ECO-FRIENDLY MANAGEMENT OF LEAF MINER AND FRUIT BORER IN TOMATO

TAKIA BENTA REZA

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

TAKIA BENTA REZA
REGISTRATION NO.: 14-05949

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APPROVED BY:

Prof. Dr. Mst. Nur Mohal Akhter Banu
Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. S.M. Mizanur Rahman
Co-Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. Md. Mizanur Rahman
Chairman
Department of Entomology
SAU, Dhaka

DEPARTMENT OF ENTOMOLOGY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, **'Eco-Friendly Management of Leaf Miner and Fruit Borer in Tomato'** submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of bona fide research work carried out by **Takia Benta Reza, Registration number: 14-05949** 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 of this investigation has duly been acknowledged.

Dated: June, 2021
Dhaka, Bangladesh

Dr. Mst. Nur Mohal Akhter Banu
Supervisor
&
Professor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedicated to...

My beloved parents
and the farmers
who feed the nation.

ABBREVIATIONS

Elaborated Form		Abbreviated Form
And others (Co-workers)	=	*et al.*
Gram	=	g
Coefficient of Variation	=	CV
Degree centigrade	=	^{o}C
Example	=	viz.
Least significant difference	=	LSD
Million tons	=	mt
Non-significant	=	NS
Per Hectare	=	ha^{-1}
Percentage	=	%
Nitrogen	=	N
Phosphorus	=	P
Potassium	=	K
Randomized Complete Block Design	=	RCBD
Standard Week	=	SW
Sher-e-Bangla Agricultural University	=	SAU
Standard Error	=	SE
that is	=	i.e.
tons	=	t

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ABSTRACT

The experiment was conducted under the central farm of Sher-e-Bangla Agricultural University, Dhaka in order to assess the efficacy of some promising botanicals against tomato leaf miner and tomato fruit borer. There were seven treatments and three replication per treatment used in a randomized complete block design (RCBD). The treatments were Neem leaf extract, Datura seed extract, Garlic bulb extract, Mahogany seed extract, Black pepper seed extract, Alamonda leaf extract and control. In case of leaf infestation by tomato leaf miners, the lowest leaf infestation (2.08% per plant) during the vegetative stage was obtained from neem leaf extract and the highest leaf infestation (10.19% per plant) was obtained from the control treatment (untreated). Similarly during fruiting stage, the lowest miner induced fruit infestation (3.18% per plot) was obtained from neem leaf extract whereas; the highest fruit infestation (14.64% per plot) was obtained from the control treatment (untreated). The lowest number of tomato fruit borer infested fruits in early, mid and late fruiting stage was 2.67, 5.63 and 4.48 fruits per plot which are obtained from neem leaf extract. On the other hand, the highest infested fruits were obtained from control treatment (11.33, 16.28, and 13.55 fruits per plot) respectively. However, in terms of healthy fruits per plot and weight of healthy fruits per plot, highest yield was obtained from neem leaf extract in all fruit bearing stages. Current study will help in botanicals control of tomato leaf miner and tomato fruit borer in tomato plants.

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) botanically referred to the family Solanaceae is one of the most important and popular vegetable crops in Bangladesh as well as in the world. Its annual production accounts for 387.7K metric tons with fresh market tomato being 47th highest producer of the total. In Bangladesh, tomato is cultivated in about 27530 ha of the total cultivable land of all vegetables and its yield was 0.37 m metric tons during the crop year of 2016-17 where ha^{-1} yield was 14044.42 t (BBS, 2017) which is very low to fulfill the demand of the country. However, 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 in each 100g edible ripen tomato (BARI, 2010).

In Bangladesh, the yield of tomatoes is not enough satisfactory in comparison with other tomato-growing countries of the World (Aditya *et al*., 2010; Alam *et al*., 2015). 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 fruit borer, tomato leaf miner, tomato fruit worm, tomato aphid, stink bugs and leaf-footed bugs, hornworms, silver leaf, whitefly, etc. Among them, tomato leaf miner, *Tuta absoluta* (Lepidoptera: Gelechiidae) is one of the most important pests of tomato, and damage by this pest may be up to 50-80% (Haque, 2015). *Tuta absoluta* in only a few years has become a serious threat to global tomato production. It is now considered to be one of the most invasive pests of tomatoes in the Mediterranean Basin countries such as Egypt, Tunisia, Bangladesh, Libya, Morocco, and Algeria (Haque, 2015). In Bangladesh, tomato leaf miner, *Tuta absoluta* is a key oligophagous pest of tomato. It causes reductions in yield and fruit quality, to a tune of 50-100% loss in either greenhouses or fields. Plants are damaged by direct feeding on leaves, stems, buds, calyces, and young & ripe fruits and by caterpillars and the invasion of secondary pathogens which enter through the wounds made by the pest (EPPO, 2005). In Bangladesh, its infestation was first recorded from the Northern part of our country and subsequently spread to other tomato growing districts viz., Kurigram, Dinajpur, Bogura, Munshiganj. Now it covers all over the country. Larvae feed on the mesophyll tissue of the leaves, leaving only the epidermis intact. They often cause conspicuous irregular leaf blotches which later turned to necrotic.On fruits, a small minute pin-sized hole is often visible. Damage fruits with galleries of open areas act as entry paths for invasion by secondary pathogens, leading to fruit rot. The insect deposits eggs usually on 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 the mature stage.Thousands of tomato farmers in Bangladesh are suffering from serious production losses due to this devastating pest that destroyed their precious crops. *T. absoluta* can be spread by seedlings, infested vines with tomato fruit, tomato fruit, and used containers.Outdoor markets, vegetable repacking, and distribution centers are potential introduction points in the spread of this pest (Retta and Berhe, 2015; Alam *et al*., 2015; Alam *et al*., 2019).

On the other hand, tomato fruit borer, *Helicoverpa armigera* is highly destructive causing serious damage (Muthukumaran and Selvanarayanan, 2013).The fruiting stage of the crop and the time of plantation govern the incidence of fruit borer (Chakraborty *et al*., 2011). Larvae invade fruits, preventing fruit development and causing the fruit to drop.Tomato Fruit Borer damage can also be responsible for decreasing the seed viability compared to undamaged fruit (Karabhantanal *et al*., 2010). Larvae can be found only by opening the infested fruit (Shah *et al*., 2013). Severe infestation causes necrosis to the leaf chlorophyllous tissue, suppresses tomato flowers to bloom, and makes the mature fruit unfit to consume (Jallow and Matsumura, 2001). It has been reported to cause serious losses throughout its range, in particular in tomatoes it has been found to cause a yield loss of 35% to 37.79% fruit (Dhandapani *et al*., 2003).

The farmers of Bangladesh usually control this pest by the application of chemical insecticides because they are available, very easy to apply on plants and most importantly, these chemicals give very quick results. The presence of residues of DDT, HCH, Endosulfan, Malathion, and Primisphos-Methyl in market samples of tomato has been reported (Ravi *et al*., 2008). To avoid such problems caused due to indiscriminate use of insecticides, utilization of biorational insecticides is an ecologically viable, alternate insect pest management strategy. Biorational or 'reduced risk' insecticides are synthetic or natural compounds that effectively control insect pests, but have low toxicity to non-target organisms (such as humans, animals, and natural enemies) and the environment (Hara, 2000). In Bangladesh, the use of botanicals insecticides to manage the tomato leaf miners and tomato fruit borer is not very common.

Objectives

Keeping the above-mentioned points in consideration, present study was taken in order to-

- Determine the level of infestation induced by tomato leaf miner and tomato fruit borer in tomato plants and
- Assess the efficacy of different botanicals in controlling leaf miner and tomato fruit borer.

CHAPTER II

REVIEW OF LITERATURE

Pool of literature regarding biology of tomato, life cycle, bio-ecology, and control measures of tomato leaf miner and tomato fruit borer has been discussed in this chapter. Potential of some plant extracts in controllinginsect pests of tomato has also been highlighted.

2.1. Tomato (*Solanum lycopersicum* L.)

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop. For a long time tomatoes were known by the name *Lycopersicon esculentum,* but recent work has shown that they are part of the genus *Solanum*.

2.1.1. Nomenclature and classification

The cultivated tomato, *Solanum lycopersicum*, is grown for its popular fleshy fruits and is known by different names worldwide like tomato (German), tomaatti (Finish), pomidoro (Italian), kamalis (Malay), jitomate (Spanish), pomidor (Russian) and tamatar (Hindi). Linnaeus (1753) classified tomatoes in the genus *Solanum* and described *S. lycopersicum* (the cultivated tomato) and *S. peruvianum*. The very next year Miller (1754) followed Tournefort (1694) and formally described the genus *Lycopersicon*. Miller did not approve of Linnaeus's binomial system, and he continued to use polynomial phrase names for all plants until 1768. Miller's circumscription of the genus *Lycopersicon* also included potatoes as "*Lycopersiconradice tuberose, esculentum*".

Later, Miller (1768) began to use Linnaeus binomial system and published descriptions under *Lycopersicon* for several species. It included *L. esculentum*, *L. peruvianum*, *L. pimpinellifolium* and *L. tuberosum* (potatoes). In the posthumously published edition of 'The gardener's and botanist's dictionary' (Miller, 1807) the editor, Thomas Martyn, followed binomial system of Linnaeus and merged *Lycopersicon* back into *Solanum*.

Following Miller's early work, a number of classical and modern authors recognized tomatoes under *Lycopersico*n, but other taxonomists included tomatoes in *Solanum*.Today, based on evidence from phylogenetic studies using DNA sequences and more in-depth studies of plant morphology and distribution, there is general acceptance of the treatment of tomatoes in the genus *Solanum* by both taxonomists and breeders alike. Theuse of *Solanum* names has gained wide acceptance by the breeding and genomics community such as the Solanaceae Genomics Network (SGN) and the International SOL Project (http://www.sgn.cornell.edu/).

Scientific classification of cultivated tomato

Kingdom	:	Plantae
(Unranked)	:	Angiosperms
(Unranked)	:	Eudicots
(Unranked)	:	Asterids
Order	:	Solanales
Family	:	Solanaceae
Genus	:	*Solanum*
Species	:	*S. lycopersicum*

Source: CABI, 2021

2.1.2. Nutritional composition of tomato

The Nutritional composition of tomato is given below-

Table 1. Nutritional composition of tomato

Content	/100 g of red tomato	Content	/100 g of red tomato	Content	/100 g of red tomato
Energy	18 K cal	Lycopene	2537 µg	Vit B1 (Thiamine)	0.037 mg
Carbohydrate	3.9 g	Mg	11 mg	Vit B3 (Niacin)	0.594 mg
Fat	0.2 g	Ca	20 mg	Vit B6	0.08 mg
Protein	0.9 g	P	24 mg	Sugar	2.6 g
Water	94.5 g	K	237 mg	Dietary Fiber	1.2 g
Vit A	833 IU	Oxalic acid	2 mg	Vit E	0.54 mg
Cu	0.19 mg	Mn	0.114 mg	Vit K	7.9 µg
Cl	38 mg	Fe	0.3 mg	Vit C	14 mg
Na	5 mg	S	24 mg		

2.1.3. Centre of origin and diversity

Wild tomatoes are native of western South America, distributed from Ecuador to northern Chile (Darwin *et al.*, 2003; Peralta and Spooner, 2005). They grow in variety of habitats, from near sea level to over 3,300 m in elevation, in arid coastal lowlands and adjacent regions where the pacific winds drop scarce rainfall and humidity; in isolated valleys in the high Andes, and in deserts like the severe Atacama Desert in northern Chile.

Andean topography, diverse ecological habitats and different climates have contributed significantly to wild tomato diversity.

Based on morphological characters, phylogenetic relationships, and geographic distribution, scientists proposed the segregation of four species within the highly polymorphic green-fruited species *S. peruvianumsensulato* (*sensulato* refers to a broad concept of a species): *S. arcanum*, *S. huaylasense*, *S. peruvianum*, and *S. corneliomulleri*. The first

two have been described as new species (Peralta *et al*., 2005) from Perú, while the latter two had already been named by Linnaeus (1753) and MacBride (1962), respectively. Another new yellow- to orange-fruited tomato species, *S. galapagense*, segregated from *S. cheesmaniae*, have been recognized; both are endemic to the Galápagos Islands (Darwin *et al*., 2003). In total, 13 species of tomatoes, including the cultivated tomato (*Solanum lycopersicum*) and its weedy escaped forms are distributed worldwide.

As a crop plant, tomato is one of the best-characterized plant model systems. It has a relatively small genome of 0.95pg or 950Mb per haploid nucleus (Arumuganathan and Earle, 1991), and features such as diploidy, self-pollination, and a relatively short generation time make it amenable to genetic analysis. The tomato clade of Solanum (Solanum sect. Lycopersicon) includes 12 species and subspecies. All are diploid (2n = 2x = 24), except 2 natural tetraploid populations of S. chilense (2n = 4x = 48) (Chetelat and Ji, 2007), and share the same number of acrocentric to metacentric chromosomes with large blocks of pericentric heterochromatin and distal euchromatic arms (Brown, 1949; Barton, 1950). The only exception to this generalization is chromosome 2 with a completely heterochromatic short arm including a distal nucleolus organizing region (NOR) (Barton, 1950).

2.1.4. Reproduction and floral biology

The cultivated tomato plants generally reproduce by means of self-pollination. The reproduction of the tomato plant involves the stamen and the carpels. The stamen produces pollen that can fertilize the carpels. The carpel gets fertilized once a pollen grain enters its pollen tube. Rarely cross pollinations may occur with the help of an insect or animal bringing the pollen to another tomato plant. After the ovule is fertilized, it develops into an embryo which in turn matures into a seed. The seed is wrapped with flesh within a mature fruit. The fruit can then be spread by being eaten and digested by an animal.

Tomato plants have yellow flowers that, in full bloom, are generally less than an inch in diameter. The flowers can occur in a simple or a complex inflorescence. There are different types of inflorescences. A raceme inflorescence is one in which the flowers branch off laterally from a main shoot that grows indefinitely. The number of flowers that occur in an inflorescence is dependent upon environmental factors such as temperature. In a cyme inflorescence, the shoot apex differentiates into a flower, subsequent growth occurs due to activity in an axillary branch which will eventually terminate in a flower.

The pedicel is the stem that supports the flower. The outermost whorl consists of the sepals. Collectively, the sepals are called the calyx. The next whorl, the bright yellow petals, serves to attract pollinators. Together, the petals are called the corolla. The male reproductive organs (stamens), which house pollen production, sit inside the petals. A single tomato stamen consists of two elongated compartments. The individual stamens are fused together to form a yellow cylinder that surrounds the carpels. The tomato carpels are green. They vary in number from cultivar to cultivar, but they are invariably fused together into a single bulb-like structure. The number of carpels in the tomato flower corresponds to the number of locules found in the fruits. Fertilization takes place in the carpels. The ovules which develop into seeds are protected in the carpel.

2.2. Tomato leaf miner, *Tuta absoluta* (Lepidoptera: Gelechiidae)

T. absoluta has several common English names in the literature. These are the South American tomato pinworm, the South American tomato leaf miner, the South American tomato moth, the tomato pinworm, the tomato borer, and the tomato leaf miner. For consistency, the tomato leaf miner (TLM) will be used throughout this chapter. The TLM has been considered as a key pest of tomato, in recent years, causing a reduction in tomato yield that can reach 100% if no management action is taken (Biondi *et al*., 2018).

2.2.1. Origin, morphology and taxonomic position

T. absoluta originated in the Peruvian Central highlands from where it spread to other areas of Peru and then to the rest of Latin American countries during the 1960s (Campos *et al*., 2017).TLM is small moth with body length of 5-7 mm and wingspan of 10-14 mm (EPPO, 2005). The moth has silvery-gray scales and black spots on the forewings. The antennae are long, filiform with black and brown scales Shashank *et al*., (2015)described the male and female genitalia as well as the pupal genital aperture as useful distinguishing character for sexing of the moth. Egg is small (0.36 mm long and 0.22 mm wide) with elliptical shape and creamy white to bright yellow color. Larva is whitish in first instar (0.9 mm long) and becomes greenish or light pink in the second and fourth instar (7.5 mm). Pupa is obtect with greenish coloration at first, turning to chestnut brown and dark brown near adult emergence (EPPO, 2005).

Tabuloc *et al*., (2019) studies the genome of *T. absoluta* to generate and design a panel of 21 SNP markers for the species identification instead of depending only on morphological identification and symptoms of damage on the host plants. *Tutaabsoluta* was originally described as *Phthorimaeaabsoluta* in Peruvian Andes. The genus was changed toGnorimoschema(Clarke, 1962) and then to Scrobipalpula and Scrobipalpuloides. Povolny (1994) corrected the currently used name

Tutaabsoluta. The EPPO code and phytosanitary categorization for *T. absoluta* are GNORAB and EPP A1 action list no. 321, respectively (EPPO, 2005).

Scientific classification of tomato leaf miner

Kingdom	: Animalia
Phylum	: Arthoproda
Class	: Insecta
Order	: Lepidoptera
Family	: Gelechiidae
Genus	:*Tuta*
Species	: *T. absoluta*

Source: CABI, 2021

2.2.2. Biology and life cycle of tomato leaf miner

The TLM has a complete metamorphosis type of reproduction, where it undergoes through four developmental stages, namely, egg, larva, pupa, and adult. Adults are nocturnal and hide between host leaves during the day. The female starts to release a sex pheromone 1-2 days after emergence to lure males for mating. The female sex pheromone is a mixture of tetradecatrienyl acetate and tetradecadienyl acetate in a ratio of 10:1, respectively (Attygalle *et al*., 1995). TLM is known to have multiple mating and the average number of mating per female is about 10.4. Both sexes are polygamous with no refractory period. The female sometimes can exhibit deuterotoky parthenogenesis, which gives both females and males from unfertilized eggs (Caparros *et al*., 2012).

Males use female sex pheromone to locate females and mating can last from few minutes to 6 hours. Female uses plant volatiles (kairomones) and leaf contact for oviposition. A single female can lay as many as 260 eggs during its life cycle, which may extend to 3 months (Uchoa-Fernandes *et al*., 1995). About 92% of the total eggs are laid in the 1-3 days following mating (EPPO, 2005). Eggs are laid singly on the upper part of the plant (young leaves, stems, and sepals). The eggs hatch in 5-7 days depending on temperature and relative humidity. After hatching, the larvae go through four instars, which are completed in about 20 days. The mature larva then gets rid of all gut materials, constructs a silken cocoon, and turns into pre-pupa and pupa. Pupation may last for 10-11 days before adult emergence for female and male, respectively. Mature larvae leave the mines and build silken cocoon on the leaflet or in the soil. When pupation occurs in the mines or tomato fruit, the pre-pupa does not build cocoon. Adult longevity may extend for 30-40 days (EPPO, 2005). The whole life cycle of the moth is completed in 29-38 days, depending on the environmental conditions.

Moreover, about 10-12 generation may be produced annually. The thermal constant from egg to adult has been estimated to be 453.6 degree days (DD) (Desneux *et al.*, 2010). TLM larvae do not enter diapause as long as food is available; however, it may overwinter as eggs, pupae, and adults (EPPO, 2005; Uchoa-Fernandes *et al.*, 1995).

2.2.3. Nature of damage

TLM usually attacks the apical buds, flowers, and new fruits of tomato. Larvae make conspicuous mines and galleries on leaves and stems. Damage can occur at any stage of tomato growth from seedlings to mature plant (EPPO, 2005). The larvae feed on the mesophyll tissue, leaving the epidermis intact, thus creating irregular mines and galleries on the leaves. The mines and galleries may become necrotic with time. This mining activities lead to reduction of the photosynthetic potential of infested leaves (Biondi *et al.*, 2018). Infested tomato with TLM show burnt up-like symptoms (Shashank *et al.*, 2015). The galleries made by the larvae are wider than that caused by the dipteran leaf miner *Liriomyzatrifolii*(Shashank et al., 2015; Nayana and Kalleshwaraswamy, 2015). Larvae can penetrate the axillary buds of young stems when at high density. Thus, it leads to plant withering and check of vegetative growth (EPPO, 2005).

After fruit setting, the larvae excavate tunnels in the The serious damage on tomato, due to *T. absoluta*, is caused by the leaf-mining activities and to a lesser extent by tunneling in the fruits. Damage on tomato can reach 100% if no action is taken against the moth. Estimation of economic losses is difficult due to the interaction of many factors including climate, production pattern (greenhouse versus open field), and production costs including seeds, insecticides, fertilization, and other resources. Most of the damage occurs at the early years of invasion, due to lack of farmers' experience on how to manage the pest (Biondi *et al*., 2018).

2.2.4. Chemical control

Chemical control of the invasive TLM is difficult; however, its arrival to new invaded areas has been linked to an excessive application of broad-spectrum insecticides (Biondi *et al*., 2018; Desneux *et al*., 2010; Balzan and Moonen, 2012), in attempts to curb the outbreaks of the pest and to reduce yield losses in tomato crop. Currently, insecticides application seems to be the most commonly used strategy against *T. absoluta* worldwide in open fields of tomato (Biondi *et al*., 2018; Silva *et al*., 2011; Guedes *et al*., 2019). The cryptic behavior and the endophagous habit of larvae make it extremely difficult to control TLM with insecticides (Biondi *et al*., 2018). The possible reasons for difficulty of controlling TLM with insecticides, according to Biondi *et al*., (2018) and Guedes *et al*., (2019)include the following:

- Infestation of tomato by the moth occurs at an early stage of plant growth

- The multiple attacks by the pest on different plant parts (stems, leaves, buds, young fruit, and ripe fruit)

- The morphology and architecture of tomato plant that provide protection for feeding larvae against insecticides

Insecticides from different chemical classes were used against TLM in South America, Europe, and other parts of the world. These chemical classes include, but not limited to, organophosphate, pyrethroids, pyrrole, spinosyns, diamides, benzoylureas, and avermactins(Ŝkaljac *et al*., 2012; Silva *et al*., 2011; Silva *et al*., 2019).Spinosad, azadirachtin, and *Bacillus thuringiensis* toxins (Bt) have been to control TLM in organic tomato production systems (Biondi *et al*., 2018; Guedes *et al*., 2019).

The excessive application of insecticides to prevent and control the outbreaks of *T. absoluta*, particularly in open fields lead to an increased selection pressure which, eventually reduce the effectiveness of such insecticides. For example, when the moth was introduced in Brazil, the farmers initially used insecticides at frequencies of 10-12 applications per cropping season, which was later increased to 30 applications (Guedes and Siqueira, 2012). In Turkey, the annual cost of chemical insecticides used against *T. absoluta* in 2014 was about 160 million Euros. The frequent use of insecticides speeded the appearance of resistance in tomato leaf miner populations, which can migrate outside their geographical range into new invaded areas.

Guedes *et al*., (2019) reported that enhanced levels of detoxification enzymes and altered target sites are the main resistance mechanisms commonly found in *T. absoluta*. In addition to the development of resistance in TLM populations, due to excessive use of insecticides, compromising of biological control, in tomato agroecosystems, is also not avoidable. In this respect, Soares *et al*., (2019) studied the lethal and sublethal effects of five insecticides (spinetoram, chlorantraniliprole + abamectin, triflumuron, tebufenozide, and abamectin) on adults and the third instar nymph of the predator Macrolophusbasicornis. They concluded that abamectin caused high mortality in both adult and nymphs. All tested insecticides caused negative effect on the predator.

To overcome the problems of insecticide resistance and other harmful effects on tomato ecosystem, due to the excessive use of insecticides, insecticide resistance management (IRM) strategies are needed to sustain production of tomato crop. Such strategies include adoption of alternative control options such as cultural control, semiochemically based control, biological control, and host plant resistance. All these alternative strategies and tactics would reduce the reliance on insecticides and accordingly the selection pressure on TLM populations.

2.3. Tomato fruit borer, *Helicoverpa armigera*

The tomato fruit borer, *H. armigera* is one of the most important pests in the production of tomato. The larva of this insect develops inside the fruit, feeding on the mesocarp and the endosperm and caused damage that fluctuates between 13 and 77%.

2.3.1. Origin and taxonomic position

Scientific classification of tomato fruit borer

Kingdom	: Animalia
Phylum	: Arthoproda
Class	: Insecta
Order	: Lepidoptera
Family	: Noctuidae
Genus	: *Helicoverpa*
Species	: *H. armigera*

Source: CABI, 2021

2.3.2. Biology and life cycle of *H. armigera*

The eggs are flat, slightly sculptured and placed in groups or individually. They are 0.5 mm long and 0.3 mm wide (Fernandez and Salas, 1985). The mature larva is between 15 and 20 mm in length, tapering posteriorly, segments IX and anal segment small. Body color from white to pink. Body pinnacula without sclerotization and pigmentation. The color of the pinacula is similar to that of the body; they are present as a slightly raised blister particularly on the meso- and meta-thorax. Prothoracic shield pale yellow with light-brown markings, with no visible black reniform spot. Head with a darkened pigmentation a little wider at the posterior margin of head capsule. The pupa is obtect. The color varies from light to dark brown, measuring 12-15 mm, with a cremaster. Dorsum of the abdominal segments smooth. The 2nd and 3rd abdominal segment with a protruding cover above each spiracle (Capps, 1948).

Dorsally the abdomen of adult male has a striking white band covering the entire 1st abdominal segment and part of the 2nd and 3rd segments, the rest of the segments covered by a mixture of dark-brown and black scales. The abdomen in ventral view, with the entire 1st abdominal segment and a large portion of the 2nd and 3rd segment white in color, the other segments paler than the dorsum. Laterally, the abdomen has small tufts of scales of the same color, often difficult to see in descaled specimens. Antenna of adult female is filiform, length of cilia slightly less than the width of the flagellum near the base. Labial palpi same as in the male except that the 3rd segment is longer, its length is equal to the 2nd segment. Color and spots, similar to the male. Wing expansion: 15-30 mm.

In tomato, larvae have an average duration of 16 ±1.88 days and the pupa lasted 11.14 ± 1.23 days. The fecundity of a female was 23.24 ± 17.60 eggs, when reared on tomato at 25° C (Clavijo, 1984). At 27°C and 67% RH (relative humidity), the total life cycle lasts 33.91 days, with eggs lasting 5.54 ± 0.57 days, larva 16.41± 1.48 days, pupa: 8.12 ± 0.53 days and adults 4.30 ± 1.69 days (Fernandez and Salas, 1985). The average number of eggs per female was 34.26, the eggs had a 74.96% fertility rate and the male:female ratio was 1:1.16 (Fernandez and Salas, 1985). In eggplant, the species has four larval instars at 24°–25°C and five larval instars at 15°-30C° (Marcano, 1991). The total developmental time was 39.16 days at 25°C (5.3 days for the eggs, 18.3 days for larvae, 9.5 for the pupa and 6.1 for the adult) (Marcano, 1991). At temperatures of 25°C and 30.2°C, the preoviposition period was 2.8 and 2.5 days, oviposition period was 3.0 and 2.8 days and the average number of eggs per female was 75.5 and 60.0, respectively (Marcano, 1991). The number of eggs per female ranged from 3 to 133 and from 4 to 159 at 25°C and 30.2°C, respectively (Marcano, 1991). Serrano *et al*., (1992) reported 6 days for the egg, 22 days for larvae, 12 days for pupa under 24°C and 74% RH conditions. Female andmale lifespan 7 days and 4 days, respectively; the female preoviposition period lasts 3 days and she lays an average of 93 eggs (Serrano *et al*., 1992).

2.3.3. Nature of damage

H. armigera is an oligophagous pest that attacks only fruits of plants belonging to the family Solanaceae. Some of these hosts are tropical fruits known for their exotic flavor, such as *Solanum quitoense* Lam., commonly known as lulo or naranjilla; the tree tomato (*S. betaceum* Cav.) and vegetable crops such as tomato (*S. lycopersicum* Lam.), eggplant (*S. melongena* L.) and green and red pepper (*Capsicum annuum* L.) (National Research Council, 1989). This pest also attacks a variety of wild solanaceous plants.

Fruit borer populations can cause 70% loss in tomato (Restrepo, 2007), 21% in tree tomato and 13% in lulo or naranjilla. In Brazil, losses of 77% were reported by Picanço *et al.,* (1998). In Venezuela, Marcano (1990) argued that the greatest loss of tomatoes (41% of damaged fruit) occurs during the rainy season, coinciding with the month of August, and the lowest losses (5.09% of damaged fruit) are recorded during the months of March and April. In Ecuador, losses of 90% in naranjilla (*S. quitoense*) have occasionally been recorded, with a maximum number of 18 larvae in a single fruit (Revelo *et al*., 2010), and in Honduras, causing 1% loss in eggplant (SENASA, 2008).

Marcano (1990) observed that adult *H. armigera* remains motionless throughout the day, with wings outstretched to the sides and the abdomen raised. The manifestation of the onset of activity by the moth is the extension of the abdomen, which is observed between 18:00 and 19:00 h, when the adult begins to move, whether walking or taking short flights. Mating occurs from 20:00 to 06:00, with a higher mating activity between 23:00 and 24:00. Oviposition occurs from 19:00 until dawn (Marcano, 1990). According to Eiras (2000) mating is preceded by male wing vibration, and occurs between the 4th and 10th hour of the scotophase, with a peak of activity in the 7^{th} hour. Only 2.8% of newly emerged adults mate (Eiras, 2000). Adult emergence occurs between 17:00 and 02:00, with peak emergence between 20:00 and 22:00 (Marcano, 1990).

2.3.4. Chemical control

Studies conducted by Eiras (2000) and Eiras and Blackmer (2003) recommended the application of pesticides when fruits are 2.5 cm in diameter. Insecticides that work by ingestion or contact, or both, will be more effective at this stage.

The most highly recommended insecticides are the chitin synthesis inhibitors Diflubenzuron, Triflumuron, Lufenuron, Methoxyfenozide etc. Lima *et al*., (2001) evaluated different insecticides in tomato and suggested triflumuron at 30 ml p.c./100 L, chlorpyrifos at 120 and 150 ml commercial product/100 L and Match® at 80 ml p.c./100 L, resulting in the reduction of fruit damage 45 days after transplant. Martinelli *et al*., (2003) evaluated indoxa- carb using 2.4-6.0 g active ingredient (AI)/100 L, esfenvalerate at 1.75AI/100 L, methomyl at 21.5 g AI/100 L and triflumuron at 15 g AI/100 L, and determined that fruit borer can be efficiently controlled after nine applications of the above-mentioned products. Motta *et al*., (2005) evaluated abamectin 18 EC (Vertimec 18 CE®; Syngenta Crop Protection AG, Birsfelden, Switzerland) in a dose of 1 L/ha for the control of *H. armigera*, using 5% of damaged tomato fruits as the economic threshold. The authors concluded that abamectin failed to the control this insect, resulting in 70% fruit infestation after its application. On the other hand, Miranda *et al*., (2005) indicated that an integrated pest management strategy using an economic threshold of 20% of mined leaves and 5% of perforated fruits, could reduce pesticide applications by 65.5%, when compared to traditional control methods.

2.4. Botanical Insecticides

Many plants and minerals have insecticidal properties; that is, they are toxic to insects. Botanical insecticides are naturally occurring chemicals (insect toxins) extracted or derived from plants or minerals. They are also called natural insecticides. Organic gardeners will choose these insecticides, in some cases, over synthetic organic materials. In general, they act quickly, degrade rapidly and have, with a few exceptions, low mammalian toxicity. Products containing ingredients derived from plants are considered botanical pesticides.

2.4.1. Some promising botanicals

Neem oil is extracted from the neem tree, *Azadirachta indica* Juss., a member of the Meliaceae family that originates from the Indian subcontinent and is now valued worldwide as an important source of phytochemicals for use in human health and pest control. *Azadirachta* is a fast-growing small-to-medium sized evergreen tree, with wide and spreading branches. It can tolerate high temperatures as well as poor or degraded soil. The young leaves are reddish to purple, while the mature leaves are bright green, consisting of petiole, lamina, and the base that attaches the leaf to the stem and may bear two small lateral leaf-like structures known as stipules (Morgan, 2009).

Neem oil contains at least 100 biologically active compounds. Among them, the major constituents are triterpenes known as limonoids, the most important being azadirachtin, which appears to cause 90% of the effect on most pests. The compound has a melting point of 160°C and molecular weight of 720 g/mol. Other components present include meliantriol, nimbin, nimbidin, nimbinin, nimbolides, fatty acids (oleic, stearic, and palmitic), and salannin. The main neem product is the oil extracted from the seeds by different techniques. The other parts of the neem tree contain less azadirachtin, but are also used for oil extraction (Nicoletti *et al*., 2012).

In addition, plant extracts of the perennial common herb *Datura stramonium* L. were defined as toxic due to their insecticidal and antifeeding properties against *Dysdercusc ingulatus* Fabricius (Hemiptera: Pyrrhocoridae), *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae), and *Pericallia ricini* Fabricius (Lepidoptera: Noctuidae) (Prakash and Rao, 1997). Furthermore, the efficacy of the compounds extracted from different parts of Datura spp. on spider mites was investigated under laboratory conditions (Kumral *et al*., 2010). For example, partial extracts of *Datura metel* L. (Solanaceae) had repellent effects on adults and affected oviposition in the Cassada red mite *Oligonychus biharensis* Hirst (Acari: Tetranychidae) (Fang Ping *et al*., 2006). Additionally, *D. stramonium* extracts were tested for their acaricidal activity against *T. urticae*; the extracts were found to be 100% toxic to the organism during its active stages (Mateeva *et al*., 2003).

Mahogany (*S. macrophylla*) provides a number of functions including as shade for coffee and cacao trees, in making furniture such as cabinets, doors and decorative borders and medicines. Mahogany contains flavonoids and saponins and because of these compounds, mahogany's parts can be used as vitamins and drugs to reduce high blood pressure, hypertension, blood sugar disorder and fever. This plant is quite bitter and it has antipyretic and antifungal property. Additionally, most parts of the mahogany tree such as leaves, barks, and seeds can be used for controlling and killing insects and pests like mosquitoes, cockroaches, flies, moths, beetles, termites, and ants which may be harmful to people and can also destroy some of the plants and trees and their surroundings (Moghadamtousi *et al*., 2013).

Garlic, *Allium sativum* (Family: Alliaceae) is one of the most important ingredients of human food and Ayurvedic medicines since ancient time. Allicin, a key component of garlic reduces blood pressure by inhibiting angiotensin II and vasodilating effects. Its various preparations have antidiabetic properties. Its consumption protects human from cancer. Garlic inhibits proliferation of atheroscleroticcells and other cell types as well as collagen synthesis andaccumulation in the aorta. Garlic preparations having allyl sulfides show antibacterial activity against both gram-negative and gram-positive bacteria like *Bacillus*, *Clostridium*, *Escherichia*, *Klebsiella*, *Proteus*, *Salmonella*, *Staphylococcus* and *Streptococcus* and antifungal activities against *Candida albicans*. Diallyl sulfide and diallyl disulfide act as free radical scavangers by activating antioxidant enzymes like glutathione-s-transferase and catalase. Alcoholic extract of garlic shows anthelmintic activity against *Ascaris lumbricoldes*.

A. sativum essential oil contains 1,3-Dithiane, di-2-propenyl, 1-Propene, 3, 3'-thiobis, methyl 2-propenyl, 3-vinyl-1, 3-dithiin, 2-vinyl-1, 3-dithiin, di-2-propenyl, 3-vinyl-1, 2 dithiin1-chloro-4-(1- ethoxy) -2-methylbut-2-ene, methyl 2-propenyl, diallyl disulfide, 3-vinyl-1, 2 dithiin, methyl1-methyl-2-butenyl sulphide, octane 4-brom. These components contribute to acaricidal, antibacterial, fungicidal, insecticidal, molluscicidal, nematicidal and antiparasitic properties of garlic.

The Piperaceae family is considered to be among the most archaic of pan-tropical flowering plants. The genus Piper contains approximately 1,000 species of herbs, shrubs, small trees and hanging vines. Several *Piper* spp. from India, Southeast Asia and Africa are of economic importance since they are used as spices and traditional medicines. As a spice, black pepper has been traded world-wide for many centuries and represents a highly important cash crop for many tropical countries including India, Indonesia, Vietnam, Malaysia and Brazil.

The wide variety of secondary plant compounds found in *Piper* were suggested as potential leads for novel insecticides (Miyakado *et al*., 1989), while many varieties are used in traditional control of insects that are vectors of disease (Okorie and Ogunro, 1992) and damage stored crops (Mbata *et al.*, 1995; Keita *et al*., 2000). Early investigations with *P. nigrum* seed extracts indicated that piperamides were responsible for the toxicity of the extracts to the adzuki bean weevil *Callosobruchus chinensis* L. (Miyakado et al., 1980). *P. nigrum* seed oil formulations were found to effectively protect stored wheat from both stored grain pests, *Sitophilus oryzae* (L.) and *Rhyzopertha dominica* (F.), at concentrations above 100 mg/l for up to 30 days (Sighamony *et al.*, 1986). Stored beans were protected from the bruchid *Acanthoscelides obtectus* Say by ground black pepper for up to 18 weeks (Baier and Webster, 1992). Three of the piperamides isolated from *P. nigrum*, pipercide, pellitorine and piperine ranged in toxicity from 0.15, 2 and 20 µg/ male *C. chinensis* respectively(Dev and Koul, 1997).

These potential biopesticides i.e. botanicals can solve the biggest obstacles of synthetic pesticide such as chemical resistance, ecological disruption, and harm to beneficial organisms and so on.

CHAPTER III

MATERIALS AND METHODOLOGY

Current study was carried out in the central farm of Sher-e-Bangla Agricultural University,Sher-e-Bangla Nagar, Dhaka-1207 during September 2019 to January 2020 i.e. in the rabi season with a view to assessing the efficacy of some botanicals against tomato leaf miner and tomato fruit borer. The materials and methods used for conducting the experiment presented in this chapter under the following headings-

3.1. Description of experimental site

The experiment was conducted during the period from September 2019 to January 2020. Field work was conducted in the experimental area of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental site is situated at 23.074^0/N latitude and 90.0035^0/E longitude with an altitude of 8.2 meter from sea level. In terms of climate, the experimental site is under the subtropical climate and its climatic conditions are characterized by low temperature and scanty rainfall during the winter i.e. rabi season. Soil of the experimental site belongs to “The Modhupur Tract”, AEZ-28. However, the experimental site was flat having a provision of available irrigation and an ample drainage system.

3.2. Planting materials

In order to conduct the current experiment, BARI Tomato-15 was collected. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. This variety is heat tolerant, fruits are red, heart shaped, slightly ribbed, and average fruit weight 40-50g.

3.3. Treatments of the experiment

There are seven treatments including control (absolute) used in this experiment. Followings are the name of the treatments and respective doses.

Table 2.List of botanicals and their doses

Treatment No.	Botanicals	Dose
T_1	Neem leaf extract	5ml/L of water
T_2	Datura seed extract	5ml/L of water
T_3	Garlic bulb extract	5ml/L of water
T_4	Mehagany seed extract	5ml/L of water
T_5	Black pepper seed extract	5ml/L of water
T_6	Alamonda leaf extract	5ml/L of water
T_7	Control	

3.4. Experimental design and layout

The experimental field was designed in a single factor randomized complete block design (RCBD) with three replications, where the experimental site was divided into three blocks allocating the replications to assemble homogeneous soil conditions. Every block was divided into seven-unit plots as treatments. Raised bunds were used as identifiers for treatment demarcation. However, the total numbers of experimental plots were 7X3=21. Each plot size was 3.6 m × 1.6 m. Eventually, 0.5 m and 0.5 m distance were maintained between two blocks and two plots respectively.

3.5. Seedbed preparation and seed sowing

Tomatoes are normally transplanted because much better results are gained when seedlings are raised in a seedbed. The seedbed was 60-120 cm wide and 20-25 cm high. Initially, the clods of earth and stubble were removed. Then well composted farmyard manure and fine sand were added. Eventually, the seedbed was brought to fine tilth. Lines were drawn 10-15 cm apart, over the length of the seedbed. The seeds were sown thinly spaced on the lines and pressed gently. The seeds were covered with fine sand and straw. The seedbeds were watered twice a day to ensure sufficient moisture for germination. After germination the straw was removed.

3.6. Main field preparation and seedling transplanting

The seedlings were transplanted to the field 3 to 6 weeks after sowing. A week before transplanting, seedlings were hardened by reducing the application of water, further 12-14 hours before they were taken out of the seedbed were thoroughly watered again to avoid excessive damage to the roots. Seedlings of 15-25 cm tall with 3-5 true leaves were selected for transplanting. Transplanting was done in the afternoon to reduce the transplanting shock.

The plants were watered immediately once they had been transplanted. Spacing between plants and rows was maintained as per recommendation of Bangladesh Agricultural Research Institute (BARI). The common spacing is 50 cm between plants and 75 - 100 cm between rows. The holes for the plants were made deep enough so that the lowest leaves were at ground level. The soil was pressed firmly around the root, and watered around the base of the plant to settle the soil.

3.7. Manure and fertilizer

To get high yields, tomatoes need to be fertilized. There are two groups of crop nutrients: organic manures and chemical fertilizers. Well decomposed cow dung was applied at the time of final land preparation.

As suggested by the Bangladesh Agricultural Research Institute, fertilizers N, P, K in the form of Urea, TSP, MoP and S, Zn, and B in the form of gypsum, zinc sulphate and borax were applied (Mondal *et al.* 2011).

Table 3. Fertilizer and manure used in the experiment

Name of Fertilizer and manure	Total Amount (Kg/dec.)	Last plough (Kg/dec.)	Before transplanting (Kg/dec.)	15 DAT	35 DAT
Cow dung/ FYM	40	40	-	-	-
Urea	2.0	-	0.7	0.7	0.6
TSP	1.6	1.6	-	-	-
MoP	0.8	0.4	-	0.40	0.40
Gypsum	0.38	0.38	-	-	-
Boric Acid	0.3	0.3	-	-	-
Zinc Sulphate	0.03	0.03	-	-	-

Source: Mondal *et al.* 2011

3.8. Intercultural operation

Soon after the seedling establishment various intercultural operations were done in the main field. Surface irrigation was done as per necessity. When the plant developed 6-7 branches with tomatoes, the plants were stopped from growing further by breaking off the growing tip. The small side-shoots were removed and only one main stem remained. The fruit clusters grew along this main stem. Nipping enhanced the quality and size of the fruits. Staking or trellising tomato plants with bamboo poles, wood stakes, or other sturdy material provides support and keeps the fruit and foliage off the ground. Frequent weeding, and pesticide spraying was done in order to protect the plants from different abiotic and biotic stresses (Figure 1).

Figure 1. Figure showing tomato plants in the field.

3.9. Data collection

3.9.1. Data recording on the leaf infestation by tomato leaf miner

Five plants per plot which were randomly selected were used for data collection from each replicate before spraying as well as 7 and 14 days after spraying. Alive larvae in each replication were counted. Percentreduction in infestation was calculated. To assess the effect of tested botanicals on reduction in fruit damage, numbers of infested and uninfested tomato fruits from 5 plants were randomly counted from each replicate and percent of infested tomato fruits in different treatments was calculated.

3.9.2. Data recording on the fruit infestation by tomato fruit borer

Total number of fruits and infested fruits of five randomly selected plants per plot were recorded at each harvest and continued up to the last harvest. Infested fruits recorded at each observation were pooled and finally expressed in percentage. The damaged fruits were spotted out by the presence of holes made by the larvae. In the similar way, the number of healthy fruits per plot were selected. In order to determine the weight of healthy fruits, collected healthy fruits were measured by a weighing machine in the laboratory(Figure 2).

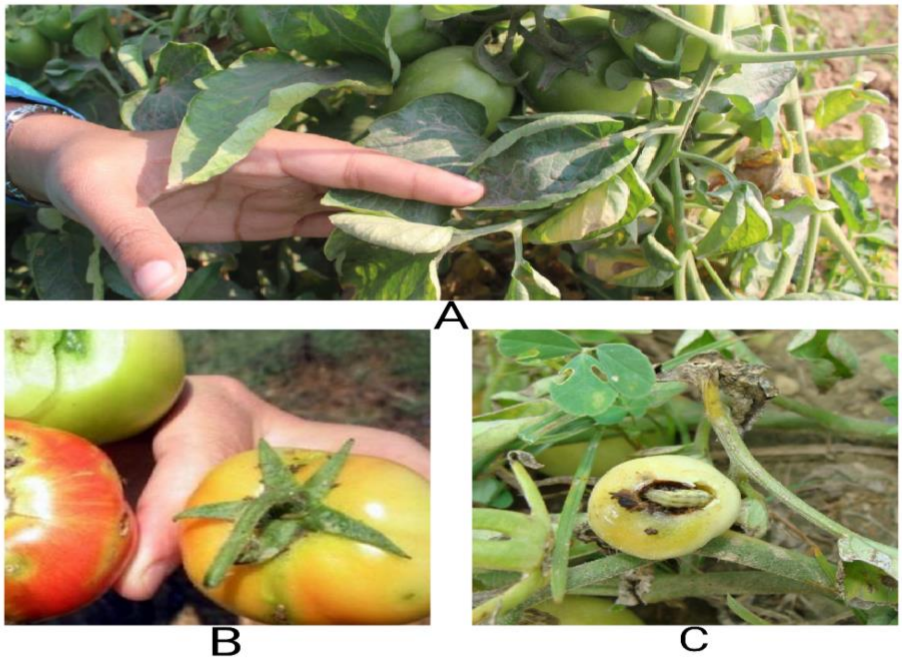

Figure 2. A. leaf miner infested leaf   B.leaf miner infested fruit

C.fruit borer instead fruit

3.10. Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance for different treatments. The analysis of variance was performed by using the STAT-10 Program. The significance of the difference among the treatment combinations was estimated by Tukey's HSD Test at 5% level of probability.

CHAPTER IV

RESULT AND DISCUSSION

Leaf miners attacked vegetative stage of tomato plants in the experimental field to varying degrees. Treatments showed different levels of infestation upon leaf miner invasion.

4.1. Effect of treatments against leaf miner infestation in leaves of tomato plants

Table 4. Effect of botanicals against tomato leaf miner during vegetative stage

Sl.	Treatment	% leaf infestation at vegetative stage	Decrease over control (%)
1	Neem leaf extract (T_1)	2.08 f	79.58
2	Datura seed extract (T_2)	6.56 c	35.62
3	Garlic bulb extract (T_3)	5.57 c	45.33
4	Mehagany seed extract (T_4)	3.39 e	66.73
5	Black pepper seed extract (T_5)	4.42 d	56.62
6	Alamonda leaf extract (T_6)	8.30 b	18.54
7	Untreated (T_7)	10.19 a	-
8	**$lsd_{0.05}$**	**1.02**	-
9	**CV (%)**	**9.97**	-

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

It is evident that the lowest leaf infestation (2.08%) during vegetative stage was obtained from T_2 and it was significantly different from any other treatment used in the experiment. Subsequently, it showed 79.58% decrease of leaf infestation over control (untreated) treatment. Leaf miner infestation was then followed by T_4 (3.39%) and it was also significantly different from other treatments of the experiment. Subsequently, it showed 66.73% decrease over absolute treatment. Infestation was then followed by T_5 (4.42%) which significantly differed from other experimental treatments. It showed a 56.62% decrease of leaf infestation over control treatment. Infestation was then followed by T_3 (5.57%) and T_2 (6.56%). Though numerically different, there is no significant variation between T_3 and T_2. However, they showed 45.33% and 35.62% decrease over control respectively. Later on, T_6 showed 8.30% leaf infestation by leaf miner during vegetative stage of tomato plants in the experiment and reduced 18.54% leaf infestation compared to control treatment. However, it was significantly different from any other treatments used in the experiment. Lastly, the highest leaf infestation (10.19%) was obtained from control treatment (untreated). It showed significant variation from all other treatments of the present experiment. It is seen that overall, leaf miner had attacked to a limited extent to the vegetative stage i.e. leaves of tomato plants. Among the other botanicals, neem seed extract showed highest efficiency. The tomato leaf miner, *Tuta absoluta*, a major pest in Bangladesh, has caused extensive damage to tomato and other Solanaceous plants since its introduction to the country. Many previous studies reported effective control of *T. absoluta* with botanical materials. Trindade *et al*., (2000) reported that application of 4 concentrations of Neem seed extract against young larvae of *T. absoluta* resulted in 84-100% mortality after 4 days. Goncalves-Gervasio and Vendramin, (2008) in South America found that neem seed extract, Azadiractin acts as contact and systemic insecticide against *Tuta absoluta*. In a soil application 48.9-100% larval mortality was recorded. Application of neem oil in the adaxial surface of the foliage causes 57-100% larval mortality. However, it is reported that application directly on larvae caused 52.4- 95% mortality by the same authors. Similar results were found by Braham and Hajii (2012) who obtained 87% mortality of *Tuta absoluta* larvae after 12 day where neem seed extract was used as 100 cc/h.

4.2. Effect of botanicals against leaf miner infestation in fruits of tomato plants

Table 5. Fruit infestation by tomato leaf miner during fruiting stage

Sl.	Treatment	% fruit infestation at maturing stage	Decrease over control (%)
1	Neem leaf extract (T_1)	3.18 g	78.27
2	Datura seed extract (T_2)	10.76 c	26.51
3	Garlic bulb extract (T_3)	9.71 d	33.67
4	Mehagany seed extract (T_4)	4.56 f	68.85
5	Black pepper seed extract (T_5)	7.76 e	46.99
6	Alamonda leaf extract (T_6)	13.21 b	9.76
7	Untreated (T_7)	14.64 a	-
8	**$lsd_{0.05}$**	**2.17**	-
9	**CV (%)**	**13.67**	-

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

Leaf miners attacked the fruiting stage of tomato plants in the experimental field to varying degrees. Treatments showed different levels of fruit infestation upon miner invasion.It is evident that the lowest fruit infestation (3.18%) during the maturity stage was obtained from T_1 and it was significantly different from any other treatment used in the experiment. Subsequently, it showed 78.27% decrease of fruit infestation over control (untreated) treatment. Leaf miner infestation was then followed by T_4 (4.56%) and it was also significantly different from other treatments of the experiment. Subsequently, it showed 68.85% decrease over absolute treatment. Infestation was then followed by T_5 (7.76%) which significantly differed from other experimental treatments. It showed a 46.99% decrease of fruit infestation over control treatment. Infestation was then followed by T_3 (9.71%) and T_2 (10.76%). There is significant variation between T_3 and T_2. Eventually, they showed 33.67% and 26.51% decrease over control respectively. Later on, T_6 showed 13.21% fruit infestation by leaf miner during the fruiting stage of tomato plants in the experiment and 9.76% reduction of fruit infestation was exhibited compared to control treatment. However, it was significantly different from any other treatments used in the experiment. Lastly, the highest fruit infestation (14.64%) was obtained from control treatment (untreated). It showed significant variation from all other treatments of the present experiment. Though not very severe, fruits of tomato plants were also affected by miner attack. Larvae of *T. absoluta* can destroy the developing fruit by mining its flesh. Infested fruit will usually fall to the ground. Larvae can attack the flower, but the most severe damage is found in developing (early instars) or maturing fruit (later instars). The larva usually enters the fruit under the calyx and tunnels the flesh, leaving galleries clogged with frass that cause the fruit to drop or to rot on the vine. Larvae can also enter the fruit through the terminal end or through other fruit parts that are in contact with leaves, other fruits, or stems. Active ingredient of neem viz. gedunin, azadirachtin, nimbolinin, nimbin, nimbidin, nimbidol, sodium nimbinate, salannin, quercetin, nimbanene, nimbandiol, nimbolide, ascorbic acid etc. are present in different parts of neem. The most important active ingredient is azadirachtin which is effective on insects as an antifeedant, insect growth regulation, sterility and cellular processes. This azadirachtin can play effectively on *T. absoluta* and mortality is high (Kubo *et a*l., 2012; Retta and Berhe, 2015).

4.3. Effect of botanicals against fruit infestation and yield attributes of tomato plants during early fruiting stage

Table 6. Effect of botanicals against fruit borer at early fruit bearing stage

Sl.	Treatment	Number of infested fruit per plot	Decrease over control (%)	Number of healthy fruit per plot	Increase over control (%)	Weight of healthy fruits per plot	Increase over control (%)
1	Neem leaf extract (T_1)	2.67 f	76.43	48.33 a	70.59	2449 a	75.30
2	Datura seed extract (T_2)	9.67 b	14.65	34.00 e	20.01	1653 e	18.32
3	Garlic bulb extract (T_3)	8.33 c	26.47	37.33 d	31.76	1816 d	29.99
4	Mehagany seed extract (T_4)	5.33 e	52.95	45.66 b	61.17	2237 b	60.12
5	Black pepper seed extract (T_5)	6.67 d	41.12	42.66 c	50.58	2018 c	44.45
6	Alamonda leaf extract (T_6)	10.33 b	8.82	31.66 e	11.75	1498 f	7.22
7	Untreated (T_7)	11.33 a	-	28.33 f	-	1397 f	-
8	$lsd_{0.05}$	**1.23**	-	**2.54**	-	**121.179**	-
9	CV (%)	**11.48**	-	**13.74**	-	**13.66**	-

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

4.3.1. Effect of botanicals against fruit infestation of tomato plants during early fruiting stage

Tomatoes exhibit synchronous maturity of fruits which means several pickings are required to harvest. In current study, tomato plants started fruit setting 40-45 days after planting and harvesting was continued upto 100-110 days after planting. It is evident that the early fruit bearing stage was attacked by the fruit borer in the current experiment. Different treatments showed different degrees of infestation induced by tomato fruit borer. The lowest number (2.67 fruits/plot) of infested fruit obtained from T_2 which is significantly different from any other treatments in the experiment. This treatment showed a 76.43% decrease of fruit infestation over control treatment.

Fruit borer infestation was then followed by T_4 (5.33 infested fruits per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed 52.95% decrease over absolute treatment. Number of infested fruit was then followed by T_5 (6.67 fruits per plot) which significantly differed from other experimental treatments. It showed a 41.12% decrease of fruit infestation over control treatment. Later on, T_3 showed 8.33 fruit infestation per plot by fruit borer during the early fruiting stage of tomato plants in the experiment and 26.47% reduction of fruit infestation was exhibited compared to control treatment. However, it was significantly different from any other treatments used in the experiment. Infested fruit numbers were then followed by T_2 (9.67 fruits per plot) and T_6 (10.33 fruits per plot). Though numerically different, there is no significant variation between T_2 and T_6. However, they showed 14.65% and 8.82% decrease over control respectively. Lastly, the highest fruit infestation per plot (11.33 per plot) was obtained from control treatment (untreated). It showed significant variation from all other treatments of the present experiment. Leaf miner and tomato fruit borer concurrently attacked on the early fruiting stage of tomato. The less infestation of tomato fruit borer in early fruit setting might be due to the presence of both pests. However, like above; neem based biopesticide was highly effective against borer infestation. Our results show uniformity with previous studies. Mustafiz et al. (2015) reported that the lowest number of infested fruit (0.17) was obtained when the crop was treated with neem oil @ 3.0 m/l of water at three days intervals. The controlling of tomato fruit borer was highest against the effectiveness of neem oil @ 3.0 m/l of water at three days intervals in different stages of plant growth. According to Gandhi *et al*., (2020), Neemarin (commercial neem product) 300 proved to be the best in percent larval reduction under field conditions which was similar to the findings of Rao *et al*., (1999) who reported satisfactory control of *H. armigera* on pigeon pea with neem oil (Azadirachtin 0.3%) @ 0.33 percent. Pant (2000) also reported that neemactin (0.00075%) and neem gold (0.00045%) were very effective in reducing larval population of *H. armigera* on tomato(Table no.6).

4.3.2. Effect of botanicals on number of healthy fruits of tomato plants during early fruiting stage

Healthy tomatoes are inevitable from the consumer point of view because tomatoes can make people healthier and decrease the risk of conditions such as cancer, osteoporosis and cardiovascular disease. In the current experiment, different treatments showed different numbers of healthy tomatoes in reference to infestation induced by tomato fruit borer. The highest number (48.33 fruits/plot) of healthy fruit obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 70.59% increase over control treatment. Number of healthy fruits was then followed by T_4 (45.66 fruits per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed 61.17% increase over absolute treatment. Number of healthy fruits was then followed by T_5 (42.66 fruits per plot) which significantly differed from other experimental treatments. It showed a 50.58% increase over control treatment. Later on, T_3 showed 37.33 healthy fruits per plot during the early fruiting stage of tomato plants in the experiment and 31.76% increase in the number of healthy fruits was exhibited compared to control treatment. However, it was significantly different from any other treatments used in the experiment. Healthy fruit numbers were then followed by T_2 (34.00 fruits per plot) and T_6 (31.66 fruits per plot). Though numerically different, there is no significant variation between T_2 and T_6. However, they showed 20.01% and 11.75% increase over control respectively. Lastly, the lowest number of healthy fruits per plot (28.33 per plot) was obtained from control treatment (untreated). Eventually, it showed significant variation from all other treatments of the present experiment. Mustafiz *et al.*, (2015) reported that the highest yield (66.80 tonnes) was recorded when the crop was treated with neem oil @ 3.0 m/l of water at three days intervals. Highest number of healthy fruits obtained from neem treatment may be attributed to the holistic contribution of neem oil on the plant health. The secondary metabolites originated from neem have an immense impact on crop protection. For example, ethanol extracts of *A. indica* showed fungal toxic properties against *Alternaria brassicola* and *F. oxysporum* (Bansal and Rajesh, 2000). Kishore *et a*l., (2001) reported that ethanol leaf extract of *A. indica* was highly inhibitory to Phaeoisariopsis personate, the causal agent of late leaf spot of groundnut. Double effect in controlling pest and disease led to the highest number of healthy fruits in tomato plants in neem oil treatment(Table no.6).

4.3.3. Effect of botanicals on the weight of healthy fruits of tomato plants during early fruiting stage

Weight of healthy fruits is positively related with the number of healthy fruits obtained from the experimental plots. Each fruit weighed around 45-60 gm thus the total weight of collected fruits from per plot was determined. In the current experiment, the weight of healthy fruits varied in different treatments. The highest weight (2449 gm/plot) of healthy fruits obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 75.30% increase over control treatment. Weight of healthy fruits was then followed by T_4 (2237 gm per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed a 60.12% increase over absolute treatment. Weight of healthy fruits was then followed by T_5 (2018 gm per plot) which significantly differed from other experimental treatments. It showed a 44.45% increase over the control treatment. Later on, T_3 showed 1816 gm healthy fruits weight per plot during the early fruiting stage of tomato plants in the experiment and 29.99% increase in the weight of healthy fruits was exhibited compared to the control treatment. It was also significantly different from any other treatments used in the experiment. Subsequently, weight of healthy fruits obtained from T_2 is 1653 g per plot which showed 18.32% increase over control treatment. Healthy fruit weight was then followed by T_6 (1498 gm per plot) with a slight increase over control treatment. Lastly, the lowest weight of healthy fruits per plot (1397 gm per plot) was obtained from control treatment (untreated). Eventually, there is no significant difference between T_6 and control treatment. The present findings are agreed with the findings of Rahman *et al*., (2011). They reported the lowest percentage of fruit infestation by number (5.72%) and weight (9.69%) in total cropping season using Marshal @ 6.0 ml/2 litre of water at 7 days interval which was statistically similar (6.22% in number and 10.03% in weight) to that of neem leaf extract @ 0.5 kg/2 litre of water applied at 7 days interval. Bhushan *et al.*, (2011) also reported that Neem seed kernel extract (NSKE 5%) was found most effective in reducing the larval population and pod damage in chickpea. It was demonstrated that azadirachtin was effective systemically and where insects ingest azadirachtin it had a toxic effect, interrupting growth and development (Table no.6).

4.4. Effect of botanicals against fruit infestation and yield attributes of tomato plants during mid fruiting stage

Table 7. Effect of botanicals against fruit borer at mid fruit bearing stage

Sl.	Treatment	Number of infested fruit per plot	Decrease over control (%)	Number of healthy fruit per plot	Increase over control (%)	Weight of healthy fruits per plot	Increase over control (%)
1	Neem leaf extract (T_1)	5.63 f	65.41	63.32 a	48.98	3103 a	56.01
2	Datura seed extract (T_2)	13.33 bc	18.12	46.67 e	9.81	2179 e	9.55
3	Garlic bulb extract (T_3)	12.23 cd	24.87	50.56 d	18.96	2448 d	23.07
4	Mehagany seed extract (T_4)	8.33 e	48.83	59.28 b	39.48	2864 b	43.99
5	Black pepper seed extract (T_5)	10.67 d	34.45	54.68 c	28.65	2606 c	31.02
6	Alamonda leaf extract (T_6)	14.67 ab	9.88	44.21 f	4.02	2115 e	6.33
7	Untreated (T_7)	16.28 a	-	42.50 g	-	1989 f	-
8	$lsd_{0.05}$	**1.42**	**-**	**1.36**	**-**	**117.77**	-
9	CV (%)	**6.99**	-	**9.08**	**-**	**12.67**	-

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

4.4.1. Effect of botanicals against fruit infestation of tomato plants during mid fruiting stage

Due to several picking harvesting behavior, tomato fruits were also harvested after the early bearing fruiting stage. The mid fruit bearing stage was prolonged from 60-70 days after planting. It is evident that the mid fruit bearing stage was attacked by the fruit borer in the current experiment. Different treatments showed different degrees of infestation induced by tomato fruit borer. The lowest number (5.63 fruits/plot) of infested fruit obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 65.41% decrease of fruit infestation over control treatment. Fruit borer infestation was then followed by T_4 (8.33 infested fruits per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed 48.83% decrease over absolute treatment. Number of infested fruit was then followed by T_5 (10.67 fruits per plot) which showed a 34.45% decrease of fruit infestation over control treatment. Later on, T_3 showed 12.33 fruit infestation per plot by fruit borer during the mid-fruiting stage of tomato plants in the experiment and 24.87% reduction of fruit infestation was exhibited compared to control treatment. However, there was no significant difference between T_3 and T_5. Infested fruit numbers were then followed by T_2 (13.33 fruits per plot) and T_6 (14.67 fruits per plot). Though numerically different, there is no significant variation between T_2 and T_6. However, they showed 18.12% and 9.88% decrease over control respectively. Lastly, the highest fruit infestation per plot (16.28 per plot) was obtained from control treatment (untreated). It showed no significant variation from T_6 of the present experiment (Table no.7).

4.4.2. Effect of botanicals on the number of healthy fruits of tomato plants during mid fruiting stage

In the current experiment, different treatments showed different numbers of healthy tomatoes in reference to infestation induced by tomato fruit borer. The highest number (63.32 fruits/plot) of healthy fruit obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 48.98% increase over control treatment. Number of healthy fruits was then followed by T_4 (59.28 fruits per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed a 39.48% increase over absolute treatment. Number of healthy fruits was then followed by T_5 (54.68 fruits per plot) which significantly differed from other experimental treatments. It showed a 28.65% increase over control treatment. Later on, T_3 showed 50.56 healthy fruits per plot during the mid-fruiting stage of tomato plants in the experiment and 18.96% increase in the number of healthy fruits was exhibited compared to control treatment. However, it was significantly different from any other treatments used in the experiment. Healthy fruit numbers were then followed by T_2 (46.67 fruits per plot) and showed 9.81% increase over control. Further, from T_6 we obtained 31.66 fruits per plot with an 11.75% increase over control. Lastly, the lowest number of healthy fruits per plot (42.50 per plot) was obtained from control treatment (untreated). Eventually, it showed significant variation from all other treatments of the present experiment(Table no.7).

4.4.3. Effect of botanicals on the weight of healthy fruits of tomato plants during mid fruiting stage

Since the weight of healthy fruits is positively related with the number of healthy fruits obtained from the experimental plots, in the current experiment, the weight of healthy fruits varied in different treatments. The highest weight (3103 gm/plot) of healthy fruits obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 56.01% increase over control treatment. Weight of healthy fruits was then followed by T_4 (2864 gm per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed a 43.99% increase over absolute treatment. Weight of healthy fruits was then followed by T_5 (2606 gm per plot) which significantly differed from other experimental treatments. It showed a 31.02% increase over the control treatment. Later on, T_3 showed 2448 gm healthy fruits weight per plot during the mid-fruiting stage of tomato plants in the experiment and 23.07% increase in the weight of healthy fruits was exhibited compared to the control treatment. It was also significantly different from any other treatments used in the experiment. Subsequently, weight of healthy fruits obtained from T_2 is 2179 g per plot which showed 9.55% increase over control treatment. Healthy fruit weight was then followed by T_6 (2115 gm per plot) with a slight increase (6.33%) over control treatment. Lastly, the lowest weight of healthy fruits per plot (1989 gm per plot) was obtained from control treatment (untreated). Eventually, there is no significant difference between T_7 and other treatments(Table no.7).

4.5. Effect of botanicals against fruit infestation and yield attributes of tomato plants during late fruiting stage

Table 8. Effect of botanicals against fruit borer at late fruiting stage

Sl.	Treatment	Number of infested fruit per plot	Decrease over control (%)	Number of healthy fruit per plot	Increase over control (%)	Weight of healthy fruits per plot	Increase over control (%)
1	Neem leaf extract (T_1)	4.48 d	66.93	59.35 a	82.72	2908 a	88.83
2	Datura seed extract (T_2)	10.35 b	23.61	42.67 e	31.37	1948 e	26.49
3	Garlic bulb extract (T_3)	8.77 c	35.27	46.50 d	43.16	2209 d	43.44
4	Mehagany seed extract (T_4)	5.24 d	61.32	55.23 b	70.04	2746 b	78.31
5	Black pepper seed extract (T_5)	7.68 c	43.32	50.78 c	56.34	2415 c	56.81
6	Alamonda leaf extract (T_6)	11.72 b	13.50	37.34 f	14.96	1726 f	12.07
7	Untreated (T_7)	13.55 a	-	32.48 g	-	1540 g	-
8	$lsd_{0.05}$	**1.74**	**-**	**2.07**	**-**	**114.05**	**-**
9	CV (%)	**11.5**	**-**	**12.51**	**-**	**12.9**	**-**

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

4.5.1. Effect of botanicals against fruit infestation of tomato plants during late fruiting stage

The late fruit bearing stage was prolonged from 85-100 days after planting. It is evident that the late fruit bearing stage was attacked by the fruit borer in the current experiment. Different treatments showed varying degrees of infestation induced by tomato fruit borer. The lowest number (4.48 fruits/plot) of infested fruit obtained from T_1 which is significantly different from any other treatments except T_4 in the experiment. This treatment showed a 66.93% decrease of fruit infestation over control treatment. Fruit borer infestation was then followed by T_4(5.24 infested fruits per plot) and it was also significantly different from other treatments of the experiment except T_1. Subsequently, it showed 61.32% decrease over absolute treatment. Number of infested fruit was then followed by T_5 (7.68 fruits per plot) which showed a 43.32% decrease of fruit infestation over control treatment. Later on, T_3 showed 8.77 fruit infestation per plot by fruit borer during the late fruiting stage of tomato plants in the experiment and 35.27% reduction of fruit infestation was exhibited compared to control treatment. However, there was no significant difference between T_3 and T_5. Infested fruit numbers were then followed by T_2 (10.35 fruits per plot) and T_6 (13.50 fruits per plot). Though numerically different, there is no significant variation between T_2 and T_6. However, they showed 23.61% and 13.50% decrease over control respectively. Lastly, the highest fruit infestation per plot (13.55 per plot) was obtained from control treatment (untreated). It showed significant variation from other treatments of the present experiment (Table no.8).

4.5.2. Effect of botanicals on the number of healthy fruits of tomato plants during late fruiting stage

In the current experiment, different treatments showed different numbers of healthy tomatoes in the late fruiting stage in reference to infestation induced by tomato fruit borer. The highest number (59.35 fruits/plot) of healthy fruit obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 82.72% increase over control treatment. Number of healthy fruits was then followed by T_4 (55.23 fruits per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed a 70.04% increase over absolute treatment. Number of healthy fruits was then followed by T_5 (50.78 fruits per plot) which significantly differed from other experimental treatments. It showed a 56.34% increase over control treatment. Later on, T_3 showed 46.50 healthy fruits per plot during the late fruiting stage of tomato plants in the experiment and a 43.16% increase in the number of healthy fruits was exhibited compared to control treatment. However, it was significantly different from any other treatments used in the experiment. Healthy fruit numbers were then followed by T_2 (42.67 fruits per plot) and showed 31.37% increase over control. Further, from T_6 we obtained 37.34 fruits per plot with a 14.96% increase over control. Lastly, the lowest number of healthy fruits per plot (32.48 per plot) was obtained from control treatment (untreated). Eventually, it showed significant variation from all other treatments of the present experiment(Table no.8).

4.5.3. Effect of botanicals on the weight of healthy fruits of tomato plants during late fruiting stage

In the current experiment, the weight of healthy fruits varied in different treatments. The highest weight (2908 gm/plot) of healthy fruits obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 88.83% increase over control treatment. Weight of healthy fruits was then followed by T_4 (2746 gm per plot) and it was also significantly different from other treatments of the experiment. Subsequently, it showed a 78.31% increase over absolute treatment. Weight of healthy fruits was then followed by T_5 (2415 gm per plot) which significantly differed from other experimental treatments. It showed a 56.81% increase over the control treatment. Later on, T_3 showed 2209 gm healthy fruits weight per plot during the late fruiting stage of tomato plants in the experiment and 43.44% increase in the weight of healthy fruits was exhibited compared to the control treatment. It was also significantly different from any other treatments used in the experiment. Subsequently, weight of healthy fruits obtained from T_2 is 1948 g per plot which showed 26.49% increase over control treatment. Healthy fruit weight was then followed by T_6 (1726 gm per plot) with a slight increase (12.07%) over control treatment. Lastly, the lowest weight of healthy fruits per plot (1540 gm per plot) was obtained from control treatment (untreated). Eventually, there is no significant difference between T_7 and other treatments (Table no.8).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was undertaken to assess the efficacy of some promising botanicals against tomato leaf miner and tomato fruit borer. Experimental work was conducted in the research field of the department of entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. There were seven treatments and three replication per treatment used for the experiment. The total research plot was divided into 21 units in a randomized complete block design (RCBD) in order to distribute the treatments. Neem leaf extract, Datura seed extract, garlic bulb extract, mahogany seed extract, black pepper seed extract, alamonda leaf extract, and control treatment were used as treatments in the experiment.

In the case of leaf infestation by tomato leaf miners, the lowest leaf infestation (2.08% per plant) during the vegetative stage was obtained from neem leaf extract and it was significantly different from any other treatment used in the experiment. Subsequently, it showed a 79.58% decrease in leaf infestation over the control (untreated) treatment. On the other hand, the highest leaf infestation (10.19% per plant) was obtained from the control treatment (untreated). It showed significant variation from all other treatments of the present experiment.

In the case of fruit infestation induced by tomato leaf miners, the lowest fruit infestation (3.18% per plot) during the maturity stage was obtained from neem leaf extract and it was significantly different from any other treatment used in the experiment. It showed a 78.27% decrease in fruit infestation over control (untreated) treatment. The highest fruit infestation (14.64% per plot) was obtained from the control treatment (untreated). It showed significant variation from all other treatments of the present experiment.

Tomato fruit borer attacked early, mid, and late fruiting stage in tomato plants. In the case of the early fruiting stage, the lowest number (2.67 fruits/plot) of infested fruit was obtained from neem seed extract is significantly different from any other treatments in the experiment. This treatment showed a 76.43% decrease of fruit infestation over control treatment. However, the highest fruit infestation per plot (11.33 per plot) was obtained from the control treatment (untreated). The highest number (48.33 fruits/plot) of healthy fruit in the early-stage was obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 70.59% increase over the control treatment. However, the lowest number of healthy fruits per plot (28.33 per plot) was obtained from the control treatment (untreated). Eventually, it showed significant variation from all other treatments of the present experiment. in terms of weight of healthy fruits, the highest weight (2449 gm/plot) of healthy fruits was obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 75.30% increase over the control treatment.

In the mid-fruiting stage, the lowest number (5.63 fruits/plot) of infested fruit was obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 65.41% decrease of fruit infestation over control treatment. However, the highest fruit infestation per plot (16.28 per plot) was obtained from the control treatment (untreated). The highest number (63.32 fruits/plot) of healthy fruit was obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 48.98% increase over the control treatment. However, the lowest number of healthy fruits per plot (42.50 per plot) was obtained from the control treatment (untreated). The highest weight (3103 gm/plot) of healthy fruits was obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed a 56.01% increase over the control treatment. The lowest weight of healthy fruits per plot (1989 gm per plot) was obtained from the control treatment (untreated).

In the late fruit-bearing stage, the lowest number (4.48 fruits/plot) of infested fruit was obtained from T_1 which is significantly different from any other treatments except T_4 in the experiment. This treatment showed a 66.93% decrease of fruit infestation over control treatment. Whereas, the highest fruit infestation per plot (13.55 per plot) was obtained from the control treatment (untreated). The highest number (59.35 fruits/plot) of healthy fruit was obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed an 82.72% increase over the control treatment. However, the lowest number of healthy fruits per plot (32.48 per plot) was obtained from the control treatment (untreated). On the other hand, the highest weight (2908 gm/plot) of healthy fruits obtained from T_1 which is significantly different from any other treatments in the experiment. This treatment showed an 88.83% increase over the control treatment. Lastly, the lowest weight of healthy fruits per plot (1540 gm per plot) was obtained from the control treatment (untreated).

Recommendations

Following the major findings of the experiment, several concluding remarks and recommendations are given-

- Tomato plants are affected by tomato leaf miners and tomato fruit borers, however, tomato leaf miners attacked first.
- Tomato fruits are affected by fruit borers mostly at the mid-fruit-bearing stage.
- The number of fruits is highest at the mid-fruit-bearing stage.
- Neem leaf extract is most effective against pest complex of tomato plants.

CHAPTER VI

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