomato in different tomato growing countries [7]. Previous studies reported leafminer with blotch type of damage i.e., *Tuta absoluta* from tomato crop from Pakistan [8,9]

Vegetable leaf miners are known to infest a wide range of crops, including vegetables, and horticultural plants. They have been seen on various wild hosts species. Crops of *Cucurbitaceae*, *Leguminosae*, and *Solanaceae* families are primarily affected by *Liriomyza sativae* (Diptera). In addition to this, a total of twenty genera from ten different families have been identified as hosts [10]. There are at least 14 plant families where *L. huidobrensis* has been found [11]. Three species of Genus *Liriomyza* shared a lot of similarities in their biology. The egg stage, three phases of larval, pupal, and adult stages made up their lifecycle. Although mating can take place at any time, usually it happened more frequently during the daytime and individual emerge within 24 h [12]. It only takes one successful mating to ensure that all the eggs are fertilized [13]. Within one or two days of the female emergence, ovulation begins and peaks within one week, but may continue for several weeks at a reduced pace [14].

Serpentine type leaf miner in it's immature stage lives inside and consumes the leaf tissues of host plants. Majority of leaf-mining insects belong to the order *Lepidoptera* i.e., butterflies, moths, wasp i.e., sawflies and *Diptera* i.e., flies, and some beetles also show this behavior. It is a major insect pest of vegetables and ornamentals especially tomato crop in the countries of the Mediterranean basin [15] and its area of origin, namely South America [16]. This pest can cause major production and economic losses in host crops [17].

Worldwide, there are more than 330 leaf miner species that belong to genus *Liriomyza* which are important insect pests of many vegetables and ornamental plants [18]. More than twenty *Liriomyza* species have been reported as economic insect pests of tomato, out of which, six species are polyphagous i.e *Liriomyza sativae* (Branchard), *L. trifolii* (Burgess), *L. huidobrensis* (Branchard), *L. bryoniae* (Kaltenbach), *L. strigata* (Meigen) and *L. longei* (Frick) [19].

Regarding management of agromyzid leaf miners, there had been an extensive debate among researchers. Farmers commonly used the synthetic and natural insecticides for the control of this pest for better production of vegetables especially tomato. Due to the use of these insecticides in a disorganized way, the effectiveness of these insecticides reduced. Synthetic insecticides may kill natural enemies and development of resistance in the insect pests [20]. To the best of our knowledge, no significant work has been reported regarding the identification, host plants, biology of leaf miner on different host plants, colored preference of leaf miner. Tomato varietal preference of leaf miner and efficacy of different insecticides for management strategies. These findings will provide some basic information and management options to reduce it's population.

2. Materials and Methods

2.1. Identification of Vegetable Leaf Miner

Tomato plants were grown in the plastic pots and placed in mesh cages. Insect pupae were collected from leaves of tomato plants and were released in the wooden cages (dimensions 90 $\times$ 60 $\times$ 45 cm) with glass top, front side with round opening of 30 cm diameter fitted with muslin cloth to shift plant culture and insects) in 2017. Adults emerged from these pupae, laid the eggs on the potted plants for first generation. Different stages of F1 generation were collected and observed under the microscope for identification purpose. Samples of larvae (maggots), pupae and adults were preserved in formalin. The damage symptoms were observed carefully. Then morphological characters were noted for proper identification under stereomicroscope up to 40$\times$ and compared with morphological keys [21].

2.2. Biology of Tomato Leaf Miner on Different Host Plants

Leaf miner adults were reared on four different host plants *Solanum lycopersicum* L., *Petunia alba*, *Lagenaria siceraria*, and *Brassica juncea*, separately in 2017. The experiment was planned to know the biology and development of leaf miner on different host plants. Four potted plants of each host plant were taken and put into different wooden cages. Ten pairs of 2–3 days old leaf miner flies per plant were obtained and released in the oviposition cages. They were allowed to oviposit for 24 h on the potted plants. After 24 h, plants were removed from cages and placed in cages for emergence. After two to three days, leaves were observed to check the presence of larvae (maggots) and marked for daily observations. Larvae came out from mines and pupated on the leaves at the end of mine. Observations for each fly stage i.e., larval, pupal, and adult durations were counted. Percent survival from larvae to adult were taken for each host plant.

2.3. Survey of Host Plants

Farmer fields of vegetable areas of Multan and Agricultural farm of MNS University of Agriculture Multan were surveyed for leaf miner infestation in 2017 and 2022. Infested crops were identified initially, then 20 leaves per host were checked and infestation percentage was calculated. Leaf miner infestation was observed visually based on symptoms i.e., presence of active mines on the leaves and leaf samples were brought to the laboratory for further confirmation of suitability of host plants, under the microscope (10×).

Infestation percentage of each host plant observed was calculated using following Formula (1).

$$Infestation\ (\%) = \frac{Infested\ leaves}{Total\ leaves\ observed} \times 100 \quad (1)$$

2.4. Colored Preference

Color preference of *Liriomyza* spp. in tomato fields were determined by hanging blue and yellow colored sticky trap cards. These cards were hung on a wooden stick at four different locations of each tomato field at farmer field in 2017 and at Agricultural farm of MNS University of Agriculture Multan in 2022. Four yellow and four blue cards in pairs of combination of blue and yellow, were placed in four different directions i.e., North, South, East and West, to minimize the impact of light and air currents in one acre field of tomato. Old cards replaced by fresh cards after 15 days interval in a similar pattern. Magnified lens (10×) was used to count the leaf miner population on sticky cards. Cards were observed carefully to check the presence of tomato leaf miner in the field on three different dates 30 March 15 April and 30 April. The experiment was conducted in 2017 and repeated in 2022.

2.5. Tomato Varietal Preference of Liriomyza Spp.

Four varieties of tomato crop i.e., Baby red, Super, ICI-1205 and Sehar were sown in the field with Randomized Complete Block Design (RCBD). Four beds A, B, C, D were selected for each Variety. Four plants were selected from each bed randomly. Plant to Plant (P-P) distance was maintained at a spacing of 60 cm and Row to Row (R-R) distance was maintained at 0.76 m. Distance between each selected plant was more than 1.5 m. Leaves having even single fresh and active mine were taken as infested leaves. The tomato plants were selected randomly from each replication. A leaf was considered as infested when it contained active mines and when larvae were visible. After that we calculated the percent infestation of tomato leaf miner by using the Formula (1):

The population data were analyzed statistically using Analytical Software (Statistix 8.1) and subjected to the ANOVA (Analysis of variance). Means were separated using Least Significance Difference test [22,23] (at $p \leq 0.05$).

2.6. Field Evaluation of Different Insecticides against Liriomyza Spp. on Tomato Crop

To test the efficacy of different insecticides against tomato leaf miners, tomato variety ICI-1205 was sown in Randomized Complete Block Design (RCBD) with four replications including control. Commercially available insecticides i.e., Spintoram, Deltaphos, Bifenthrin, Spinosad were used (Table 1). Four plants were selected from each replication and tagged. Insecticides were applied at recommended doses mentioned in Table 1. Each insecticide was considered as one treatment with four replications. Insecticides were used at recommended dosage on tomato. Insecticides were applied with motorized knap sack sprayer. Each insecticide was applied three times on same beds to avoid residual effect. Pre-treatment data were taken one day before spray (DBS) and post treatment data were recorded 3 days after spray (DAS) and 7 days after spray (DAS). Data were taken by counting total leaves observed and infested leaves based on active mines from the whole plant. Percent infestation was calculated. Data were subjected to Statistix 8.1 for Analysis of Variance. Means were separated using Tukey's HSD test at $p \leq 0.05$.

Table 1. List of insecticide used against tomato leaf miner.

Treatment	Product Name	Chemical Name	Dose	Company
T0	-	-	-	-
T1	Radiant®	Spintoram 120 SC	60 mL/acre	Arysta
T2	Deltaphos®	Deltamethrin + triazophos 36 EC	500 mL/acre	Bayer Crop Science
T3	Talstar®	Bifenthrin 10%EC	330 mL/acre	FMC
T4	Tracer®	Spinosad 240 SC	80–100 mL/acre	Arysta/Corteva

Whereas percent control after application of insecticide was calculated by using following Formula (2).

$$Population\ Reduction\ (\%) = \frac{Population\ in\ Pre-treatment - Population\ in\ Post-treatment}{Population\ in\ Pre-treatment} \times 100 \quad (2)$$

3. Results

3.1. Identification and Biology

The results revealed that vegetable leaf miners are minute flies which belong to Order: Diptera, family: Agromyzidae and Genus *Liriomyza.* Damage symptoms were observed carefully and compared with online sources i.e., serpentine type mines found on leaves. Collected samples were observed carefully, salient characters observed were same as of Agromyzidae like minute flies with 2–4 mm in size, as majority are of size i.e., 1–3 mm, which could be up to 1–6 mm), [24], vibrissae and 1–7 frontal setae found, wing with costal break found at the apex of Sc, wing cell cups are small, veins of the wing i.e., A1+CuA2 shorter and not reaching wing margin. These characters confirmed the family Agromyzidae (Diptera). Further observations confirmed that morphological characters of adult flies showed were front-orbital setulae reclinate (backward pointing), dark prescutellar area concolorous with the scutum in most species, color rarely yellow, while color of scutellum yellow in the most of species, dark rarely, whereas sub costa distally becomes a fold and it ends in costa separately extended to vein M1+2. Discal cell (dm) are small and 2nd (outer) cross vein (dm-cu) present in most species. In males a stridulating organ present [21,25]. These morphological characters are most common in four to five different species that belong to genus *Liriomyza*. So, as a whole we called as *Liriomyza* spp. However, we could not identified upto species level and in future it could be identified through molecular characterization. The length of each stage of leaf miner i.e., larvae, pupae and adults in days were recorded on four host plants named *Solanum lycopersicum* L, *Petunia alba*, *Lagenaria siceraria*, and *Brassica juncea*. Results revealed that there was no significant difference between larval and pupal period among the host plants. Whereas adults were significantly different from each other. The percent survival (larvae to adults) was significantly different in host plants. The maximum survival percentage was recorded on tomato (*S. lycopersicum* L) plants (88.25) with respect to *Petunia alba* (79.00) and round gourd (*L. siceraria*) (85.50). While minimum percent survival was recorded on mustard plant (*B. juncea*) (50.25) shown in Table 2. It could be concluded that most suitable host of leaf miner were *S. lycopersicum* and *L. siceraria* as compared to *Petunia alba* and *B. juncea*, based on percent survival of larvae to adult.

Table 2. Mean (±SE) for traits under study in leaves of four host plants.

Host Plant	Larvae (Days)	Pupae (Days)	Adult (Days)	% Survival (Larval to Adult)
S. lycopersicum	5.00 ± 0.82 a	10.00 ± 0.91 a	13.25 ± 0.75 ab	88.25 ± 1.38 a
Petunia alba	4.75 ± 0.48 a	10.50 ± 1.04 a	11.75 ± 0.75 b	79.00 ± 0.71 b
L. siceraria	5.25 ± 0.25 a	10.25 ± 1.32 a	11.50 ± 0.96 b	85.50 ± 0.65 a
B. juncea	6.25 ± 0.48 a	10.50 ± 1.04 a	14.25 ± 0.48 a	50.25 ± 1.11 c

Means followed by same letter within each column are not significantly different, Tukey's HSD ($p \leq 0.05$).

3.2. Survey of Host Plants of Vegetable Leaf miner

List of infested plant species with infestation percentage as host plants during the survey period are shown in Table 3 (2021–2022). Out of 27 available plant species observed, twenty-four (24) plant species were found infested by vegetable leaf miner during the survey period. Infestation of leaf miner observed on vegetable crops with variable percentage of infestation pumpkin (71%), round gourd (67%), snake melon (70%), bitter gourd (50%), long gourd (89%), bottle gourd (93%), pointed gourd (80%), snap gourd (86%), ridge gourd (83%), cucumber (98%), mung bean (98%), eggplant (60%), okra (5%), tomato (89%) and pea (52%). Among melon plants leaf miner infestation was observed in watermelon (24% infestation), long melon (75%), ornamental plants like *Petunia alba* (88%), *Zinnia elegies* (30%), field crop cotton (10%), and Canola (28%), fodder crop barseem showed 7% leaf miner infestation. No infestation of leaf miners was observed on potato, chilies, and sweet potatoes during study period. It was observed that *Liriomyza* spp. were found most in number from February to April with average mean temperature ranging from 15 °C to 30 °C. While its number begin to decrease from May onward, however it found on shady places and on lower leaves of crops during hot summer days.

Table 3. List of plant species infested by vegetable leaf miner (*Liriomyza* spp.) (2021–2022).

Sr. No.	Common Name	Scientific Name	Infestation (%)
1	Watermelon	*Citrullus lanatus*	24
2	Long melon	*Cucumis melo*	75
3	Pumpkin	*Cucurbita moschata*	71
4	Round gourd	*Lagenaria siceraria*	67
5	Snake melon	*Trichosanthes cucumerina*	70
6	Bitter gourd	*Momordica charantia*	50
7	Long gourd	*Lagenaria siceraria*	89
8	Bottle gourd	*Lagenaria siceraria*	93
9	Pointed gourd	*Trichosanthes dioica*	80
10	Snap gourd	*Cucumismomotdica*	86
11	Ridge gourd	*Luffa acutangular*	83
12	Cucumber	*Cucumis sativus*	98
13	Moong bean	*Vigna radiata*	98
14	Eggplant	*Solanum melongena*	60
15	Garden petunia	*Petunia alba*	88
16	Zinnia	*Zinnia elegies*	30
17	Dhahlia	*Dhahlia pinnata*	40
18	Cucamelon	*Melothria scabra*	47
19	Cotton	*Gossypium hirsutum*	10 (lower leaves in early stage)
20	Okra	*Abelmoschus esculentus*	5 (lower leaves in early stage)
21	Barseem	*Trifolium alexandrinum*	7
22	Canola	*Brassica Napus*	28
23	Tomato	*Solanum lycopersicum* L.	89
24	Pea	*Pisum sativum*	52

3.3. Colored Preference of Liriomyza Spp. in Tomato Crop

It is evident from the experiments that leaf miner used visual cues for identification of its host plants. The colour preference of tomato leaf miner showed that there was a maximum population of tomato leaf miner in field from 15 March to 30 April in Multan region (Punjab, Pakistan). The results showed that there was significant difference among two coloured traps blue and yellow (Figures 1 and 2). Maximum attraction of tomato leaf miner toward yellow card and relatively less attraction towards blue cards in both years 2017 and 2022. Yellow sticky cards could be used to reduce leaf miner's population in the field.

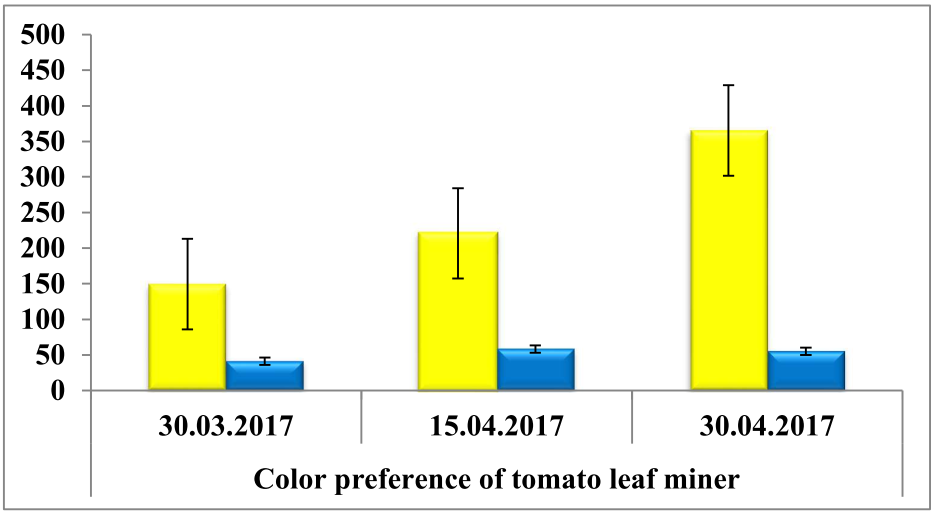

Figure 1. Color preference of *Liriomyza* spp. 2017.

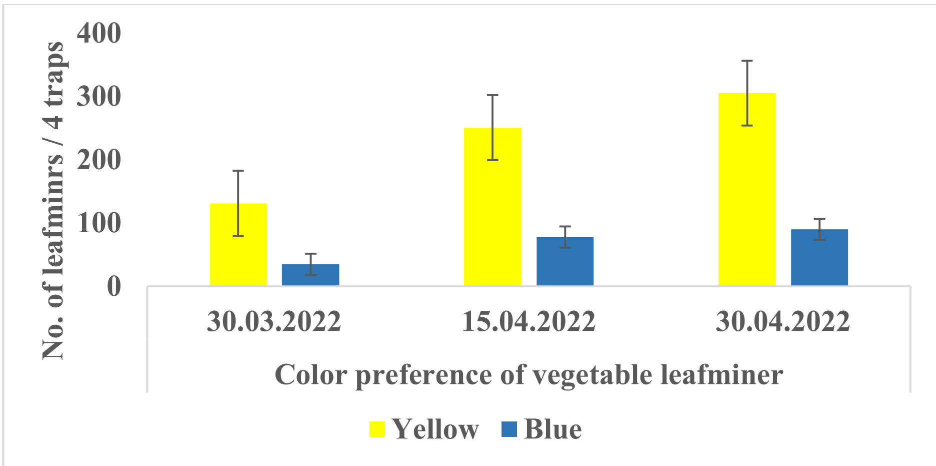

Figure 2. Color preference of *Liriomyza* spp. 2022.

3.4. Varietal Preference of Tomato Crop by Liriomyza Spp.

Liriomyza spp. showed attraction toward all the sown varieties of tomato. Data showed that the most preferred variety of tomato for vegetable leaf miner was Baby red. Maximum number of active mines were found on Baby red variety. According to data the maximum population and infestation was found between mid of March to end of April. Super variety was highly infested after Baby red variety. There was no significant difference in infestation of Super and Sehar variety. Percent infestation given in Table 4 was in order of Baby red > Super > ICI-1205 and Sehar, i.e., 56, 48, 44 and 42 % respectively ($p = 0.003$; F = 11).

Table 4. Percent infestation of *Liriomyza* spp. on tomato cultivars.

Tomato Varieties	Leaf Miner Infestation (%)
Baby Red	55.88 ± 1.37 a
Super	47.83 ± 1.47 ab
ICI-1205	44.01 ± 1.95 b
Sehar	41.84 ± 4.52 b

Values sharing same letters within column are not significant. Tukey's HSD test (p = 0.003, F = 11.37).

3.5. Efficacy of Insecticides against Vegetable Leaf miners (Liriomyza Spp.)

Insecticides were used to determine their efficacy against leaf miner on tomato crop under field conditions. Results (Table 5) showed the effectiveness of different insecticides against tomato leaf miner. Our experiments revealed that Spinetoram provided maximum control in terms of percentage reduction in all three applications after 3rd and 7th DAS (days after spray) i.e., first application reduction (%) was 75, 80%), after second application reduction was (77, 80 %) and third application (80, 77). While Deltaphos for three applications showed as first application, (30, 44), second application, (29, 41) and third application (34, 43), Bifenthrin first application (69, 65), second application, (70, 62) and third application (68, 57). While Spinosad, percent reduction after 1st application was (71, 71), 2nd application, (73, 71), 3rd application, (70, 60). The infestation of leaf miner in control during last 10 weeks from Mid-February to April was increased repeatedly and the number of mines were also increased over time in these weeks as shown in Figure 3. It showed that timely management of leaf miner is necessary through suitable insecticides to avoid economic losses.

Table 5. Population reduction of tomato leaf miner after first, second and third spray of insecticides.

Treatment	Dose (ml/acre)	First Application 1 March			Second Application 15 March,			Third Application 10 April		
		Pre-Treatment (No. of Infested Leaves/Plant, 1DBS)	Reduction (%) 3 DAS	Reduction (%) 7 DAS	Pre-Treatment (No. of Infested Leaves/Plant, 1DBS)	Reduction (%) 3 DAS	Reduction (%) 7 DAS	Pre-Treatment (No. of Infested Leaves/Plant, 1DBS)	Reduction (%) 3 DAS	Reduction (%) 7 DAS
Spinetoram 120SC	60	6.10 ± 1.37	75.03 ± 1.8 *a	80.05 ± 2.84 a	8.48 ± 1.76	76.83 ± 3.32 *a	79.82 ± 2.50 a	8.46 ± 1.10	79.86 ± 3.04 a	76.98 ± 3.37 a
Deltaphos 960 EC	500	10.47 ± 1.21	30.27 ± 1.12 b	43.50 ± 0.57 c	11.36 ± 1.20	28.98 ± 1.44 c	40.50 ± 1.47 d	12.35 ± 1.41	33.74 ± 3.20 c	43.31 ± 1.39 c
Bifenthrin10% EC	330	8.98 ± 2.16	68.79 ± 2.71 *a	65.42 ± 2.22 *b	10.19 ± 1.98	69.55 ± 2.22 ab	61.65 ± 1.14 c	10.57 ± 1.45	68.18 ± 3.46 * b	56.63 ± 2.05 *b
Spinosad 240SC	80–100	7.17 ± 1.71	71.42 ± 0.79 *a	70.75 ± 0.48 *b	8.06 ± 1.37	72.89 ± 1.72 *a	71.42 ± 1.96 b	8.73 ± 1.23	69.95 ± 1.82 * b	60.02 ± 1.73 *b
Control		10.51 ± 0.46	0.00 ± 0.00 d	0.00 ± 0.00 d	13.05 ± 0.50	0.00 ± 0.00 d	0.00 ± 0.00 e	15.10 ± 0.31	0.00 ± 0.00 d	0.00 ± 0.00 d
Df			19	19		19	19		19	19
F			151.87	13.83		109.17	25.75		83.66	21.29
P			0.001	0.002		0.001	0.001		0.001	0.001

* Mean sharing same letter within column are non-significant. DBS = days before spray, DAS = days after spray. Means followed by different letter within each column are significantly different, Tukey's HSD ($p \leq 0.05$).

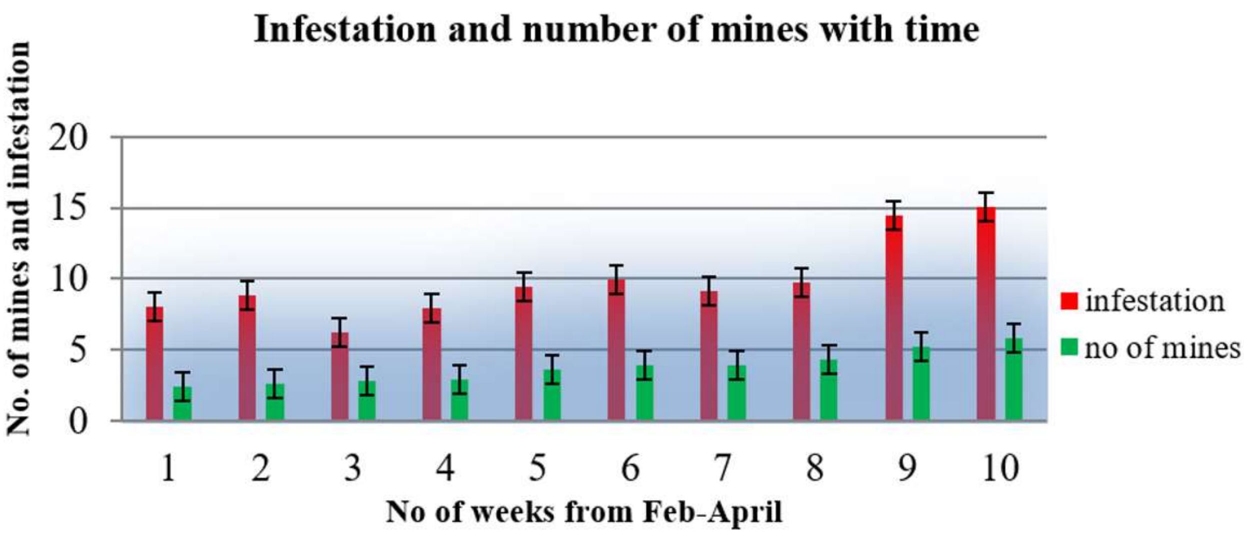

Figure 3. Infestation and No. of mines increased over time in controlled field.

4. Discussion

Thousands of plants and insect/pests lived in the world which not only interacts with each other but also with the environment. Due to variations in environmental conditions the diversity, living organisms were found to be increased day by day. Some of insect were fed by their predators and some of them killed by environmental conditions. Human have also fear of these insect pests, as they damage the crops and create yield losses. To control this loss, human used different management practices including physical, chemical or biological control methods. Numbers of resistant varieties were used against these insect pests as these possess anti toxicant enzymes in it or it contain one or more of preference/non-preference, antibiosis and tolerance mechanisms. Majority of leaf-mining insects belong to order Lepidoptera i.e., moths, Symphyta a type of wasp i.e., sawflies and Dipteran flies, some of the beetles also showed this behavior. It is a major insect pest of tomato crops in countries of the Mediterranean basin [26]. *Tuta absoluta* is one of the most important insect pests of tomato crop also found mining in the tomato leaves. It could mostly lay eggs on the leaves of tomato crop and its larvae make mines in leaf tissue, stem and fruit of tomato. There are many species of tomato plant which are susceptible as well as resistant to tomato leaf miner. It is sometimes confused with *Liriomyza* spp. damage but there is difference in the mines created by Tuta absoluta i.e., blotch type mines whereas mines appeared after the attack of *Liriomyza* spp. are serpentine type. *Tuta absoluta* could also damage fruits and growing shoots while *Liriomyza* spp. never appear on the fruiting parts [8,16,27].

Twenty-four different crops including vegetables, ornamentals and field crops were found infested with *Liriomyza* spp. during study period in Multan region (Punjab Pakistan). These have been a great economic importance throughout the world [18]. More than twenty species of Genus Liriomyza have been found great important, from which at least six species reported for polyphagous nature. These species included *Liriomyza sativae* (Branchard), *Liriomyza trifolii* (Burgess), *Liriomyza huidobrensis* (Branchard), *Liriomyza bryoniae* (Kaltenbach), *Liriomyza strigata* (Meigen) and *Liriomyza longei* Frick [19]. Numbers of management practices including synthetic and natural insecticides were used for leaf miners which belong to family agromyzidae to control this pest to conserve the production [20].

A significant attraction of *Liriomyza* spp. toward yellow-colored sticky traps as compared to blue colored traps. Yellow sticky cards used to monitor and minimize leaf miners with other control tactics. There are number of pests of agro-ecosystem which are difficult to control through insecticides due to their small size and cryptic habits. Farmers generally rely on insecticides for the pest control which resulted into resistance development against insecticides. To avoid resistance problems, non-chemical methods need to be assessed. Thus, cultural control, sex pheromone traps, light traps and sticky traps could be used as a component of integrated pest management (IPM). This also helps in reducing the use of insecticide and increasing the economical benefit to farmers because the color traps are easily available and work as cheaper methods to check the abundance of the pests [28]. Yellow sticky traps were the most attractive to many species of insects like leaf miners, whiteflies, moths, and aphids [29,30]. Yellow sticky traps are recommended for early detection and sometimes as scouting tool employed as integrated pest management strategy as well for *Liriomyza spp*. [31]. These were found effective control measure at low density leaf miners [32]. Adult leaf miners are drawn to yellow and green, yellow color is the most attractive color for most of insects when cards are deployed in the field [33]. Suction backpacks and yellow sticky cards have been demonstrated to be effective in reducing leaf miner populations [14]. Generally, yellow-colored traps are used for catching the different insect pests belonging to order Coleoptera, Hemiptera, Hymenoptera and Thysanoptera [34]. Yellow colored traps had been reported to be effective tool for catching different parasitic bees [35]. Mostly blue and green colored traps were found less attractive for hoverflies and honeybees [36]. Whereas yellow-colored traps, attracted maximum population of thrips from okra crop followed by green colored trap [37].

Four different tomato varieties i.e., Super, Sehar, Baby red and ICI 1205 evaluated. Percent infestation was varied from 48% to 86%. Maximum infestation was observed in hybrid 101-super (86%) followed by Anjali (83%), while lowest infestation was recorded in Varalakshmi (48%). All of them were equally attacked; however baby red showed less attack in terms of percent infestation. Due to polyphagous nature of leaf miner *S. lycopersicum* (tomato) and *L. siceraria* (round gourd) were found the most suitable host plants available as compared to other host plants studied. The plant contains trichomes, phenol contents and depend upon the quality of host plant [38]. Certain nutrients present in host plants which attract the host [39]. Sahil, Nova Mecb and Paket cultivars of tomato found resistant against fruit borer [38]. The Roma VFN, NARC-1 and FS-8002 genotypes were found susceptible due to rich in nitrogen content [40]. Tomato hybrids are more susceptible to leaf miner (*L. trifolii*) from which Avinash II showed maximum infestation whereas Rakshita showed more susceptibility whereas Arjuna and Rupali were moderately tolerant to this pest. Maximum numbers of mines per leaf (2.88) were recorded on Arka Meghali followed by challenger-1 (2.81) and Arka Vikas (2.74) and the minimum number of mines were recorded on 101 super (1.24). The experiment showed that all the genotypes were found most susceptible, except Varalakshmi and Arka Ahuti showed maximum damage followed by Arka Saurabh; Arka Ashish and Anjali [41].

Insecticides are the most effective tool for management of insect pests. Chemical control is an important component of IPM, however least preference is given to it. Present study revealed that Spintoram could be applied for its effective control. Due to environmental safety this product is most suitable for integrated pest management system. In order of toxicity, following insecticides proved as spintorum > Deltaphos > bifenthrin > spinosad. Insecticides are good intervention option when insect population increased to certain level. Most of the farmers or crop managers prefer to apply insecticides against insect pests of agricultural crops. Spintoram belonged to spinosyn group with novel mode of action and it's a better choice for application against *Liriomyza* spp. However, there are chances of insecticides resistance development against various insecticides as we already had reported in *Spodoptera exigua* from the same region [42]. Therefore, it is recommended to use insecticides with alternate mode of actions, or integrated approaches combined with other control tactics.

The infestation of *Liriomyza* spp. in Punjab, Pakistan increased in Feb-April. Timely intervention to control leaf miner is recommended. Integrated approaches could be recommended to manage vegetable leaf miner, *Liriomyza* spp. like application of yellow sticky traps, discouraging preferred host plants, use of biorational insecticides with novel modes of actions like spintoram and spinosad for effective management.

5. Recommendation/Conclusions

Leaf miners found on different vegetables, ornamental plants and field crops were minute flies of Genus *Liriomyza* spp. (*Diptera: Agromyzidae*) found in vegetable areas with serpentine type mines.

Flies were more attracted towards yellow sticky traps than blue sticky traps.

Almost twenty-four different host plants were identified infested by leaf miners i.e., *Liriomyza* spp. in Multan (Punjab, Pakistan). Tomato varieties tested almost all were found susceptible to leaf miner attack, however Baby red, variety of tomato showed relatively less attack than other varieties i.e., ICI 1205, Super and Seher.

Spintoram proved to be more effective against *Liriomyza* spp. than other insecticides tested.

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