MANAGEMENT OF VEGETABLE LEAF MINER IN TOMATO USING BIOPESTICIDES AND CHEMICAL INSECTICIDES

PREUNKA RANI

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

PREUNKA RANI

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Approved by:

Prof. Dr. Md. Abdul Latif
Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. Mst. Nur Mohal Akter Banu
Co-Supervisor Department
of Entomology SAU,
Dhaka

Prof. Dr. S. M. Mizanur Rahaman
Chairman
Examination committee

DEDICATED TO

MY BELOVED

PARENTS

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, **"MANAGEMENT OF VEGETABLE LEAF MINER IN TOMATO USING BIOPESTCIDES AND CHEMICAL INSECTICIDES"** submitted to the Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **Prof. Dr. Md. Abdul Latif**, Registration No. **18-09027** under my supervision and guidance**.** No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course study of this investigation has been duly acknowledge

Dated: June, 2020

Dhaka, Bangladesh

Prof. Dr. Md. Abdul Latif
Supervisor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207

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MANAGEMENT OF VEGETABLE LEAF MINER IN TOMATO USING BIOPESTICIDES AND CHEMICAL INSECTICIDES

PREUNKA RANI

ABSTRACT

The experiment was conducted in the experimental central field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Bangladesh during the period from October 2018 to March, 2019 to evaluate the abundance of vegetable leaf miner and their control measures in the tomato. The experiment was comprised in a Randomized Complete Block Design (RCBD) with three replications .The treatments, viz. T_1= Tracer 45SC @ 0.5 ml L^{-1} of water, T_2= Avermectin 1.8EC @ 1.0 ml L^{-1} of water, T_3= Calden 45SC @ 2.0 ml L^{-1} of water, T_4= Confidor 17.80 SL @ 0.5 ml L^{-1} of water,T_5= Bombard 10EC @ 1.0 ml L^{-1} of water, T_6= Sevin 85WP @ 2.0 g L^{-1} of water, T_7= Neem oil @ 3.0 ml L^{-1} of water and T_8= Untreated control were applied. Infestation status and number of mine leaf^{-1} due to attack of vegetable leaf miner (*Lyriomyza sativa*) was found in the experimental field. It was observed that T_4 treatment was best in controlling vegetable leaf miner infestation in tomato based on the lowest percent of leaves infestation during early, mid and late stages 2.47%, 2.08%, 1.75% was observed in T_4 treatment where the highest percent of leaves infestation (15.16%, 13.41%, 12.18%) was observed in T_8 treatment. The lowest number of mine leaf^{-1} was observed in T_4 (spraying of 0.5 ml L^{-1} of Confidor 17. 80SL at 15 days interval) and the highest number of mine leaf^{-1} was observed in T_8 (untreated control) treatment. The lowest total fruit yield (18.74 t ha^{-1}) was observed T_8 treatment while the highest total fruit yield (22.20 t ha^{-1}) was observed in T_4 treatment. In T_4 treatment provided the best performance in yield production of the experiment.

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ABBREVATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
Cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAT	=	Days After Transplanting
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
G	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ML	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
Mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) botanically referred to the family Solanaceae is one of the most important and popular vegetable crop in Bangladesh as well as in the world. It is cultivated extensively for its edible fruits. Labeled as a vegetable for nutritional purposes, tomatoes are a good source of vitamin C and the phytochemical lycopene. The fruits are commonly eaten raw in salads, served as a cooked vegetable, used as an ingredient of various prepared dishes, and pickled.

Additionally, a large number of the world's tomato crop is used for processing; products include canned tomatoes, tomato juice, ketchup puree, paste, and "sun-dried" tomatoes or dehydrated pulp. Its annual production accounts for 107 million metric tons also fresh market tomato represents 72 % of the total (FAO 2002). In Bangladesh, the area of cultivation is 13,066 ha with the production of about 74,000 M tons. Each 100g edible ripen tomato contains 94g water, 0.5g minerals, 0.8g fiber, 0.9g protein, 0.2g fat and 3.6g carbohydrate and other elements like 48mg calcium, 0.4mg iron, 356mg carotene, 0.12mg vitamin B-1, 0.06mg vitamin B-2 and 27mg vitamin-C. (BARI 2010).

This crop is grown for its fruits which are used in a variety of ways. Ripe tomatoes are consumed fresh as salads or cooked with relish, or processed into various products such as puree, paste or canned as whole fruits (Naika *et al*. 2005). Medicinal uses of tomatoes have also been documented. Rao *et al*. (1998) reported that tomatoes and tomato products have numerous health benefits also contribute to a well-balanced diet. Tomatoes are known to be important source of lycopene, which is a powerful antioxidant that acts as an anti-carcinogen and reduces the risks of getting certain neurodegenerative diseases (Kelley and Boyhan 2014, Srinivasan 2010, Sies *et al*. 1992). In rural areas, its production can increase employment and improve farmer's livelihood (Kennedy 2008). In Bangladesh; it is mainly cultivated as winter vegetable, which occupies an area of 58,854 acres in 2011-12 with the total production of 190 thousand Metric tons (BBS 2013). Due to increasing consumption of tomato products, the crop is becoming promising. In Bangladesh, the yield of tomato is not enough satisfactory in comparison with other tomato growing countries of the World (Alam *et al*. 2015, Aditya *et al.* 2010). There are several economic benefits of growing tomatoes. Growing the crop co-potentially generate rural employment, stimulate urban employment, increase farmers' income and expand exports as compared to other vegetables (Villareal 1993). Tomato is susceptible to insect pests and all parts of the plant including leaves, stems, flowers and fruits are subjected to attack by the pest.

This crop is mainly attacked by tomato leaf miner, tomato fruit borer, tomato leaf miner, tomato fruit worm, tomato aphid, tomato fruit worm. Vegetable leaf miner is a fly-like pest, Leaf miners (Diptera: Agomyzidae) are pests of economic importance on several vegetable and ornamental plants growing around the world. The known world of vegetable leaf miners is more than 3000 species (Shahreki *et al.* 2012, Gencer 2004). Damage is caused by larval feeding in the spongy mesophyll layer of the leaf and by the feeding and oviposition punctures of the agromyzid females.

The feeding punctures, referred to as stippling, can decrease photosynthesis and create entry sites for plant pathogens. Agromyzid larval mining can also decrease photosynthesis rates and can reduce tissue conductance (Chow and Heinz 2004, Rauf *et al*. 2000). Leaf miner damage results mainly from larval feeding, which causes aesthetic damage, reduces yield, and at high larval densities, can destroy plants. This has an adverse effect on the horticultural industry. Tomato farmers in Zimbabwe many of whom are smallholder growers (Saunyama and Knapp 2003, Zitsanza, 2000) are affected when extensive mining causes premature leaf drop which can result in lack of shading and sun scalding of fruit tomato plants, from seedlings to mature stages are attacked by this pest. On fruits, small minute pin sized hole is often visible. (Spencer 1990) details a considerable increase in the number of species identified, no doubt in part due to increased work done on the Agromyzidae, but also to increased international commerce in fresh plant material creating opportunities for the establishment of flies across continents. The potential impact of the mining activity is evident from the work of (Sharma *et al*. 1980), who studied the value of treating squash with insecticides. These authors reported that 30 to 60% yield increases when effective insecticides were applied, but as is often the case with leaf miners, many insecticides were not effective. Damage fruits with galleries of open areas acts as entry paths for invasion by secondary pathogens, leading to fruit rot.

The insect deposits eggs usually the underside of leaves, stems and to a lesser extent on fruits. After hatching, young larvae penetrate into tomato fruits, leaves on which they feed and develop creating mines and galleries. On leaves, larvae feed only on mesophyll leaving the epidermis intact (EPPO 2005). Tomato plants can be attacked at any developmental stage, from seedlings to mature stage. Thousands of tomato farmers in Bangladesh are suffering from serious production losses due to devastating pest the use of chemical pesticides as its control measure is highly sought and the most effective method to reduce *Liriomyza sp.* treatment level.

However, the need for alternative control methods is encouraged, considering that, the pest has developed resistance to dozens of the pesticides and the negative side effects of pesticides over-use to the environment and beneficial arthropods (Alam *et al*. 2015, Bawin *et al.* 2014). To control these pests effectively, it is critical to combine all available control measures including cultural methods, biological control agents and the correct use of registered pesticides (Gozel and Kasap 2015, Alam *et al*. 2014). An Integrated Pest Management (IPM) strategy that employs bio-chemical, biological, physical and cultural methods is the only best option we had at time. According to (Haque 2015), the management of Agromyzid leaf miners has long been and continues to be a topic of extensive research and scientific debate. Both synthetic and natural insecticides have been broadly researched and are generally used by farmers and producers for leaf miner control in spite of production scale and crop (Liu *et al*. 2009). Control of leaf miners is mainly chemical, predominantly translaminar insecticides (Bjorksten *et al*. 2005, Civelek and Weintraub 2003). The indiscriminate use of insecticides is the reason why leaf miners became a pest of economic importance (Reitz *et al*. 2013, Chavez and Raman 1987). However, according to Civelek and Weintraub (2004), the advent of synthetic insecticides has led to botanical insecticides constituting only about 1% of the global market place. They attributed the lack of commercial use of botanical insecticides to poor efficacy compared with synthetic pesticides.

However, due to the increasing incidences of insecticide resistance, it is felt that efficacious botanical derivatives can provide an alternative to synthetic pesticides (Addor 1995). Bangladesh is an agro-based country where agriculture is considered as backbone of her economy. About 80 percent of its population lives in rural areas and 62 percent of total labor force are engaged in agriculture (BBS 2005). Further, to develop economically feasible management strategy and to reduce unnecessary pesticide load in the environment, safer pesticides like microbial derivatives, botanicals, and informative knowledge on cost effective management is also essential.

In view of above facts and scarcity of related information on leaf miner with special reference to tomato, therefore, the present study was undertaken to fulfill the following objectives:

- To evaluate some bio-pesticides and chemical insecticides for the management of vegetable leaf miner
- To find out the effective bio-pesticides and chemical insecticides for the management of vegetable leaf miner

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most nutritious vegetables in Bangladesh which is generally grown in the winter season. Vegetable production in our country is far below of actual requirements, so the demand of vegetable is increasing day by day. So vegetables production should be increased per unit area to meet up the demand of vegetables. But vegetable cultivation are faced by various problems including the pest management of our country farmers. Tomato is infested by large number of insect pests in the field, which causes significant yield loss in every year to the vegetable farmers. Among different kinds of insect pests, Leaf miner is one of the most harmful pests for vegetables, which causes significant damage of tomato fruits and market demand great loss to the vegetable growers. An attempt has been taken in this chapter to review the pertinent research work related to the present study. But the research work in these aspects so far done in Bangladesh and elsewhere, which are not adequate and conclusive. Nevertheless, some of important and informative works and research findings related to the species and their management of leaf miner in tomato vegetable so far been done at home and abroad. The information is given below under the following headings:

2.1 General review of leaf miner

2.1.1 Nomenclature

Liriomyza sativae, commonly known as the vegetable leaf miner, is a species of insect, a fly in the family Agromyzidae. The larvae of this fly mine the leaves of a range of vegetables and weeds, but seem to favor plants in the Families Cucurbitaceae, Fabaceae and Solanaceae. *L. sativae* is one of a group of six polyphagous *Liriomyza* flies which have developed into serious agricultural pests in all parts of the world (CABI 2019).

They may be divided into two sub-groups: *L. huidobrensis, L. trifolii, L. sativae* and *L. brassicae*, originally discovered in the Americas, forming one group, and *L. bryoniae* and *L. strigata* from Europe forming the other. Spencer (1990, 1973a) details a considerable increase in the number of species identified, no doubt in part due to increased work done on the Agromyzidae, but also to increased international commerce in fresh plant material creating opportunities for the establishment of flies across continents. The extent of the darkening of the hind-margin of the eye and of the mesopleura is not constant and the attachment of too much importance to these characters led Frick (1952), incorrectly to describe *L. sativae* as three species in Hawaii as *L. pullata*, *L. canomarginis* and *L. minutiseta*, thus emphasizing the need for caution in the use of external morphology alone. The hind margin of the eye is always darker than in *L. trifolii* and the mesopleura is always paler than in *L. huidobrensis* (Spencer 1973b).

2.1.2 Systematic position

English name: Cabbage leaf miner; leaf miner of vegetables; melon leaf miner; serpentine vegetable leaf miner.

Preferred Common Name: Vegetable leaf miner

Kingdom: Metazoa

Phylum: Arthropoda

Subphylum: Uniramia

Class: Insecta

Order: Diptera

Family: Agromyzidae

Genus: Liriomyza

Species: *Liriomyza sativae*

2.2 Origin and Distribution

Liriomyza sativae was originally described in Argentina from material bred from the leaves of *Medicago sativa*. Since then it has been found in North, Central and South America, the Caribbean Islands, Africa, some Pacific Islands and some Asian countries. It has been introduced into Europe, usually via imports for glasshouse cultivation. Its many synonyms are evidence of its importance as a widespread pest over a large area (Spencer 1986, 1981, 1973). Agromyzid leaf miners are distributed widely but are most commonly found in temperate areas while relatively few species are found in the tropics (Parrella 1987).

Most species are cosmopolitan (Dempewolf 2006, Spencer 1973). Due to unintentional spread by man, Agromyzid leaf miners of economic importance have a broad geographical distribution and are present in both temperate and tropical regions. From 1990 to date, *L. huidobrensis* became globally invasive and can now be found in many greenhouses and vegetable and flower-growing areas of Europe, Asia, Africa and the Middle East (Scheffer and Lewis 2001). The vegetable leaf miner, *Liriomyza sativae* Blanchard, is found commonly in the southern United States from Florida to California and Hawaii, and in most of Central and South America.

Although originally limited to the New World (Western Hemisphere), it is now is also found in many areas of Asia and the Midddle East. Occasionally it is reported in colder areas because it is transported with plant material. It cannot survive cold areas except in greenhouses. There are indications that this is actually a small complex of cryptic species (Scheffer and Lewis 2005). *Liriomyza sativae* is considered to be one of the three most-damaging polyphagous leaf miners of horticultural crops (Murphy and LaSalle 1999). All originated in the New World but all have been spread widely. It is difficult to give accurate distributional notes on *L. sativae* at present, as there is every evidence that the fly is rapidly expanding its presence and colonizing most habitats to which it is introduced. An example its present status is in China, where it is widespread (Institute of Zoology, Beijing, China; report in preparation). Originally recognized as present in Sanya, Hainan Provinces in 1993 (Xie-Qonh Hua *et.al.* 1997), it has quickly spread north and west to most Provinces since that time, causing serious damage in some areas. This is probably the true situation in most countries where it has been introduced.

It will take some years before a more settled picture can be given, where a combination of natural climatic restrictions and man's effort at eradication will stabilize the flies' progress. *L. sativae* has been identified as risk in the Netherlands (OEPP/EPPO 1984) and the UK (EPPO 1984). Leaf miner was formerly considered to be the most important agromyzid pest in North America (Spencer 1981) but this distinction is now held by *Liriomyza trifolii*.

2.3 Host Ranges

Vegetable leaf miner attacks a large number of plants, but seems to favor those in the plant families Cucurbitaceae, Leguminosae, and Solanaceae. Stegmaier (1966) reported nearly 40 hosts from 10 plant families in Florida. Among the numerous weeds infested, the nightshade, *Solanum americanum* and Spanish needles, Biden alba are especially suitable hosts in Florida (Schuster *et al*. 1991).

Vegetable crops known as hosts in Florida include bean, eggplant, pepper, potato, squash, tomato, and watermelon. In California, Oatman (1959) reported a similar host range, but also noted suitability of cucumber, beet, pea, lettuce and many other composites. Celery is also reported to be attacked, but to a lesser extent by this leaf miner species than by American leaf miner, *Lyriomyza trifolii* (Burgess). In Hawaii, damage to onion foliage is a problem for the marketing of scallions (green onions) (Kawate and Coughlin 1995). Vegetable leaf miner was formerly considered to be the most important agromyzid pest in North America (Spencer 1981), but this distinction is now held by *L. trifolii.* In Bangladesh, (Alam1965, Alam *et al.* 1964) listed five species of Agromyzid flies under three genera, *Agromyza* sp., *A. ablaza*, *Melanagromyza cunetans*, *M. obtusa*. and *Ophiomyia phaseoli* as crop pests from East Pakistan (now Bangladesh). Rahman *et al.* (1983) noted *M. Phaseoli*, Biswas (2001) mentioned *O. phaseoli* and *M. sozae* as pests of Soybean and Ahmed (2005) recorded *Agromyza theae* Cotes as tea pest.

O. phaseoli is one of the major pests of Black Gram in Bangladesh causing serious damage to the crop (Prodhan*et al*. 2000, Rahman 1991). In the present study the leafminers *L. chinensis*, *L. sativae, M. obtuse* and *O. phaseoli* were reared from different plant hosts which are not recorded earlier. Moreover, *L. chinensis* was reared from onion (*A. cepa*) which constitutes its first record from Bangladesh together with the additional host record.

2.4 Seasonal Abundance

Two species, *L. oleariana* Spencer and *L. scaevolae* Spencer, persisted through summer in the pupal stage and both species have puparia remaining in the leaf (Spencer 1977). *L. cicerina* (Rondani), a serious pest of chickpeas in the Middle East, emerges from winter diapauses in March and April and is suspected of entering summer diapauses as well (Weigand and Tahhan1990). *L. huidobrensis* has become the dominant agromyzid pest in Kenya in recent years, accounting for 94% of all specimens collected in a survey between November 2011 and November 2012 (Foba *et al* 2015).

2.5 Species Diversity

Leaf miner flies (Diptera: Agromyzidae) are a highly diverse group of exclusively phytophagous species and they comprise more than 3000 known species worldwide (Shahreki *et al*. 2012, Braun *et al.* 2008). Sasakawa (1997) recorded 11 species of agromyzid flies from Ryukyus, Japan. Shiao and Wu (1999) worked on the subfamily Agromyzinae of Taiwan and recorded 38 species under 15 genera.

Sehgal *et al*. (1980) have reported 11 species of agromyzid flies associated with 25 different species of leguminous host plants in northern India. In addition, Thapa (2011) has reported 28 species of agromyzid flies belonging to seven genera reared and described on 34 different leguminous host-plants from Pantnagar, Nainital, and northern India. Benavent-Corai *et al.* (2005) published a research article from Brazil on host-plant interactions where eight agromyzid species were reared from 18 plant species of the family Asteraceae.

In Poland, about a dozen species of agromyzid leaf miners occur on cereals and locally they might occur in high abundance (Walczak and Roik 2010).Winkler *et al*. (2009), Scheffer and Lewis (2005) and Scheffer *et al*. (2007, 2006) worked on the molecular phylogeny and systematic of agromyzid flies. In Bangladesh, agomyzids were reported by different authors (Bhuiya *et al.* 2011, Ahmed 2005, Rahman *et al.*1983). Information on the host plants of *Liriomyza sp*. is also available for Bangladesh (Akter*et al.* 2001 and Bhuiya *et al*. 2010). In the present paper, four agromyzid leaf miners *Liriomyza chinensis* (Kato), *L. Sativae* Blanchard, *Melanagromyza obtusa* Malloch and *Ophiomyia phaseoli* (Tryon) and their 17 Plant hosts from Bangladesh are being reported.

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2.6 Morphology of vegetable leaf miner

Body length 1.3mm, head largely yellow, face, genae and post-genae yellow, occiput and vertical angles brown, orbits slightly brownish-tinged, lunule low semicircular; third antennal segment distinctly angulate, with distinct point at upper corner; wing length 1.3–2.0 mm; mesonotum greyish-black, scutellum entirely dark, femora yellow. In female ninth sternite bearing eight marginal setae. *Liriomyza chinensis* (Kato 1949).

2.7 Biology and life cycle of the vegetable leaf miner

Leaf miners have a moderately short life cycle therefore several generations may be produced during the year (Plant Health Australia 2009, Capinera 2007). The time required for a complete life cycle in warm environments is often 21-28 days, so numerous generations can occur annually in tropical climates (Capinera 2007). Eggs are laid singly, but frequently in close proximity to each other (Parrella 1987). The female deposits the eggs on the lower surface of the leaf, but they are inserted just below the epidermis. Eggs are oval in shape and small in size, measuring about 1.0 mm long and 0.2 mm wide (Capinera 2007). The eggs increase in size after oviposition, possibly through the imbibition of fluids from plant tissue (Parrella 1987).

Primarily they are clear but soon change into a creamy white colour. The period of egg development varies with temperature and ranges from 2-5 days (Plant Health Australia 2009). In some species, the larva may eat the eggshell before moving into the leaf mesophyll. There are three larval stages and all feed within the leaf or stem tissue (Plant Health Australia 2009, Riley *et al*. 2007). A fourth instars occurs between pupation formation and pupation; however, this is a non-feeding stage and is generally ignored by authors (Capinera 2007). The larva begins feeding immediately after reclusion and feed since scantly until it is ready to emerge from the leaf (Parrella 1987). The larva is cylindrical and maggot-like and moves via peristaltic action of its hydrostatic skeleton. As the larva developing, both the diameter of the mine and the rate of mine formation increase (Parrella1987). The larvae leave the plant to pupate (Parrella and Bethke 1985), with pupae found in the soil, crop debris or occasionally on the leaf surface. Pupation is negatively affected by high humidity or drought (PHA 2007).

The puparium is initially golden brown in color, but turns darker brown with time (Capinera 2007). Pupae duration varies inversely with temperature but at least 50% of the total development time of a *Liriomyza* individual is spent in this stage. Total development time of the pupa at greenhouse/field temperatures is about 8-11 days (Parrella 1987). Adults emerge through the dorsal anterior end of the puparium. Newly emerged adults exhibit a positive photos tactic response and climb up the stalk of a plant, where they remain quiescent for a period of approximately 20 minutes while expanding their wings and body. Adult females are usually larger than males and emerge from larger puparia (Parrella 1987).

Adults are small, measuring less than 2mm in length, with a wing length of 1.25-1.9 mm. The head is yellow with red eyes. The thorax and abdomen are mostly grey and black although the ventral surface and legs are yellow. The wings are transparent (Capinera 2007). Female flies use their ovipositor stone puncture the leaves of the host plants causing wounds which serve as sites for feeding (by both male and female flies) or oviposition (Plant Health Australia 2009). The males live only 2-3days possibly because they cannot puncture foliage and therefore feed less than females. Females usually survive for about a week; however, the life span of leaf miner adults ranges from 13-20 days (Capinera 2007). Adults are primarily active during early morning, shortly after sunrise, and again just before sunset (Weintraub and Horowitz 1995).

Egg

L. sativae eggs are 0.2-0.3 x 0.1-0.15 mm, off-white and slightly translucent. Eggs are inserted just below the leaf surface. Eggs hatched in 2-5 days according to temperature. (Harris and Tate 1933) give 4-7 days at 24°C. Many eggs may be laid on a single leaf.

Larvae

Larvae of *Liriomyza* are transparent white, older larvae have a yellow head and he larva is legless. Initially the larva is colorless, but becomes yellowish as it matures day by day. Unlike in many flies, the larva of this insect does not taper strongly toward the head end and t also bears a pair of spiracles at the posterior end of the larva.

This is a legless maggot with no separate head capsule, transparent when newly hatched but coloring up to a yellow-orange in later instars, up to 3 mm long. Both larvae and puparia have a pair of posterior spiracles terminating in three cone-like appendages. Spencer (1973) describes distinguishing features of the larvae. Petitt (1990) described a method of identifying the different instars of the larvae. The duration of larval development also depends on temperature and probably on host plant.

Stegmaier (1966) reported up to 80 larvae per leaf in ricinus. Up to 24 generations can occur during the year (Xie-Qong-Hua *et al.* 1997) although 10-14 is more normal, breeding probably only being restricted by the availability of fresh plant growth in suit oval, slightly flattened ventrally, 1.3-2.3 x 0.5-0.75 mm with variable color, pale yellow-orange, darkening to golden-brown. The pupa has posterior spiracles on a pronounced conical projection, each with three distinct bulbs, two of which are elongate. Pupariation occurs outside the leaf, either on the leaf or on the soil beneath the leaf. Menken and Ulenberg (1986) described a method of distinguishing *L. sativae* from *L. bryoniae, L. huidobrensis,* and *L. trifolii* using allozyme variation patterns as revealed by gel electrophoresis able hosts (Spencer 1973).

Puparia

Puparial development will vary according to season and temperature. Adult emergence occurs 7-14 days after pupariation at temperatures between 20 and 30°C (Leibee 1982). (Wolfenbarger 1947) gives 24-28 days for the complete cycle, in Florida (USA) during December-January (winter period).

Adult

Adult leaf miners are small yellow and black colored flies, vegetable leaf miner shiny black on upper surface -area between the eyes yellow -area just behind eyes black. *L. sativae* is very small (1-1.3 mm body length, up to 1.7 mm in female with wings 1.3-1.7 mm.) The mesonotum is shiny black to the edge of a bright yellow scutellum, face, frons and third antennal segment are bright yellow. Males and females are generally similar in appearance.

L. sativae are not very active fliers, and in crops showing active mining many flies may be seen walking rapidly over the leaves with only short jerky flights to adjacent leaves. Peak emergence of *L. sativae* adults occurs before midday (McGregor 1914). Males usually emerge before females. Mating takes place from 24 hours after emergence and a single mating is sufficient to fertilize all eggs laid. Female flies puncture the leaves of the host plants causing wounds which serve as sites for feeding or oviposition.

Adults live about 13 to 18 days. Leibee (1984) working with celery as a host plant, estimated that oviposition occurred at a rate of 35 to 39 eggs per day, for a total fecundity of 200-400 eggs. Parrella *et al.* (1983) reported similar egg production rates on tomato, but lower total fecundity, because tomato is a less suitable larval host. The female makes numerous punctures of the leaf mesophyll with her ovipositor, and uses these punctures for feeding and egg laying. Although the female apparently feeds on the exuding sap at all wounds, she spends less time feeding on unfavorable hosts. Feeding punctures cause the destruction of a large number of cells on the host plant and are more clearly visible to the naked eye. About 15% of oviposition punctures made by *L. sativae* contain viable eggs (Parrella *et al*. 1981). The males live only 2–3 days, possibly because they cannot puncture foliage and therefore feed less than females, whereas females usually survive for about a week.

Males are unable to puncture the leaves but have been observed feeding at punctures made by females. Both males and females feed on dilute honey (in the laboratory) and take nectar from flowers (EPPO 1990). Both male and female *L. sativae* may act as vectors for disease by transferring during feeding or egg laying, but are not inherent carriers of disease. Typically they feed and oviposit during much of the daylight hours, but especially near mid day. A good summary of American serpentine leaf miner biology was published by (Minkenberg and van Lenteren1986). Keys for the identification of agromyzid leaf miners can be found in (Spencer and Steyskal 1986).

2.8 Nature of damage

Damage is caused by larval feeding in the spongy mesophyll layer of the leaf and by the feeding and oviposition punctures of the females. The feeding punctures, referred to as stippling, can decrease photosynthesis and create entry sites for plant pathogens. Larval mining can also decrease photosynthesis rate and can reduce tissue conductance (Chow and Heinz 2004, Rauf *et al.* 2000). *L. sativae* feeding punctures on the upper side of the leaves appear as white speckles between 0.13 and 0.15 mm in diameter. Oviposition punctures are usually smaller (0.05 mm) and are usually more uniformly round. Mines are usually white with dampened black and dried brown areas. They are typically serpentine, tightly coiled, or of irregular shape, increasing in width as larvae mature. The frass is distinctive in being deposited in black strips alternately at either side of the mine (Spencer 1973a). In larger leaves, the mines often form an irregular 'U' shape. Fungal destruction of the leaf may also occur as a result of infection introduced from other sources during breeding activity.

Wilt may occur, especially in seedlings. The Agromyzidae are a family of small flies whose larvae feed and develop between the upper and lower epidermis of leaves or within stems (Liu *et al.* 2015*).* Scheffer *et al*. (2006) since immature stages and adult females cannot be reliably identified (Blacket *et al*. 2015). Most agromyzid species are host specific, but a few highly polyphagous species that feed on unrelated plant families (Spencer 1973) have become pests of nursery and horticultural crops in many countries (Spencer1990,1989,1973, Parrella and Keil 1984).

2.9 Management

Several methods for population assessment have been studied, and collecting puparia in trays placed beneath plants was recommended by Johnson *et al.* (1980) as a labor-saving technique. Zehnder and Trumble (1984) used yellow sticky traps to monitor adults, and reported that *Liriomyza sativae* flies were more active at the middle plant height of tomatoes, whereas *Liriomyza trifolii* was more active at low plant height. They also confirmed the value of pupal counts for prediction of adult numbers two weeks later.

Yellow sticky traps, however, have the advantage of being able to quickly detect invasion of a field by adults from surrounding areas. Sequential sampling plans were developed by Zehnder and Trumble (1985). Some crops vary in susceptibility to leaf mining. This has been noted, for example, in cultivars of tomato, cucumber, cantaloupe, and beans (Hanna *et al*.

1987). However, the differences tend to be moderate, and not adequate for reliable protection. Nitrogen level and reflective mulches are sometimes said to influence leaf miner populations, but responses have not been consistent (Hanna *et al*. 1987, Chalfant *et al*. 1977). Placement of row covers over cantaloupe has been reported to prevent damage by leaf miner (Orozco-Santos *et al.* 1995). The same study evaluated the benefits of transparent polyethylene mulch, and found no reduction in leaf miner populations.

Sometimes crops are invaded when adjacent crops are especially suitable, as reported by Sharma *et al.* (1980) in California, where cotton was an important source of invaders. Foliar application of insecticides is often frequent in susceptible crops Insecticide susceptibility varies greatly both spatially and temporally. Many insecticides are no longer effective. Insecticides are disruptive to naturally occurring biological control agents, and leaf miner outbreaks are sometimes reported to follow chemical insecticide treatment for other insects

2.9.1 Management with botanical insecticide

Plant extracts have minimal toxicity to non-targeted organisms and donotpersist in the environment (Munyima *et al*. 2004). This fact addresses environmental degradations that are associated with the use of synthetic pesticides; their use is therefore, increasingly becoming recognized as the best alternative method of insect pest management (Kopondo 2004). In a study to determine the insecticidal action of extracts from two plants, *Euphorbia myrsinites* L. (Euphorbiaceae) and *Urginea maritima* L. (Liliaceae) against *L. trifolii* on tomatoes, both plant extracts caused significant control of the leaf miner larvae (Civelek and Weintraub 2004). The plant extracts exhibited both translaminar and systemic activity, while higher dilutions of the extracts controlled leaf miners in a statistically similar manner asthetic insecticide cyromazine (Civelek and Weintraub 2004). Alternative means of leaf miner pest control have received attention for quite some time now, including host plant resistance (Dogimont *et al*. 1999, Suenaga *et al*. 1995), selective translaminar insecticides (Bjorksten *et al*. 2005) and botanical pesticides, mainly from neem (*Azadirachta indica*) extracts (Banchio *et al*. 2003). The neem tree has many compounds that have pesticidal effects; however, the most popular is azadirachtin (Mordue and Nisbet 2000). Azadirachtin has been found to have various effects on insects. These include sterilizing adults, inhibiting chitin formation (NRC 1992), anti-feedant properties, insect growth regulator (Boadu *et al.* 2011, Mordue and Nisbet 2000) and repellent properties (Panhwa 2005). Abamectin has long since been shown to be very efficient in leaf miner control (Seal *et al.* 2007).

2. 9.2 Management with chemical insecticide

At present, the only effective insecticides used for *Liriomyza* control are translaminar insecticides (e.g. abamectin, cyromazine, neem and spinosad) which penetrate the leaves to affect the leaf miner larvae (Weintraub 2002). Vegetable growers are recommended to treat fields with such translaminar insecticides for effective leaf miner control (Bjorksten *et al*. 2005, Civelek and Weintraub 2003). Control of leaf miners can be problematic for several reasons.

Leaf miner larvae are inaccessible to many pesticides because they develop inside the leaf and pupate in the soil (Bjorksten *et al.* 2005). Abamectin and cyromazine are some of the main larvicides used to control the leaf miner on tomatoes. Cyromazine is effective and widely used for control of *L. trifolii* (Saito *et al*. 1992, Foster and Sanchez 1988) and is thought to be less harmful to parasitoids (Schuster 1994). No effective insecticides for use against adults have been recorded thus growers continue to use whatever is available (e.g. chlorfenapyr, chlorfluazuron, chlorpyriphos-ethyl, deltamethrin, diazinon, endosulfan and malathion), and a few effective larvicides (Civelek and Weintraub 2003). Adults, particularly

L. trifolii, may develop pesticide resistance rapidly (McDonald 1991, Parrella and Keil 1984). Neem-based insecticides, although effective against *L. trifolii*, are expensive for non-organic agriculture (Civelek and Weintraub 2003). In the search for additional active ingredients to control Agromyzid pests, an old group of insecticides, based on secretions of marine annelids (*Lumbrineris spp.*) was examined for new applications.

These synthetic insecticides are derivatives of nerve toxin and include cartap, bensultap and thiocyclam (Perry *et al*. 1997). Due to the harmful effects posed by use of chemical pesticides, various less harmful compounds have been tested for their insecticidal properties. These include low-dose, efficient synthetic agrochemicals such as neo-nicotinoids e.g., thiamethoxam (Karmakar and Kulshrestha 2009) and other compounds such as avermectins (Lasota and Dybas 1991). Although the use of pesticides of traditional groups such as organochlorines, organophosphates, carbamates and synthetic pyrethroids are generally effective against various species of insect pests, their use is often associated with environmental contamination and pest resistance (Karmakar and Kulshrestha 2009).

One of the important factors that led to *Lyriomyza spp*. becoming pests is their ability to develop resistance to insecticides (Parrella and Keil 1984). Pesticides that kill leaf miner parasitoids may also cause or aggravate leaf miner outbreaks (Johnson *et al.* 1980). Therefore, an integrated pest management (IPM) approach that seeks to conserve natural enemies wherever possible is the most sensible approach for leaf miner control (Bjorksten *et al*. 2005).The use of conventional synthetic insecticides for controlling pests in the genus *Liriomyza* has led to the development of resistant leaf miner strains (Banchio *et al*. 2003) and rapid elimination of their natural enemies, resulting in an increase in leaf miner populations (Suenaga *et al*. 1995). Abamectin and cyzomazine are two main larvicides that are used to control Agromyzid leaf miners (Civelek and Weintraub 2003).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to evaluate the effectiveness of some bio-pesticides and chemical insecticides on vegetable leaf miner and yield of tomato. The detail materials and methods i.e. experimental period, location, soil and climatic conditions of the experimental area and also the materials that were used for the experiment i.e. treatment and design of the experiment, growing of crops, data collection and data analysis procedure of this experiment has been presented under the following headings-

3.1 Location of the experimental field

The present research work was carried out in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the site is $23^{0}74^{//}$N latitude and $90^{0}35^{//}$E longitude with an elevation of 8.2 m from sea level (Anon 1989) and experimental location is presented in Appendix I.

3.2 Climate of the experimental plot area

The climatic condition of experimental site is subtropical and characterized by three distinct seasons, the Robi from November to February and the Kharif-I, pre-monsoon period or hot season from March to April and the Kharif-II monsoon period from May to October (Edris *et al.* 1979). The maximum and minimum temperature was 29.45 ^{0}c and 13.86 ^{0}c, respectively Robi season is characterized by plenty of sunshine during the experimental period. Meteorological data which are related to the temperature, rainfall and relative humidity during the crop growing period was collected from Weather Yard, Bangladesh Meteorological Department (Climate Division) and has been presented in Appendix II.

3.3 Soil of the experimental field

The general soil type of the experimental field was Shallow Red Brown Terrace soil and it is belongs to the Tejgaon series under the Agro-ecological Zone, Madhupur Tract (AEZ-28). A composite sample of the experimental field was made by collecting soil from several place of the field at a depth of 0-15 cm before initiating of the experiment.

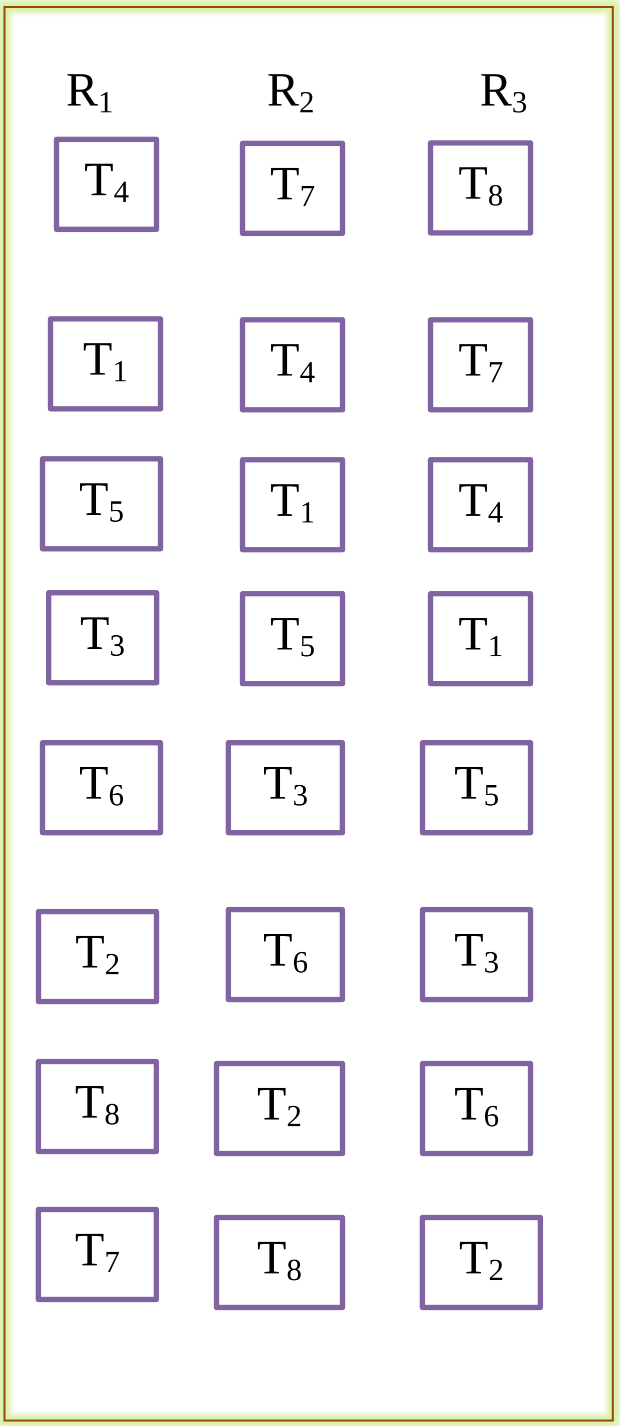
The collected soil was air-dried grind grounded available moisture and analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka, for some important chemical and physical properties. The soil was having a texture of silty clay with pH and organic matter contained 5.8 and 1.16%, respectively. The results showed that the soil composed of 27% sand, 42% silt and 30% clay. Details morphological, physical and chemical properties are presented in Appendix III.

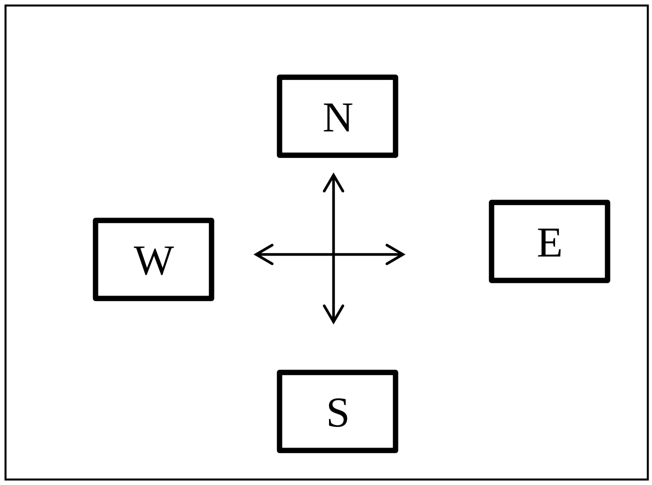
3.4 Planting material

The study crop used in the experiment was tomato and seeds are used of BARI tomato-14. It is an imported high yielding variety with average yield 55-60 $tonha^{-1}$. The seeds were collected from Gulistan seed market.

3.5 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications, where the experimental area was divided into three equal blocks representing the replications to minimize the soil heterogenetic effects. Each block was divided into 8 equal unit plots demarked with raised bunds for allocating different treatments. Thus the total numbers of plots were 24. The unit plot size was 2.5 m ×1.6 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.





T_1= Tracer 45SC (Spinosad) @ 0.5 ml L^{-1} of water

T_2= Avermectin 1.8EC (Avermectin) @ 1.0 ml L^{-1} of water

T_3= Calden 45SC (Cartap) @ 2.0 ml L^{-1} of water

T_4= Confidor 17.80SL (Imidaclorpid) @ 0.5 ml L^{-1} of water

T_5= Bombard 10EC (Cypermethrin) @ 1.0 ml L^{-1} of water

T_6= Sevin 85WP (Carbaryl) @ 2.0 g L^{-1} of water

T_7= Neem oil @ ml L^{-1} of water 3.0 ml L^{-1} of water

T_8= Untreated control
Plot size: 2.5 X 1.6 m^2

Plant spacing: 60 cm X 40 cm

Plot to plot distance = 0.5 m

Block to block distance= 1.0 m

Replication= 3

Figure 1. Layout of the experimental plot.

Plate 1. Experimental field of tomato during the study period.

3.6 Land preparation

The main plot which selected for conducting the experiment was opened in the 1st week of November, 2018 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. All weeds, stubbles and residues were eliminated from the experiment field accordingly. Finally, a good tilth was obtained for proper growth and development of plant. The experimental main plot was done on according to the experimental design. The plots were raised by 10cm from the soil surface keeping the drain around the plots. Organic and inorganic manures were mixed with the soil of each unit plot.

3.7 Manuring and fertilization

Khan (2015), he stressed that the production of vegetables in Bangladesh is inadequate and to meet the growing demand, the production has to be increased by at least eight times. Thus, BARI recommends the formulated with mineral fertilizers and also organic manures. As a result, higher yields of tomato as well as higher production of homestead vegetable cropping patterns are obtained compared to the same levels of nutrients supplied in the form of mineral fertilizers alone.

Compared to cow dung, poultry manure appeared as the best organic manure regarding yield sustainability and regeneration of soil fertility. Cow dung, urea, Triple Super Phosphate (TSP) and Murat of Potash (MoP) were used as a source of nitrogen, phosphorous and potassium, respectively. Manures and fertilizers were applied as recommended by BARI, (2018). Full doses of cow dung and TSP and MoP were applied during final land preparation. The total amounts of Urea were applied in three installments at 10, 30 and 50 day after transplanting (Table 1)

Table 1. Dose and method of application of fertilizers in tomato field

Fertilizer and Manures	Dose/ha	Application (%)			
		Basal	10 DAT	30 DAT	50 DAT
Cow dung	20 ton	100	---	---	---
Urea	280kg	---	33.00	33.00	33.00
TSP	150kg	100	---	---	---
MOP	150kg	100	---	---	---

3.8 Raising of seedling

The seedlings were grown in 3m X 1m size sees bed under special caring at SAU central farm, Dhaka. The soil of the seed bed was well ploughed with a spade and prepared into loose friable masses and to obtain good tilth and moisture to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed from the field. The seed bed was dried in the sun to destroy the soil insect pests and protect the young seedlings from the attack of damping off fungal diseases and soil borne pathogens.

For controlling fungal disease cupravit fungicide were applied. Well rotten decomposed cow dung was applied in prepared seed bed 10 t/ha. 10 g of seeds were sown in seedbed on October 15, 2018. Before sowing the tomato seeds were soaked for half an hour in water for rapid, viable and uniform generation. After sowing, the seeds were covered with fine light soil. At the end of germination shading was done by bamboo mat (chatai) over the seed bed to protect the raising seedlings from the scorching sunlight and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with an ideal condition for growth and development.

3.9 Transplanting of seedlings

Healthy and uniform 30 days old seedlings of were transplanted in the experimental plots on 15 November, 2018. The seedlings were transferred carefully from the seed bed to experimental plots to avoid damage to the root system. To minimize the roots damage of seedlings, the seed bed was watered one hour before uprooting the seedlings easily. Transplanting was done in the afternoon when sunlight was very low. The young seedlings were watered immediately after transplanting.

A total of 12 seedlings were transplanted in each plot. Seedlings were transplanted in the plot maintained distance between row to row 60cm and plant to plant 40cm. The young transplanted seedlings were provided shade by protected plastic during day to protect them from scorching sunlight and continued up to 7 days until they were set in the soil. Plants were kept open at night to allow them receiving dew and moisture. A number of seedlings were also planted in side of the border of experimental plots if these were needed for gap filling.

3.10 Intercultural operations

After transplanting seedlings, various types of intercultural operations were done to ensure normal growth and development of the crop. The following intercultural operations were done.

3.10.1 Gap filling

The transplanted seedlings in the experimental field were kept under careful observation.

Very few seedlings were damaged after transplanting and those seedlings were replaced by new healthy are from the stock. Replacement was done by healthy young seedling having a boll of earth which was also planted on the same date beside the unit plot. The transplanted seedlings were given shading and watering for 7 days for their proper growth and development.

3.10.2 Weeding

Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were removed carefully. The first weeding was done after 15 days of transplanting weeding was done after 30, 45 and 60 days of transplanting. Weeding was done by uprooting and using with mechanical weed control elements.

3.10.3 Irrigation and drainage

Irrigation was provided to maintain moisture condition in the early stages to establishment of the seedlings and then irrigated as when necessary throughout the entire growing period. Excessive water was drained out from the experiment field. No water stress was created in reproductive phase.

3.10.4 Earthing up

Earthing up was done at 20, 35 and 50 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.11Treatments used for management

The experiment comprised seven treatments including an untreated control of the following bio-pesticides –

T_1= Tracer 45SC (Spinosad) @ 0.5 ml L^{-1} of water at 15 days interval

T_2= Avermectin 1.8EC (Avermectin) @ 1.0 ml L^{-1} of water at 15 days interval

T_3= Calden 45SC (Cartap) @ 2.0 ml L^{-1} of water at 15 days interval

T_4= Confidor 17.80SL (Imidaclorpid) @ 0.5 ml L^{-1} of water at 15 days interval

T_5= Bombard 10EC (Cypermethrin) @ 1.0 ml L^{-1} of water at 15 days interval

T_6= Sevin 85WP (Carbaryl) @ 2.0 g L^{-1} of water at 15 days interval

T_7= Neem oil @ 3.0 ml L^{-1} of water at 15 days interval

T_8= Untreated control

Treatments were applied with the help of knapsack sprayer at 15 days interval. Spraying was done in the afternoon to avoid bright sunlight to safe the foraging beneficial insects and predators. The spray materials were applied uniformly to obtain complete coverage of whole plants of the field. Caution was taken to avoid any drift of the spray to the adjacent plots during the spray application. At each spray application the spray was freshly prepared and selected insecticides were applied with the help of knapsack sprayer at 15 days interval.

3.12 Monitoring of leaf miner mine

The infested leaves were monitored regularly in the study field. There are many methods of assessing leaf miner abundance. Counting spots in leaves of tomato is a good index of past activity, but many spots may be vacant. Counting damage spots is time consuming, but more indicative of future damage. Sequential sampling plans for determining the need for treatment, based on the number of mined leaves^{-1} were developed by Wolfenbarger and Wolfenbarger (1966). Similar plans based on counts of mine were developed by Zehnder and Trumble (1985).

3.13 Application of insecticides

Different treatments were used at 15 days after transplanting (DAT) following 15 days interval with the recommended doses.

3.14 Data collection

The tomato plants were closely examined at regular intervals commencing from 15 days after transplanting (DAT) to harvesting of tomato fruits. Five (5) different leaves were tagged by tagging tap and colored rope. Leaf miner infestation were recorded at 15, 30 and 45 DAT. Data of yield attributing characters of tomato plant like healthy leaves per plant^{-1}, infested leaves plant^{-1}, height of plant $^{-1}$, weight of fruits plant^{-1} and weight of fruits plot^{-1} and yield (t ha^{-1}) was recorded after harvesting.

Plate 2. Data collection plants in the tomato experiment at tomato field.

Plate 3. Tagged of 5 leaves of each plants of tomato in the experiment field.

3.15 Level of infestation

The number of leaves, healthy and infested leaves and plants of tomato caused by the vegetable leaf miner was counted. The observation was recorded as first observation of no. of damage spot leaves and plants and were continued up to harvesting stage of the tomato at 15 days of interval. The data on the yield was also recorded. The level of leaf and plant infestations per plant and plot respectively was then calculated using the following formula.

3.16.1 Leaf or plant infestation

Total numbers of leaves or plants as well as the number of infested leaves or plants were recorded at 15 days of interval. The level of leaf and plant infestations per plant and plot respectively was then calculated using the following formula:

$$\text{Leaf or plant infestation \%} = \frac{\text{Number of infested leaves or plants}}{\text{Total number of leaves or plants}} \times 100$$

3.16.3 Percent of fruit infestation

Fruit infestation by weight due to vegetable leaf miner the data on the weight of healthy and infested fruits were recorded from 5 tagged plants in each treatment of plot .The percent of fruit infestation by weight was calculated with the following formula:

$$\text{Infestation of single plant fruit \%} = \frac{\text{Weight of infested fruits}}{\text{Weight of Total number of fruits}} \times 100$$

3.16.4 Weight of single plant fruits

Weight of single fruit mean weight of fruits from randomly selected 5 plants was measured for each plot of experiment for each treatment separately. The percent increase of single plant fruits over control were calculated using the formula:

$$\text{Infestation of single plant fruit \%} = \frac{\text{Weight single plant of fruits}}{\text{Weight of Total number of fruits}} \times 100$$

3.16.5 Yield

Total yield of tomato per acre for each treatment was calculated in tons from cumulative fruit production in a plot of the experimental field. Effect of different treatments on the increase and decrease of tomato yield over control was calculated by the following formula:

$$\text{Increase of yield over control \%} = \frac{\text{Yield of treated plot – Yield of control plot}}{\text{Yield of control plot}} \times 100$$

$$\text{Increase of yield over control \%} = \frac{\text{Yield of control plot – Yield of treated plot}}{\text{Yield of control plot}} \times 100$$

3.17 Harvesting

Harvesting of the tomato yield was first harvested on 10 February 2019 at 85 DAT. Harvesting in completed within 85-110 days at three times. When the plant fruits were developed by light yellow or light red color then the harvesting of the crop was done by handpicking. Fully mature fruits of tomato and slightly ripen tomato was collected carefully in the basket.

3.18 Statistical analysis

The data collected on different parameters were compiled and tabulated for statistical analysis. Statistically analysis was done using the MSTAT computer package program. Mean values were ranked and compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez 1984).

Plate 4. Tomato infested leaflet by vegetable leaf miner.

Plate 6. Completely healthy fruits of tomato.

Plate 7. Healthy marketable tomatoes in the experimental field.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during October 2018 to March 2019 to find out the succession of vegetable insect pests and natural enemies in tomato ecosystem and management of major insect pest by bio-pesticides and chemical insecticides. The results of the present study have been interpreted and discussed under the following sub-headings:

4.1 Effect of different control measures on the infestation of leaves by leaf miner in tomato at early stage

Significant variations were observed among different treatments in terms of infestation of leaves due to attack of leaf miner in tomato during early stage (Table 2).

The highest number of healthy leaves plant^{-1} was observed in T_4 (29.47) (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely T_1 (28.80), T_5 (27.40), T_7 (26.60), T_3 (26.33) and T_2 (25.33) treatments respectively. The lowest number of healthy leaves plant^{-1} was observed in T_8 (21.33) treatment. So, it can be observed that number of healthy leaves plant^{-1} among the treatments from highest to lowest was shown as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

The highest number of infested leaves plant^{-1} was observed in T_8 (3.80) (untreated control) treatment which are closely followed by T_6 (2.07) and other treatments T_2 (1.87), T_3 (1.53) and T_7 (1.33) respectively. On the other hand the lowest number of infested leaves plant^{-1} was observed in T_4 (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely T_1 (0.93) treatment. So, it can be observed that number of infested leaves

$plant^{-1}$ among the treatments from the highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

The highest infestation (15.16%) was observed in T_8 (untreated control) treatment which are closely followed by T_6 (7.77%) and other treatments T_2 (6.87%), T_3 (5.51%) and T_7 (4.79%) respectively. On the other hand lower percent of infestation (2.47%) was observed in T_4 (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely followed by T_1 (3.16%) and T_5 (3.97%) treatments respectively. So, it can be observed that leaves infestation among the treatments from the highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

In case of % reduction over control, the highest number of infested leaf was achieved by T_4 (83.84%) where the lowest was found in T_6 (48.75%) which was closely related to T_2 (54.68%). From the above mentioned findings it was revealed that among the different treatments, T_4 (83.84%) performed the best in reducing the infestation intensity of leaves of tomato by the number of zigzag mine due to attack of leaf miner then the other treatments; whereas, T_6 (48.75%) showed the least performance in reducing the infestation intensity of leaves.

As a result The order of rank of efficiency among the different treatments including one untreated control in terms of reducing the infestation intensity of leaves of tomato by number of damage spots due to lea miner at early growth stage was $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

Table 2. Effect of different treatments on the infestation of leaf miner on tomato leaf at early stage

Treatments	Number of healthy leaves plant^{-1}	Number of infested leaves plant^{-1}	Leaf infestation (%)	Infestation reduction over control (%)
T_1	28.80 a	0.93ef	3.16ef	79.16
T_2	25.33 b	1.87 b	6.87 b	54.68
T_3	26.33ab	1.53 c	5.51 c	63.65
T_4	29.47 a	0.73 f	2.45 f	83.84
T_5	27.40ab	1.13 de	3.97 de	73.81
T_6	24.53 b	2.07 b	7.77 b	48.75
T_7	26.60ab	1.33 cd	4.79 cd	68.40
T_8	21.33 c	3.80 a	15.16 a	--
$LSD_{(0.05)}$	3.062	0.241	1.184	--
Level of significance	0.01	0.01	0.01	--
CV (%)	6.67	8.24	10.88	--

In a column, numeric data represents the mean value of 3 replications, each replication was derived from 5 plants per treatment. In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

[**T_1**= Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval, **T_2**= Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval, **T_3** = Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval, **T_4**= Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval, **T_5**= Bombard 25EC @ 1.0 ml/L of water at 15 days interval, **T_6**= Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval, **T_7**= Neem oil @ 3.0 ml L $^{-1}$ of water at 15 days interval, **T_8**= Untreated control.]

4.2 Effect of different treatments on the infestation by leaf miner on tomato leaf at mid stage

Significant variations were observed among different treatments used for control measure in terms of infestation of leaves due to attack of leaf miner in tomato during mid stage (Table 3).

The highest number of healthy leaves plant^{-1} was observed in T_4 (41.00) (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely T_1 (40.27), T_5 (39.60), T_7 (39.40), T_3 (38.53) and T_2 (38.20) treatments respectively. The lowest number of healthy leaves plant^{-1} was observed in T_8 (34.13) treatment. So, it can be observed that number of healthy leaves plant^{-1} among the treatments from highest to lowest was shown as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

The highest number of infested leaves plant^{-1} was observed in T_8 (5.27) (untreated control) treatment which are closely followed by T_6 (2.73) and other treatments T_2 (2.53), T_3 (2.13) ,T_7 (1.73) and T_5 (1.53) respectively. On the other hand the lowest number of infested leaves plant^{-1} was observed in T_4 (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment (0.87) which was closely T_1 (1.07) treatment. So, it can be observed that number of infested leaves plant^{-1} among the treatments from the highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

The highest infestation (13.41%) was observed in T_8 (untreated control) treatment which are closely followed by T_6 (6.81%), T_2 (6.23%) and T_3 (5.26%) treatments respectively. On the other hand lower % of infestation (2.08%) was observed T_4 (spraying of 0.5 ml L^{-1} of Confidor 17.80SL at 15 days interval) treatment which was closely followed by T_1 (2.59%) and T_5 (3.97%) treatments; respectively. Other treatments T_7 (4.22%) and T_5 (3.73%) which are statistically similar. So, it can be observed that leaves infestation among the treatments from highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

In case of reduction over control, the highest number of infested leaf was achieved by T_4 (84.49%) which was closely related to T_1 (80.69%) where the lowest was found in T_6 (49.22%) From the above mentioned findings it was revealed that among the different treatments, T_4 (84.49%) performed best in reducing the infestation intensity of leaves of tomato by the number of zigzag spots due to attack of leaf miner then the other treatments; whereas, T_6 (49.22%) showed the least performance in reducing the infestation intensity of leaves.

As a result the order of rank of efficiency among the different treatments including one untreated control in terms of reducing the infestation intensity of leaves of tomato by number of damage spots due to lea miner at mid growth stage was $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

Table 3. Effect of different control measures on the infestation of leaf by leaf miner of tomato at mid stage

Treatments	Number of healthy leaves $plant^{-1}$	Number of infested leaves $plant^{-1}$	Leaf infestation (%)	Infestation reduction over control (%)
T_1	40.27 a	1.07 e	2.59 e	80.69
T_2	38.20 a	2.53 b	6.23bc	53.54
T_3	38.53 a	2.13 c	5.26 c	60.78
T_4	41.00 a	0.87 e	2.08 e	84.49
T_5	39.60 a	1.53 d	3.73 d	72.18
T_6	37.60ab	2.73 b	6.81 b	49.22
T_7	39.40 a	1.73 d	4.22 d	68.53
T_8	34.13 b	5.27 a	13.41 a	--
$LSD_{(0.05)}$	3.682	0.277	0.992	--
Level of significance	0.05	0.01	0.01	--
CV (%)	5.45	7.08	10.23	--

In a column, numeric data represents the mean value of 3 replications, each replication is derived from 5 plants per treatment. In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

[$\mathbf{T_1}$= Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval, $\mathbf{T_2}$= Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval, $\mathbf{T_3}$ = Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval, $\mathbf{T_4}$= Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval, $\mathbf{T_5}$= Bombard 25EC @ 1.0 ml/L of water at 15 days interval, $\mathbf{T_6}$= Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval, $\mathbf{T_7}$= Neem oil @ 3.0 ml L^{-1} of water 15 days interval, $\mathbf{T_8}$= Untreated control.]

4.3 Effect of different control measures on the infestation by leaf miner on tomato leaf at late stage

Significant variations were observed among different treatments used for control measure in terms of infestation of leaves due to attack of leaf miner in tomato during late stage (Table 4).

The highest number of healthy leaves plant^{-1} was observed in T_4 (48.67) (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely T_1 (47.53), T_5 (47.13), T_7 (46.40), T_3 (45.67) and T_2 (45.33) treatments respectively. The lowest number of healthy leaves plant^{-1} was observed in T_8 (40.40) treatment. So, it can be observed that number of healthy leaves plant^{-1} among the treatments from highest to lowest was shown as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

The highest number of infested leaves plant^{-1} was observed in T_8 (5.60) (untreated control) treatment which are closely followed by T_6 (2.87) and other treatments T_2 (2.60), T_3 (2.27) and T_7 (1.87) respectively. On the other hand the lowest number of infested leaves plant^{-1} was observed in T_4 (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely T_1 (1.13) treatment. So, it can be observed that number of infested leaves plant^{-1} among the treatments from the highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

The highest percentage infestation (12.18%) was observed in T_8 (untreated control) treatment which are closely followed by T_6 (6.08%), T_2 (5.43%) and T_3 (4.73%) treatments respectively. On the other hand the lowest percent of infestation (1.75%) was observed in T_4 (spraying of 0.5 ml L^{-1} of confidor 17.80SL at 15 days interval) treatment which was closely followed by T_1 (2.34%) treatments respectively. Other treatments T_7 (3.87%) and T_5 (3.29%) which are statistically different. So, it can be observed that leaves infestation among the treatments from highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

In case of reduction over control, the highest number of infested leaf was achieved by T_4 (85.63%) which was closely related to T_1 (80.79%). where the lowest was found in T_6 (50.08%). From the above mentioned findings it was revealed that among the different treatments, T_4 (85.63%) performed best in reducing the infestation intensity of leaves of tomato by the number of zigzag mine due to attack of leaf miner then the other treatments; whereas, T_6 (50.08%) showed the least performance in reducing the infestation intensity of leaves.

As a result the order of rank of efficiency among the different treatments including one untreated control in terms of reducing the infestation intensity of leaves of tomato by number of damage spots due to lea miner at late growth stage was $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

Table 4. Effect of different control measures on the infestation of leaf by leaf miner of tomato at late stage

Treatments	Number of healthy leaves plant^{-1}	Number of infested leaves plant^{-1}	Leaf infestation (%)	Infestation reduction over control (%)
T_1	47.53a	1.13 g	2.34 g	80.79
T_2	45.33 a	2.60 c	5.43 c	55.42
T_3	45.67 a	2.27 d	4.73 d	61.17
T_4	48.67 a	0.87 h	1.75 h	85.63
T_5	47.13 a	1.60 f	3.29 f	72.99
T_6	44.40ab	2.87 b	6.08 b	50.08
T_7	46.40 a	1.87 e	3.87 e	68.23
T_8	40.40 b	5.60 a	12.18 a	--
$LSD_{(0.05)}$	4.444	0.248	0.534	--
Level of significance	0.05	0.01	0.01	--
CV (%)	5.55	6.05	6.14	--

In a column, numeric data represents the mean value of 3 replications, each replication is derived from 5 plants per treatment. In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

[**T_1**= Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval, **T_2**= Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval, **T_3** = Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval, **T_4**= Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval, **T_5**= Bombard 25EC @ 1.0 ml/L of water at 15 days interval, **T_6**= Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval, **T_7**= Neem oil @ 3.0 ml L^{-1} of water at 15 days interval, **T_8**= Untreated control.]

4.4 Effect of different control measures on the number of mine leaf^{-1} by leaf miner in tomato plants

Significant variations were observed among the different treatments used for the control measures in terms of the number of mine leaf^{-1}due to attack of leaf miner during at the different growth stages of (Table no. 5)

Highest number of mine (7.40) was observed at T_8 (untreated control) treatment during early growth stage which was closely followed by T_6 (2.67) and T_2 (2.33) treatments respectively. On the contrary the lowest number of mine T_4 (0.87) was observed which was closely followed by T_1 (1.07), T_5 (1.60), T_7 (1.67) and T_3 (1.93) respectively. The results obtained from other treatments showed intermediate level of leaf miner mine. So, it can be observed that leaf miner mine among the treatments from highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

Highest number of mine (6.73) was observed at T_8 (untreated control) treatment during mid growth stage which was closely followed by T_6 (1.93%). On the other hand the lowest number of mine T_4 (0.33) was observed which was followed by T_1 (0.53%) and T_5 (0.87%) and. Other treatments T_7 (1.07), T_3 (1.47) and T_2 (1.53) respectively intermediate level of the number of leaf miner. So, it can be observed that the number of leaf miner mine among the treatments from highest to lowest was show as $T_8 > T_6 > T_2 > T_3 > T_7 > T_5 > T_1 > T_4$.

In late growth stage, Highest number of mine (4.07) was observed at T_8 (untreated control) treatment during late growth stage which was closely followed by T_6 (1.53) and T_2 (1.27) respectively. On the other hand the lowest number of mine T_4 (0.27) was observed which was closely related by T_1 (0.473), T_5 (0.67) and T_7 (0.73) respectively. Other treatment T_3 (0.93) respectively intermediate level the number of leaf miner mine. So, it can be observed that leaf miner mine among the treatments from highest to lowest was shown as $T_8 > T_6 > T_2 > T_3 > T_7 >$

T_5> T_1> T_4. The highest number of mine (18.20) was observed at T_8 (untreated control) treatment during total growth stage which was closely followed by T_6 (6.13), T_2 (5.13) and T_3 (4.33) treatments respectively. On the other hand the lowest number of mine T_4 (1.47) was observed which was closely related by T_1 (2.07), T_5 (3.13) and T_7 (3.47) respectively. So, it can be observed that the number of leaf miner mine leaf^{-1} among the treatments from highest to lowest was shown as T_8 >T_6>T_2> T_3> T_7> T_5> T_1> T_4.

Table 5. Effect of different control measures on the number of mine leaf^{-1} by leaf miner in tomato plants.

Treatments	Number of mine leaf^{-1} at the different growth stage			
	Early	**Mid**	**Late**	**Total**
T_1	1.07 f	0.53 e	0.47fg	2.07 f
T_2	2.33 c	1.53 c	1.27 c	5.13 c
T_3	1.93 d	1.47 c	0.93 d	4.33 d
T_4	0.87 f	0.33 e	0.27 g	1.47 g
T_5	1.60 e	0.87 d	0.67ef	3.13 e
T_6	2.67 b	1.93 b	1.53 b	6.13 b
T_7	1.67 de	1.07 d	0.73 de	3.47 e
T_8	7.40 a	6.73 a	4.07 a	18.20 a
$LSD_{(0.05)}$	0.303	0.215	0.215	0.440
Level of significance	0.01	0.01	0.01	0.01
CV (%)	7.15	6.77	9.86	4.57

In a column, numeric data represents the mean value of 3 replications, each replication is derived from 5 plants per treatment. In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

[**T_1**= Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval, **T_2**= Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval, **T_3** = Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval, **T_4**= Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval, **T_5**= Bombard 25EC @ 1.0 ml/L of water at 15 days interval, **T_6**= Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval, **T_7**= Neem oil @ 3.0 ml L^{-1} of water 15 days interval, **T_8**= Untreated control.]

4.5.1 Height of Plant during harvesting

Significant variations were observed among different treatments used for control measure in terms of height of Plant due to attack of leaf miner in tomato during harvesting period (Table 6). The height of plant decreases due to hamper of photosynthesis of leaves by the infesting of leaf miner. The highest height of plant (98.83cm) was observed in T_4 treatment which are closely followed by T_1 (98.20 cm), T_5 (97.75cm), T_7 (96.84cm), T_3 (96.34cm) and T_2 (96.28cm) treatments respectively. On the other hand the lowest height of plant (91.91cm) was observed T_8 (uncontrolled treatment) which was closely followed by T_6 (95.07cm) treatments. The gradually decreased trend was observed in case of height of plant as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

4.5.2 Number of flower bunch plant^{-1} during harvesting

Significant variations were observed among different treatments used for control measure in terms number of flower bunch plant^{-1} due to attack of leaf miner in tomato during harvesting period (Table 6). The number of flower bunch plant^{-1} decreases lack of properly photosynthetic activity. The highest number of flower bunch plant^{-1} was observed in T_4treatment during harvesting (14.13) which are closely followed by T_1 (13.80), T_5 (13.75), T_7 (13.71) andT_3 (13.60) treatments respectively. On the other hand lowest number of flower bunch plant^{-1} (12.27) was observed T_8 (untreated treatment) .Other treatments like T_2 (12.93) and T_6 (12.80) treatments which are statistically identical. The gradually decreased trend was observed in case of number of flower bunch plant^{-1}as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

4.5.3 Number of flower bunch^{-1} during harvesting

Significant variations were observed among different treatments used for control measure in terms number of flower plant^{-1} due to attack of leaf miner in tomato during harvesting period

(Table 6). The number of flower bunch^{-1} decreases due to hamper of photosynthesis of leaves by the infesting of miner .The highest number of flower bunch^{-1} during harvesting (7.27) was observed in T_4treatment which are closely followed by T_1 (7.07), T_5 (6.87), T_7 (6.80) and T_3 (6.60) treatments respectively. On the other hand lowest number of flower bunch^{-1} (6.13) was observed T_8 (uncontrolled treatment) .Other treatments like T_2 (6.47) and T_6 (6.33) treatments which are statistically identical. The gradually decreased trend was observed in case of number of flower/ bunch as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_{8.}$

Table 6. Effect of different control measures on yield attributes of tomato

Treatments	Plant height (cm)	Number of flower bunch $plant^{-1}$	Number of flower $bunch^{-1}$
T_1	98.20 a	13.80 a	7.07 ab
T_2	96.28 a	12.93ab	6.47 bcd
T_3	96.34 a	13.60 a	6.60 abcd
T_4	98.83 a	14.13 a	7.27 a
T_5	97.75 a	13.75 a	6.87 abc
T_6	95.07ab	12.80ab	6.33 cd
T_7	96.84 a	13.71 a	6.80 abcd
T_8	91.71 b	12.27 b	6.13 d
$LSD_{(0.05)}$	4.057	1.136	0.648
Level of significance	0.05	0.05	0.05
CV (%)	2.40	4.82	5.53

In a column, numeric data represents the mean value of 3 replications, each replication is derived from 5 plants per treatment. In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

[**T_1**= Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval, **T_2**= Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval, **T_3** = Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval, **T_4**= Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval, **T_5**= Bombard 25EC @ 1.0 ml/L of water at 15 days interval, **T_6**= Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval, **T_7**= Neem oil @ 3.0 ml L^{-1} of water at 15 days interval, **T_8**= Untreated control.]

4.6.1 Number of fruits plant^{-1} during harvesting

Significant variations were observed among different treatments used for control measure on number of fruits plant^{1}of tomato due to attack of leaf miner in tomato during harvesting (Table 7).

The highest number of fruits plant^{-1} during harvesting (31.47) was observed in T_4 treatment which are closely followed by T_1 (30.93), T_5 (30.67) and T_7 (29.33) treatments. On the other hand the lowest number of flower bunchplant^{-1} (28.00) was observed in T_8 (untreated treatment). Other treatments like T_3 (28.73) and T_2 (28.47), T_6 (28.20) are statistically identical. The gradually decreased trend was observed in case of number of fruits plant^{-1} as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_{8.}$

4.6.2 Single fruit weight (g) during harvesting

Significant variations were observed among different treatments used for control measure on yield attributes and yield of tomato due to attack of leaf miner in tomato during harvesting (Table 7).

The highest single fruit weight (g) during harvesting (42.37g) was observed in T_4 treatment which are closely followed by T_1 (41.70g), T_5 (41.31g), T_7 (40.62g) and T_3 (40.17g) treatments respectively. Conversely the lowest single fruit weight (36.33g) was observed T_8 (uncontrolled treatment) which are closely followed by T_2 (39.23g) and T_6 (38.18g) treatments. The gradually decreased trend was observed in case of Single fruit weight as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_{8.}$

4.6.3 Total fruit yield

Significant variations were observed among different treatments used for control measure on total fruit yield (t ha^{-1}) due to attack of leaf miner in tomato (Table 7).

The highest total fruit yield (22.20t ha^{-1}) was observed in T_4 treatment which are closely followed by T_1 (21.80t ha^{-1}), T_5 (21.66t ha^{-1}), T_7 (21.46t ha^{-1}), T_3 (21.07t ha^{-1}) and T_2 (20.77 t ha^{-1}) treatments respectively. On the other hand lowest total fruit yield (18.74t ha^{-1}) was observed T_8 (uncontrolled treatment) which is closely followed by T_6 (20.51t ha^{-1}) treatment statistically. The gradually decreased trend was observed in case of total fruit yield as $T_4 > T_1 > T_5 > T_7 > T_3 > T_2 > T_6 > T_8$.

Table 7. Effect of different control measures on yield attributes and yield of tomato

Treatments	Number of fruits plant^{-1}	Single fruit weight (g)	Fruit yield (t ha^{-1})
T_1	30.93 a	41.70ab	21.80 a
T_2	28.47 c	39.23 a-c	20.77 a
T_3	28.73 c	40.17ab	21.07 a
T_4	31.47 a	42.37 a	22.20 a
T_5	30.67ab	41.31ab	21.66 a
T_6	28.20 c	38.18bc	20.51ab
T_7	29.33bc	40.62ab	21.46 a
T_8	28.00 c	36.33 c	18.74 b
$LSD_{(0.05)}$	1.521	3.470	1.857
Level of significance	0.01	0.05	0.05
CV (%)	2.95	4.95	5.04

In a column, numeric data represents the mean value of 3 replications, each replication is derived from 5 plants per treatment. In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

[**T_1**= Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval, **T_2**= Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval, **T_3**= Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval, **T_4**= Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval, **T_5**= Bombard 25EC @ 1.0 ml/L of water at 15 days interval, **T_6**= Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval, **T_7**= Neem oil @ 3.0 ml L $^{-1}$ of water at 15 days interval, **T_8**= Untreated control.]

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CHAPTER V SUMMARY AND

CONCLUSION

The current study was carried out at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2018 to March 2019 to evaluate the infestation of leaf miner infestation and chemical control of leaf miner attacking in the tomato field. Eight treatments viz. (i) T_1 (Tracer 45SC @ 0.5 ml L^{-1} of water at 15 days interval), (ii) T_2 (Avermectin 1.9EC @ 1.0 ml L^{-1} of water at 15 days interval), (iii) T_3 (Calden 45SC @ 2.0 ml L^{-1} of water at 15 days interval), (iv) T_4 (Confidor 17.80SL @ 0.5 ml L^{-1} of water at 15 days interval), (v) T_5 (Bombard 25EC @ 1.0 ml/L of water at 15 days interval), (vi) T_6 (Sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval), (vii) T_7 (Neem oil 3.0 ml L^{-1} of water at 15 days interval), (viii) T_8 (Untreated control). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

The infested leaves by leaf miner was found into in the research field during the experimental period. Results showed that the significant variations were observed among different stages of tomato plant in terms number of leaf miner at the different growth stages, number of healthy leaves plant^{-1}, number of infested leaves plant^{-1}, number of mine leaf^{-1}, number of flower branch plant^{-1}, number of flower branch^{-1}.

From beginning of yield formation stage to at harvest, Results showed that the significant variations were observed on percent of leaf or plant infestation, plant height (cm), percent of infestation of single fruit weight (g) and total fruit yield (t ha^{-1}). Results showed that the lowest number of mine leaf^{-1} (0.87, 0.33, 0.27, at 15, 30, 45 DAT, respectively, i.e. mean=1.47) was observed in T_4 (spraying of 0.5 ml L^{-1} of Confidor 17.80SL at 15 days interval) treatment where the highest number of mine leaf^{-1} (7.40, 6.73, 4.07 at 15, 30, 45 DAT, respectively, i.e. mean=18.20) was observed in T_8 treatment. But in the treated plot highest number of mine leaf^{-1} (2.67, 1.93, 1.53 at 15, 30, 45 DAT, respectively i.e. mean= 6.13) was observed in T_6 treatment. Again the lowest infested leaves were found during early, mid, late stage 2.47%, 2.08%, 1.75% at 15, 30, 45 DAT, respectively) was observed in T_4 treatment where the highest of leaves infestation (15.16%,13.41%, 12.18%, at 15, 30, 45 DAT, respectively) was observed in T_8 treatment. But in the treated plot highest leaves infestation during early, mid, late stage (7.77%, 6.81%, 6.08% at 15, 30, 45 DAT, respectively) was observed in T_6 treatment.

Again result showed that the lowest height of plant (91.91cm) was observed T_8 treatment during harvesting period while the highest (98.83cm) in T_4 treatment. But in the control treated the highest height of plant was (98.20cm) observed in T_1 treatment. The lowest number of flower bunch plant^{-1} (28.00) was observed T_8 (untreated treatment) and the highest number of fruits plant^{-1} during harvesting (31.47) was observed in T_4 treatment. But in the control treated the highest number of fruits plant^{-1} (30.93) was observed in T_1 treatment.

The lowest number of single fruit weight (36.33g) was observed T_8 (uncontrolled treatment) and the highest Single fruit weight (42.37g) was observed in T_4 treatment.

But in the treated control, the highest single fruit weight (41.70g) was observed in T_1 treatment. The lowest total fruit yield (18.74t ha^{-1}) was observed T_8 treatment and the highest total fruit yield (22.28t ha^{-1}) was observed in T_4 treatment. But in the treated control the highest total fruit yield (21.80t ha^{-1}) was observed in T_1 treatment. In terms of percent reduction of or increase over control of treated plots at early stage, the lowest number of infested leaf reduction over control (48.75%), at mid stage the lowest number of infested leaf (49.22%) and at late stage the lowest number of infested leaf (50.08%). In terms of reduction of or increase over control at early stage, the highest number of infested leaf reduction over control (83.84%), at mid stage the highest number of infested leaf (84.49%) and at late stage, the highest number of infested leaf (85.63%).

From the above discussion on summary, it can be concluded that, the treatment of T_4 comprised of Confidor 17.80SL @ 0.5 ml L^{-1} at 15 days interval gave the best performance compared to all other treatments is the present study but the lowest performance was obtained by control treatment. On the other hand, the lowest performance among the treated plots was achieved by T_6 sevin 85WP @ 2.0 g L^{-1} of water at 15 days interval).

RECOMMENDATIONS

Considering the findings of the present experiment, further studies in the following areas may be suggested:

1. Survey should be done in several years all over Bangladesh for identification of existing species.
2. Further trials with effective bio-pesticide (Imidaclorpid) and chemical insecticide (Cypermethrin) should be done for controlling vegetable leaf miner at different AEZ of the country.
3. Botanicals with their derivatives may be included for the management of vegetable leaf miner.

CHAPTER VI

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental locationand experimental site at Sher-e-Babgla Agricultural University, Dhaka-1207.

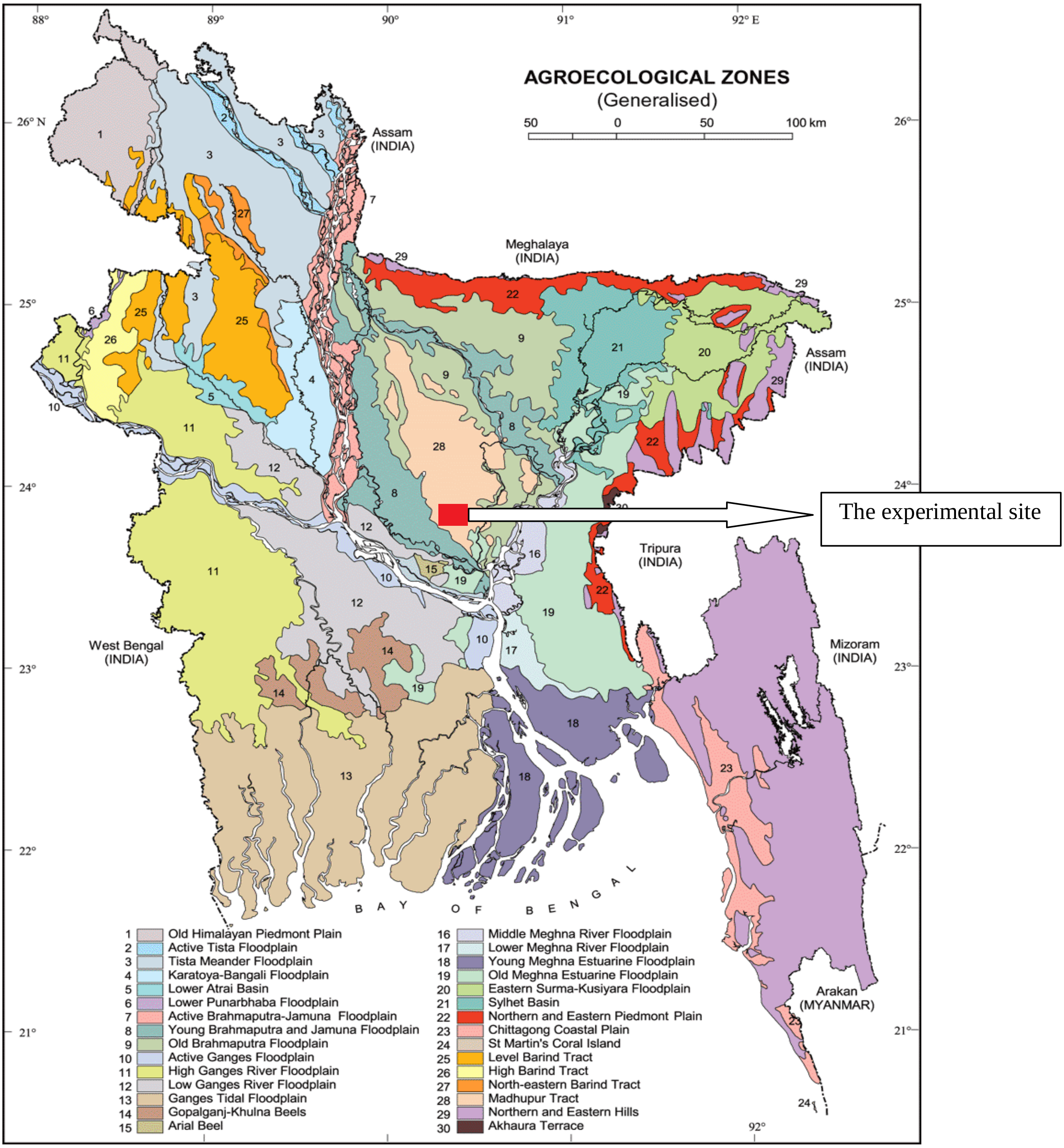

Figure: The map of Bangladesh showing experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from October 2018 to February 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max.	Min.	Mean		
2018	October	30.42	16.24	23.33	67.48	52.60
2018	November	28.50	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.70	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	36.80	0.0

[Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.]

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
PH	5.47-5.63
Organic matter	0.82
Total N(%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq/100 g soil

[Soil Resource Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.]

Appendix IV. Analysis of variance of the data on the infestation of leaf by leaf miner of tomato at early stage as influenced by different control measures

Source of variation	Degrees of freedom	Mean square		
		At early stage		
		Number of healthy leaves plant^{-1}	Number of infested leaves plant^{-1}	Leaf infestation (%)
Replication	2	0.665	0.0001	0.200
Treatment	7	19.825**	2.817**	48.851**
Error	14	3.057	0.019	0.457

** Significant at 0.01 level of probability.

Appendix V. Analysis of variance of the data on the infestation of leaf by leaf miner of tomato at mid stage as influenced by different control measures

Source of variation	Degrees of freedom	Mean square		
		At mid stage		
		Number of healthy leaves plant^{-1}	Number of infested leaves plant^{-1}	Leaf infestation (%)
Replication	2	0.572	0.012	0.047
Treatment	7	13.411*	5.794**	38.494**
Error	14	4.421	0.025	0.321

** Significant at 0.01 level of probability.

Appendix VI: Analysis of variance of the data on the infestation of leaf by leaf miner of tomato at late stage as influenced by different control measures

Source of variation	Degrees of freedom	Mean square		
		At late stage		
		Number of healthy leaves plant^{-1}	Number of infested leaves plant^{-1}	Leaf infestation (%)
Replication	2	3.672	0.005	0.033
Treatment	7	19.124*	6.590**	32.053**
Error	14	6.439	0.020	0.093

** Significant at 0.01 level of probability. * Significant at 0.05 level of probability.

Appendix VII. Analysis of variance of the data on the number of mine leaf^{-1} by the infestation of leaf miner in tomato plants as influenced by different control measures

Source of variation	Degrees of freedom	Mean square			
		Number of mine leaf^{-1} due to infestation of leaf miner at the growth stage of			
		Early	Mid	Late	Total
Replication	2	0.027	0.002	0.002	0.052
Treatment	7	13.108**	12.729**	4.415**	86.133**
Error	14	0.030	0.015	0.015	0.063

** Significant at 0.01 level of probability.

Appendix VIII. Analysis of variance of the data on yield attributes of tomato as influenced by different control measures

Source of variation	Degrees of freedom	Mean square		
		Plant height (cm)	Number of flower bunch/plant	Number of flower/bunch
Replication	2	2.599	0.082	0.082
Treatment	7	14.980*	1.301*	0.434*
Error	14	5.368	0.421	0.137

* Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on yield attributes and yield of tomato as influenced by different control measures

Source of variation	Degrees of freedom	Mean square		
		Number of fruits plant^{-1}	Single fruit weight (g)	Fruit yield (ta^{-1})
Replication	2	0.005	1.764	0.074
Treatment	7	5.529**	12.000*	3.477*
Error	14	0.754	3.926	1.124

** Significant at 0.01 level of probability * Significant at 0.05 level of probability