EFFECT OF SOME SELECTED INSECTICIDES AND BOTANICALS AGAINST INSECT PESTS FOR YIELD AND SEED QUALITY OF TOMATO

NOWSHER AHMED MOON

INSTITUTE OF SEED TECHNOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

JUNE 2021

EFFECT OF SOME SELECTED INSECTICIDES AND BOTANICALS AGAINST INSECT PESTS FOR YIELD AND SEED QUALITY OF TOMATO

BY

NOWSHER AHMED MOON

REGISTRATION NO. : 13-05453

A Thesis
Submitted to the Institute of Seed Technology
Sher-e-Bangla Agricultural University, Dhaka
partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)

IN

SEED TECHNOLOGY

SEMESTER: JANUARY- JUNE, 2019

Approved by:

Prof. Dr. Ayesha Akter
Department of Entomology
SAU, Dhaka
Supervisor

Prof. Dr. Md. Ismail Hossain
Department of Horticulture
SAU, Dhaka
Co-Supervisor

Prof. Dr. Md. Ismail Hossain
Chairman
Examination Committee
&
Director
Institute of Seed Technology

INSTITUTE SEED TECHNOLOGY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF SOME SELECTED INSECTICIDES AND BOTANICALS AGAINST INSECT PESTS FOR YIELD AND SEED QUALITY OF TOMATO"** submitted to the **INSTITUTE OF SEED TECHNOLOGY**, 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 **SEED TECHNOLOGY**, embodies the result of a piece of bonafide research work carried out by **NOWSHER AHMED MOON**, Registration No. **13-05453** 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 been duly acknowledged.

June 2021

Dhaka, Bangladesh

Prof. Dr. Ayesha Akter
Department of Entomology
SAU, Dhaka

Supervisor

DEDICATED TO
ALL MY TEACHERS

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the Almighty Allah for His ever ending blessings for the successful completion of the research work.

The author wishes to express his gratitude and best regards to his respected Supervisor, Prof. Dr. Ayesha Akter, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, for her continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.

The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, Prof. Dr. Md. Ismail Hossain, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.

The author further feels to express his heartfelt thanks to the Director, Prof. Dr. Ismail Hossain, Institute of Seed Technology along with all other teachers and staff members, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.

The author feels proud to express his deepest and endless gratitude to all of his course mates and friends specially Kazi Mohammad Rabbi,Sourav Saha to cooperate and help him during taking data from the field and preparation of the thesis.

The author expresses his heartfelt thanks to his beloved parents,Elder Brother, Reverend Aunt(Khala) and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.

The Author

EFFECT OF SOME SELECTED INSECTICIDES AND BOTANICALS AGAINST INSECT PESTS FOR YIELD AND SEED QUALITY OF TOMATO

ABSTRACT

The present experiment was conducted to study the effect of some selected insecticides and botanicals against insect pests for yield and seed quality of tomato at the farm of Shcr-e-Bangla Agricultural University, Dhaka during the period from October 2019 to March 2020. The experiment consisted of 7 treatments *viz*,T_1 = Spinosad 45EC @ 0.4 ml/L of water, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water, T_4 = Proclaim 5SG @ 1.0 g/L of water, T_5 = Mig 5EC @ 1.0 ml/L of water, T_6 = Admire 20SL @ 0.5 ml/L of water and Untreated control, applied at 7 days interval through out the cropping season. The experiment was laid out in Randomized Complete Block Design with three replications. Among different treatments, T_6 (Admire 20SL) showed the best performance on the incidence of whitefly, aphid and leaf miner plant^{-1} and showed lowest number (2.97, 4.00 and 1.21, respectively) and gave 72.45%, 80.55% and 72.26% reduction of incidence over control, respectively and regarding borer infestation of tomato, this treatment also showed highest healthy fruit plant^{-1} by number (25.87) and weight (1.72 kg) compared to untreated control which showed least performance. Treatment T_6 (Admire 20SL) also showed highest healthy fruit yield (86.18 t ha^{-1}) and maximum 68.81% increase of healthy fruit yield over control while the lowest infested fruit yield (3.02 t ha^{-1}) was obtained with this treatment which was followed by T_3 (Bioneemplus 1EC) whereas untreated control gave lowest healthy and the highest infested fruit yield (51.05 and 10.18 t ha^{-1}, respectively).The yield contributing parameters and seed yield of tomato, treatment T_6 (Admire 20SL) performed the highest plant height (94.29 cm), number of branches plant^{-1} (11.25), number of flower clusters plant^{-1} (8.63), number of fruits cluster^{-1} (6.37), single fruit weight (66.64 g), seed weight fruit^{-1} (0.57 g), seed weight plant^{-1} (12.73 g) and seed yield (636.70 kg ha^{-1}) whereas untreated control treatment showed poorest performance.In case of seed quality parameters, treatment T_3 (Bioneemplus 1EC) treated plot showed the highest seed germination (97.23%), root length (3.41 cm), shoot length (5.25 cm) and seed vigor index (842.70) followed by T_6 (Admire 20SL) whereas untreated control plot showed the lowest results (83.80%, 1.91 cm, 3.75 cm and 473.70, respectively). From the above result, it may be concluded that the treatment T_6 (Admire 20SL) showed the best performance in suppressing whitefly, aphid and leaf miner plant^{-1} which resulted higher healthy fruit yield and seed yield followed by T_3 (Bioneemplus 1EC). In case of seed quality parameters, T_3 (Bioneemplus 1EC) showed best performance while T_6 (Admire 20SL) showed comparatively better performance.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.	=	And others
e.g.	=	exempli gratia (L), for example
FAO	=	Food and Agricultural Organization
i.e.,	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
M.S.	=	Master of Science
No.	=	Number
^{o}C	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tomato *(Solanum lycopersicum* L.) is one of the most highly praised vegetables consumed widely. It is the major source of vitamins and minerals. Tomato belongs to the family Solanaceae which are diploid with 12 pairs of chromosomes (2n = 24) (Jenkins, 1948). This crop originated from the South American and the first used as a food in Mexico and extended worldwide. It is widely employed as salad vegetable and is taken with great relish. Globally, it is one of the most important economically growing vegetable crops in terms of human consumption due to its valuable nutritional components such as niacin, riboflavin, thiamine, beta-carotene, lycopene, iron, magnesium, phosphorus, potassium, and sodium (Kavanaugh *et al*. 2007, Rouphael *et al*. 2010).

After potato, tomato is the second- largest vegetable crop grown all over the world. Worldwide 4,762,129 ha cultivable land was devoted to tomato cultivation in 2018 and the total production was about 182,258,016 metric tons (FAO, 2018).

In Bangladesh, Tomato has been growing as the second horticultural crop after potato which is cultivated in two seasons annually. For tomato cultivation in both winter and summer season, 68,366 acres cultivable land (8.59% of total cultivable land) was dedicated and the total production was about 3,88,725 metric tons in the year of 2016-2017 (BBS 2017).

Among the various factors that limit its production and quality, insect-pest infestation is undoubtedly the most important one. Worldwide, more than one hundred different insect pests have been recorded on tomato crop (Taleker *et al.* 1983). Tomatoes are subject to insect pests that affect plants directly by feeding and indirectly by transmission of diseases from the time of emergence up to harvesting (Khan 2018, Bhattacharjee and Dey 2014). Insect pests such as leaf miners, *Tuta absoluta*, aphids and flea beetles affect the foliage while fruit borers affect the tomato fruits (Kandil *et al.* 2020, Syed 2015, Taha *et al.* 2013). These insect pests not only cause major losses in its quality and quantity but act as vector of diseases (Dharumarajan *et al.* 2009).

Among these, an invasive insect pest, tomato leaf miner, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) has become the most destructive pest for tomato production in different parts of the world (Zappala *et al.* 2013, Tonnang *et al.* 2015, Biondi *et al.* 2018). In Bangladesh, Tomato leaf miner, *Tuta absoluta* is newly emerged as an invasive pest of tomato and causing an explicative decrease in tomato production. *T. absoluta* can cause high production losses of tomato (i.e, up to 100%) in open field and greenhouse cultivation if left uncontrolled (Biondi *et al.* 2018, Bajracharya *et al.* 2016).

Whitefly (*Bemisia tabaci*, Homoptera: Aleyrodidae) and aphid (*Myzus persicae*, Homoptera: Aphidae), obligates phloem-feeding insects, are two economically important pests affecting tomato production, both under protected and field conditions. Adults of these insects suck cell contents of infested plants and while feeding, excrete huge amounts of honeydew that eventually promotes development of sooty mould, which reduces the photosynthetic efficiency of the plant (Jazzar and Hammad, 2003). Severe infestation can lead to reduced plant vigour and growth, chlorosis, uneven ripening or reduced crop yield (Hammad *et al.* 2000). Phloem-feeding insects, in addition to transmitting viruses, pose additional challenges as they may introduce enzymes into the phloem which may alter plant defense signaling (Kaloshian and Walling 2005; Walling 2008).

Tomato fruit borer *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is also a key pest which infest buds, flowers and fruits of tomato. The adults lay majority of the eggs on the upper and lower leaf surfaces of the first four leaves in the top canopy. The larvae scrape the tomato foliage until early or late second instar stage. The larva bores into the fruit making it unfit for marketing. It infests the marketable parts of the tomato plant, that is, fruits which makes fruit unfit for human consumption causing considerable crop loss (Kashyap 1983). Various workers reported yield losses to the extent of 42.55 percent (Kashyap and Verma 1986), 51.20 percent (Singh and Narang 1990) and 42.50 percent (Dhandpani and Balasubramanium 1984) due to attack of *Helicoverpa armigera* in tomato crop. Whereas, Sivakumar *et al.* (2003) recorded up to 55 percent yield loss in tomato

Farmers involved in tomatoes production using synthetic pesticides which is the most convenient for suppressing these pests and diseases which are managed by a mixture of protective and curative synthetic chemicals yet the losses in the field are still high (Kansiime *et al.* 2017, Rutiganga 2015). Since synthetic pesticides partially solve the threat, they also have negative effect on environment due to nonbiodegradability, health hazards to the farmers and consumers, pollute the environment, toxicity to nontarget natural enemies and other beneficial organisms (Dar *et al*. 2021, Saberi *et al.* 2020, Bhattacharjee and Dey, 2014). Commonly used pesticides in vegetables are Monocrotophos, Acephate, Endosulfan, Carbofuran and Chlorpyrifos.

Synthetic pesticides could be complemented with biopesticides as substitute pest and disease management products due to non-compliance with the market requirements (Engindeniz and Ozturk 2013). Biopesticides are agents that are obtained from plants, microorganisms and animals which are used to control crop pests and pathogens (EPA 2021). In addition, biopesticides have been getting much practical consideration as alternates to synthetic chemical plant protection products due to biodegradability and reduction of risks associated with use of synthetic chemicals (Liu *et al.* 2021, Rutinganga 2015).

Use of different synthetic and biopesticides have significant effect on seed quality of vegetables. Ramphal *et al*. (2003) confirmed the seed treatment with neem oil produces the highest seedling length and high seed vigour index in tomato crop. Shakir *et al*. (2015) reported that excess use of synthetic chemical inhibit seed quality such as seed germination, shoot and root length, fresh and dry weight of tomato.

Considering the above fact, the present investigation aimed to the effect of some selected insecticides and botanicals on yield and seed quality of tomato was undertaken with the following objectives:

- to evaluate the effectiveness of selected insecticides and botanicals on tomato yield and seed quality and
- to assess the impacts of selected insecticides and botanicals on seed quality of tomato

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the important vegetable in Bangladesh and as well as many countries of the world and a major source of vitamins and minerals. The experiment was conducted in order to control insect pest of tomato on yield and seed quality of tomato using some selected insecticides and botanicals. Sutton (1991) reported aphids, whitefly, cutworm, leaf miner, red spider, mite, thrips, and tomato hornworm as the pest of vegetative stages of tomato. Fruit borer, fruit worm, budworm are the pest of flower, fruits and leaves. Large number can defoliate tomato plant. Of these insect pests aphids, whitefly, leaf miner and red spider mite are most damaging and could cause 25-60 percent yield loss (Khan and Griffin, 1999). Available literatures related to the present study are reviewed in this section. The review of literature related to "effect of some selected insecticides and botanicals on yield and seed quality of tomato" by utilizing some botanicals and chemical insecticides in tomato" cited here with suitable headings:

2.1 Origin and cultivation of tomato

The wild relatives of cultivated tomato *(Solanum lycopersicum* L.) are native to western South America, including the Galapagos Islands (Peralta *et al.* 2008). After its introduction to Europe, tomato cultivation found success mainly in the Mediterranean countries, including Spain and Italy, which formed secondary centers for diversification (Garcia-Martinez *et al.* 2006).

Tomatoes grow well in well-drained, deep, uniform clay or silty loam soils, which are high in organic matter (Saeed *et al.* 2007). The crop is adapted to a wide range of climatic conditions and the optimum temperature required for growth and development for most varieties lies between 21 and 24°C (Naika *et al.* 2005). According to these author, tomato is moderately tolerant to a wide range of pH (level of acidity), but grows well in soils with a pH of 5.5 - 6.8 with adequate nutrient supply and availability.

Tomato is used in various forms, such as fresh salad, cooked foods, and in processed forms like ketchup and paste (Saeed *et al.* 2007). Tomatoes have numerous health benefits and contribute to a well-balanced diet (Rao and Agarwal, 1999). Tomato is an important source of antioxidant compounds such as lycopene and nutrients such as vitamin A, vitamin C, potassium, phosphorous, magnesium and calcium as well as calories (Miller *et al.* 2002).

Tomato yields in the tropics vary widely, between one to 23 tons per hectare compared to the temperate regions, where yields of 10 to 20 tons per hectare have been realized (Lanny, 2001). Yields are lowest in tropical Africa as a result of both abiotic and biotic factors of which the latter include primarily insect pests, diseases, and weeds (Tumwine *et al.* 2002).

2.2 Major insect pests of tomatoes

Insect pests are one of the most significant constraints to tomato production. According to Lange and Bronson (1981) between 100 and 200 pest species are reported to attack tomatoes worldwide. According to Waiganjo *et al.* (2006) some of the major tomato pests reported include spider mites, *Tetranychus* spp. (Acari: Tetranychidae), tomato fruit borer (African bollworm), *Helicoverpa armigera,* (Lepidoptera: Noctuidae), whiteflies, *B. tabaci,* (Hemiptera: Aleyrodidae) leafminers, *Liryomyza* spp. (Diptera: Agromizydae) thrips, *T. tabaci* and *F. occidentalis,* (Thysanoptera: Thripidaej and russet mites, *Aculops lycopersici* Massee (Acari: Eriophyidae).

Various insects and mites cause damage to tomato plants at all stages of growth as a result of direct feeding and through transmitting disease causing organisms (Lange and Bronson, 1981). According to them, damage on fruits was observed in the form of scarring, tissue reduction, and aberrations in shape or color making the fruits unmarketable. Fruits also become contaminated by insect presence, insect excreta, insect parts, cast skins, and eggs which reduce market acceptability.

Insects attack tomatoes from the seedling stage until harvesting. The major soil insect pests attacking tomato seedlings are cut worms, *Agrotis* spp., (Lepidoptera: Noctuidae) which damage by cutting off the plant just below the surface of the soil making the plant fall over, and, chafer grubs, *Schizonycha* spp., (Coleoptera: Scarabaeidae) which feed on the roots of the plant (Waiganjo *et al.* 2006). Foliage pests such as aphids, *Aphis gossypii*, thrips and whiteflies suck plant sap and cause leaf distortion and stunting of tomato plants (Waiganjo *et al.* 2006). More importantly, *F. occidentalis* has been recorded on tomatoes, and is the key vector of the tomato spotted wilt virus (TSWV) disease (Kirk and Terry 2003). Whiteflies are known vectors of the tomato yellow leaf curl viruses (TYLCV) which are the most widespread and currently rank third among the economically and scientifically most important tomato viruses worldwide (Scholthof *et al.* 2011).

Feeding by *Helicoverpa armigera* (tomato fruit borer) causes tomato fruit to rot as a result of secondary infection by bacterial and fungal pathogens which penetrate the fruit through the feeding holes (Waiganjo *et al.* 2006). *Helicoverpa armigera* is one of the most destructive insect pests of tomato, causing yield losses as high as 70% due to fruit boring (Varela *et al.* 2003). The red spider mites, *Tetranychus urticae* Koch, infest tomato leaves and suck the sap thus interfering with nutrient uptake and may be serious pests in hot weather and during drought (Knapp, 1999). Severe infestation by these insect pests usually causes significant yield loss and may result in total crop loss.

Very few studies related to growth, yield and development of tomato and pests management through botanicals and/or chemicals have been carried out in the country as well as many other developing countries of the world. So the research works so far done in Bangladesh are not adequate and conclusive**.** Nevertheless, some of the important and informative description of common insect pests of tomato in Bangladesh are reviewed under the following heading:

2.2.1 Whitefly

Whiteflies (*Bemisia tabaci*) are the most common and most problematic insect pests of tomatoes. Despite their name, whiteflies are not true flies; they are closely related to aphids (Ateyyat *et al.* 2009). Adults are about one-sixteenth of an inch long and have four wings covered with a white, powdery material. They rest with their wings folded tent-like over their backs and are weak fliers (Hammad *et al.* 2000). Immature whiteflies are very different from adults. Except for the newly hatched crawlers, immatures are immobile scale-like insects. They look like tiny, oval scales attached to the undersides of leaves. Whiteflies cause damage by sucking sap from plants and producing honeydew, which supports the growth of sooty mold. These insects can build up to very high levels in protected greenhouse environments and are capable of causing severe crop loss (Ateyyat *et al.* 2009, Dar *et al.* 2021). Female whiteflies lay about 150 eggs, usually attached to the undersides of leaves. In greenhouses, eggs hatch in 4 to 7 days into tiny, white, oval crawlers. These move a short distance, insert their mouthparts into the plant tissue, produce a protective scale-like covering, and do not move for the rest of their nymphal development (Dar *et al.* 2021). Nymphs go through three instars and a pupa stage before reaching adulthood. The winged adults emerge through a slit in the pupal covering. Full development usually takes 25 to 30 days in greenhouses. Adults may live up to 30 days (Engindeniz and Ozturk 2013, Dar *et al.* 2021).

The whiteflies cause damage to plant by three means, (i) large population of nymphs and adults suck sap directly from plant and greatly reduce yield, (ii) heavy colonization of *B. tabaci* can cause serious damage to some crops due to honeydew excreted by all stages, particularly the late nymphal instars which encourages growth of “sooty mould” that affect yield both in quantity and quality and (iii) they reduce crop yield through transmission of viral diseases (Kajita and Alam 1996).

The adult of whitefly is soft and pale yellow, change to white within few hours due to deposition of wax on the body and wings (Haider, 1996). Eggs are laid indiscriminately almost always on the under surface of the young leaves. The whitefly, *Bemisia tabaci* is an important pest worldwide. The whiteflies are very small, fragile and active insects, jump from plant to plant with very slight disturbance and because of this there is great difficulty in handling them during experimental work (Parihar *et al.* 1994).

Brown and Bird (1992) have pointed out the increased prevalence as well as expanded distribution of whitefly borne viruses during the last decade and resulting devastating impact. Yield loss range from 20-100 percent, depending on the crop, season, vector prevalence and other factors.

The whitefly acts as a mechanical vector of many viral diseases (Butani and Jotwani, 1984), Young plant may even die in case of severe infestation. The pest is active during the dry season and its activity decreases with the onset of rains. As a result of their feeding the affected parts become yellowish; the leaves become wrinkle, and curl downwards and eventually fallen off. This happens mainly due to viral infection. Bock (1982) reported yield loss due to *Bean golden mosaic virus* (BGMV) varied from 40-100%, depending on age and variety.

2.2.2 Leafminer

Tuta absoluta is a micro lepidopteron moth with rapid reproduction capability (Retta and Berhe 2015, Megido *et al.* 2013). This pest may complete about 10–12 generations per year under suitable environmental conditions. The life cycle of *T. absoluta* consists of 4 developmental stages: egg, larva, pupa and adult which takes about 24-28 days to complete it, depending on temperatures (Joshi *et al.* 2018). The developmental periods (Egg to adult emergence) are 76.3, 39.8 and 23.8 days at 14°C, 19.7°C and 27.1°C, respectively (Barrientos *et al.* 1998)]. Adults are nocturnal moth and active at night and hide in the leaves in the day time. The adult is consists of black spots (Retta and Berhe, 2015) and grey to silvery scales (Berxolliand Shahini, 2017) and black spots with silver or brown speckle on wings. They have also one pair of filiform (bead-like structure) antennae (Ballal *et al.* 2016). Adult lifespan ranges between 6–7 days for males and 10–15 days for females (Desneux *et al.* 2010). Females lay about 200 eggs during their lifespan (Hossain *et al.* 2016).

Currently, the tomato leaf miner, *Tuta absoluta*, is the major insect pest affecting tomato production. It infests the leaves, stems, and fruits (Tumuhaise *et al.* 2016), causing between 80–100% loss in yield, both in protected and native fields if left uncontrolled (Desneux *et al.* 2010). Tomato leaf miners a serious pest of tomato it belongs to the order Lepidoptera and Family Gelechiidae. Leaf miners attack many row crops but are particularly damaging on celery, crucifers, cucurbits, okra, potato and tomato. Leaf miners population peaks between October and March. The two major species of leaf miner that cause problems in vegetables are leaf miner - *Liriomyza sativae* and most commonly *Liriomyza trifolti* - sometimes referred to as the celery leaf miner but which has no approved common name. The adults are small yellow and black flies about the size of a gnat, the female punctures or "stipples" the leaves with her ovipositor to lay eggs in the leaf tissue or to feed on sap (Birhan, 2018).

Leaf miner damage is easily recognized by the irregular serpentine mines in leaves, which are caused by feeding larvae. Heavy leaf mining damage can reduce photosynthesis and cause leaf desiccation and abscission. The yellow maggots with black, sickle-shaped mouthparts feed on the mesophyll or chlorophyll tissue between upper and lower leaf surface leaving a winding trail or pattern through the leaf. The tunnel is clear with the exception of a trail of black fecal material left behind as the maggot feeds (Birhan, 2018 and Gajanana *et al.* 2006).

There are three larval stages. Each larval instar is completed in 2-3 days. The larvae feed approximately 7 days growing to about 1/10 to inch in length prior to exiting the leaf to pupate on the ground or mulch under infested plants. Leaf miner injury is readily visible to the grower but healthy plants can tolerate considerable damage without excessive loss of vigor and yield. Heavily damaged leaves will often drop, due in part to entry of pathogenic organisms into old mines (Midingoyi *et al.* 2019 and Gajanana *et al.* 2006).

Due to its feeding habit, this pest is resistant to many insecticides. Cyromazinc (Trigard) alternated with abamectin (Agrimek) arc effective against leafminer in tomato. Both of these products have limited crop registrations and must not be used on unregistered crops. Some other materials that may be used to conserve beneficial include azadiraehtin (Neem ix) and Neem seed oil. Both products are approved for use by organic growers. Field sanitation is an important control tactic that is overlooked, when crops are not present in the fields, leafminers can survive on a variety of broad-leaf weeds. These plants serve as reservoirs for pest (Gajanana *et al.* 2006 and Allahyari 2017).

Oloan *et al.* (2003) reported that the population of leaf miner on selected highland crops was assessed and the percent leaf injury caused by adult and larval leafminer and effect of leaf miner population and leaf injury on the yield of garden pea, potato, onion, and tomato were determined. Population of leaf miner adult (8.15/m^2) and leaf injury (47.5%) were highest in potato. Larval count was highest in onion (3.03/leaf) and leaf injury by leaf miner larva was highest in garden pea (31.25%). Tomato had the lowest count of adult and larval leaf miner and the lowest leaf injury of all the crops tested. An increase in leaf injury by leaf miner adult and larva decreased yield by 0.26% and 0.87%, respectively.

2.2.3 Aphid

Most aphid species reproduce without mating and give birth to live aphid nymphs rather than laying eggs. Under the best conditions, the nymphs, which are usually all females, can reach maturity and begin bearing young of their own within 7 days (Pickel *et al.* 1994, Nault and Speese 2001). Because of this high reproductive rate, heavy infestations can develop quickly. Mature females may be winged or wingless depending on environmental conditions. Infestations easily spread through the wind1assisted flight of winged females. Although aphids usually have a fairly narrow host range, many species occur on a number of vegetable plants as well as certain weeds (Hummel, 2004). Outdoors, aphids are preyed on and parasitized by many beneficial insects, and this naturally occurring biological control normally keeps aphid populations in check (Zalom 2003).

Aphid feeds by inserting a stylet into plant tissues and withdrawing plant sap. Curling and stunting of leaves and stems is the most obvious damage. This damage reduces fruit set and, if severe enough, can kill the plant. In addition as a byproduct of feeding, aphids excrete honeydew, which acts as a growth medium for sooty mold. The black-colored mold, on the foliage, reduces the light available for photosynthesis and on the fruit, causes discoloration and acts as a solar heat sink, increasing the severity of fruit sunburn (Farrar *et al.* 1986). High levels of aphids cause significant fruit quality and yield losses. Fruit quality loss also results from sunscald because of plant defoliation resulting from aphid feeding (Hummel 2004).

Aphid (*Myzus persicae*, Homoptera: Aphidae), obligates phloem-feeding insect, is economically important pest affecting tomato (*Solanum lycopersicum*) production, both under protected and field conditions. Adults of this insect suck cell contents of infested plants and while feeding, excrete huge amounts of honeydew that eventually promotes development of sooty mould, which reduces the photosynthetic efficiency of the plant (Jazzar and Hammad, 2003). Severe infestation can lead to reduced plant vigour and growth, chlorosis uneven ripening or reduced crop yield (Hammad *et al.* 2000). Phloem-feeding insects, in addition to transmitting viruses, pose additional challenges as they may introduce enzymes into the phloem which may alter plant defense signaling (Kaloshian and Walling 2005; Walling 2008).

Aphids are small, soft-bodied insects with long slender mouthparts that they use to pierce stems, leaves, and other tender plant parts and suck out fluids. Almost every plant has one or more aphid species that occasionally feed on it. Many aphid species are difficult to distinguish from one another; however, management of most aphid species is similar. Aphids have soft pear-shaped bodies with long legs and antennae and may be green, yellow, brown, red, or black depending on the species and the plants they feed on. A few species appear waxy or woolly due to the secretion of a waxy white or gray substance over their body surface. Most species have a pair of tubelike structures called cornicles projecting backward out of the hind end of their body. The presence of cornicles distinguishes aphids from all other insects (Beale *et al.* 2006).

Generally adult aphids are wingless, but most species also occur in winged forms, especially when populations are high or during spring and fall. The ability to produce winged individuals provides the pest with a way to disperse to other plants when the quality of the food source deteriorates. Although they may be found singly, aphids often feed in dense groups on leaves or stems. Unlike leafhoppers, plant bugs, and certain other insects that might be confused with them, most aphids don’t move rapidly when disturbed. Young aphids are called nymphs. They molt, shedding their skin about four times before becoming adults. There is no pupal stage. Some species produce sexual forms that mate and produce eggs in fall or winter, providing a more hardy stage to survive harsh weather and the absence of foliage on deciduous plants. In some cases, aphids lay these eggs on an alternative host, usually a perennial plant, for winter survival (Saikia *et al.* 2000).

Aphids are most commonly seen in spring and autumn when the weather is mild and humid. They are small, soft-bodied, green, grey or black insects with thin legs. Aphids may be winged or wingless and are usually slow moving. The insects cluster on the tips of the plant shoots. By sucking the sap they reduce the vigour of the plants. Aphids can also be carriers of virus disease which can severely reduce yields and quality. When the weather is warm, many species of aphids can develop from newborn nymph to reproducing adult in seven to eight days. Because each adult aphid can produce up to 80 offspring in a matter of a week, aphid populations can increase with great speed (Zaki 2008).

Low to moderate numbers of leaf-feeding aphids aren't usually damaging in gardens or on trees. However, large populations can turn leaves yellow and stunt shoots; aphids can also produce large quantities of a sticky exudate known as honeydew, which often turns black with the growth of a sooty mold fungus. Some aphid species inject a toxin into plants, which causes leaves to curl and further distorts growth. A few species cause gall formations (Beale *et al.* 2006).

2.2.4 Fruit borer

The tomato fruit borer (*Helicoverpa armigera Hub.)* has been identified as a major pest of tomato in many countries of the world and cause damage to the extent of about 50-60 percent fruits (Singh and Singh, 1977). It has a wide range of hosts including chickpea, pigeon pea (Arhar), cow pea (as the pod borer), blackram (as gram caterpillar), various leguminous crops (as pod borer), cotton (as Amcrican ball worm), maize (as cobworm), millets, sorghum and oil seed crops such as sunflower, soybean, groundnut etc. (Haque, 1995). It has been reported to infest 181 cultivated and uncultivated plant species in India, distributed in 45 families (Manjunalh *et al.* 1985). Eggs of tomato fruit borer are 0.4-0.5 mm in diameter, nearly spherical with flattened base, glistering yellowish-white in color, changing to dark brown prior to hatching (Singh and Singh, 1977). The fully grown larva is about 40 mm in length, general color varies from almost black, brown or green to pale yellow or pink and is characterized by having a dark band along the back to each side of which there is a pale band. The larval period varies from 15-35 days (Singh and Singh, 1977). The light brown pupa is about 22 mm in length, living in the soil, is seldom seen unless special sampling techniques are used (Nachiappan and Subramanium 1974). Husain *et al*. (1998) reported that stout bodied moth has a wing span of 40 mm. General color varies from dull yellow or olive grey to brown with little distinctive marking. The moths become sexually mature and mate about four days after emergence from the pupae having fed from the nectars of plants. The moth is only active at night and lays eggs singly on the plant. The larva passes through six instars and the larval period varies from 15-35 days (Ewing *et al.* 1947). The larvae of this pest bore circular holes and thrust only a part of their body inside the fruit and eat the contents. If the fruit is bigger in size, it is only partly damaged by the caterpillar but later it is invariably invaded by fungi, bacteria and spoiled completely. A small-darkened partially healed hole at the base of the fruit pedicle is evident. The inside of the fruit has a watery cavity that contains frass and decay. Tomatoes ripen early but not usually consumable and marketable (Husain *et al*. 1998).

Tomato fruit borer, *Heticoverpa annigera* (Hub.) is one of the serious pests attacking tomato. The pest causes damage to the extent of about 50-60 percent fruit (Singh and Singh, 1977). Data revealed that damage by this pest might be up to 85-93% (Tewari, 1985). Due to severe infestation fruits as well as seeds maturation hampered greatly (Dhamo *et al.* 1984). The viability of the seeds is reduced and quality seed is degraded. They bore circular holes and thrust only a part of their body inside the fruit and eat the contents. If the fruit is bigger in size, it is only partly damaged by the caterpillar hut later it is invariably invaded by fungi bacteria and spoiled completely. A small-darkened partially healed hole at the base of the fruit pedicel is evident. The inside of the fruit has a watery cavity that contains frass and decay. Tomatoes ripen early but not usually marketable. Sometimes the damage by this pest is followed by fungal infection which causes rotting of the fruits (Husain *et al.* 1988).

Jitender *et al.* (1999) conducted the estimation of avoidable yield loss due *to* fruit borer, *Helicoverpa armigera,* in tomato (cv. Roma) planted at three dates (first week each of April, May and June), showed that in crop transplanted in the first week of April yield loss to the extent of 105.29, 76.02 and 57.02% could be avoided by giving three sprays of acephate (0.05%), fenvalerate (0.01%) and endosulfan (0.05%), respectively. In crop transplanted in the first week of May yield loss of 32.64, 28.04 and 18.50% could be avoided as a result of sprays of respective insecticides. Whereas in June-transplanted crop, 2 sprays each of acephate, fenvalerate and endosulfan helped in avoiding 25.03, 13.91 and 11.76% yield loss, respectively. Irrespective of dates of transplanting, the average yield loss to the extent of 49.27, 36.54 and 26.59% could be avoided by sprays of acephate, fenvalerate and endosulfan.

Pinto *et al.* (1997) high infestations of the noctuid *Helicoverpa armigera* on field-cultivated tomatoes. The infestations caused serious damage, resulting in a reduced, and at times, inadequate commercial return. Notes are given on the geographic distribution, host plants, morphology, biology, ecology, injuriousness, natural enemies and control of the pest, When the population exceeds the economic threshold, control can be effected using systemic products such as phosphoric esters (accphate, methomyl, dimethoate) or synthetic pyrethroids (alphamethrin [alpha-cypermelhrin], deltamethrin); the latter must be used once only so as not to favour the build-up of miles. Agronomic methods of defense may also be used, such as weeding to kill the pupae, deep ploughing of adjacent uncultivated areas during the period of oviposition, and elimination of weeds on which the females oviposit.

Tomato fruit borer is a versatile and widely distributed polyphagous insect. Beside Bangladesh, this pest occurs in Southern Europe, probably the whole of Africa, the Middle East, India, Central and South East Asia to Japan, Philippines, Indonesia, New Guinea, the eastern part of Australia, New Zealand and a number of pacific islands except for desert and very humid region (Singh 1972).

Tomato fruit borer *Helicoverpa armigera* (Hub.) is a polyphagous insect, belonging to the family Noctuidae of the order Lepidoptera. There are several genera under this family and the genus *Heliothis* contains more number of species, including *Heliothis armigera,* which is the serious pest of tomato (Mishra *et al.* 1996).

Adult females lay eggs on the flowering and fruiting structures of pulse crops, where voracious larval feeding leads to substantial economic loss (Reed and Pawar, 1982). The adult insect is a pale-brown or reddish-brown moth with a black dot on each of the *forewings.* Full-grown caterpillars are 44-48 mm long, apple green in color *with* whitish and dark-grey broken longitudinal stripes. Full-grown caterpillars drop down to ground and pupate in the soil (Butani and Jotwani 1984). Incubation, larval and pupal periods is 2-4, 15-24 and 10-14 days, respectively. Eggs are generally laid singly on the leaves at the top of the plant or on the flowers or on the fruits. After 1-3 days of hatching the larvae begin feeding. They feed inside the fruit when only the posterior of the larval body is visible from outside. When first instar larvae emerged from eggs and fed on leaves, occasionally on inflorescence, and some burrowed into fruit when they reached the 3^{rd} instar. During the 4^{th} and 5^{th} instars, they fed alternately on leaves and fruit, and occasionally on stems. Towards the end of their development, the larvae went through a searching phase to look for a shelter for metamorphosis. This typical sequence could *be* altered and become *more* complex in relation to the emerging site of the larvae. Green fruits of tomato are usually damaged by larvae of at least 7-8 days old which made several entry holes. Normally there is only one larva per green fruit, in which they complete their life cycle (Sutton 1991).

2.3 Management of insect pest using synthetic and botanical pesticides

The term “pesticide” includes any substance used for the control of pests during production, storage, transport, marketing, or processing of food for man or animals and which may be administered to animals for the control of insects or arachnids in or on their bodies. Pesticides are toxic chemicals used in preventing, destroying, repelling, or mitigating pests (USEPA 2005). Pesticides are most commonly used chemical substances in agricultural sector in order to increase the agricultural efficiency. Use of indiscriminative and improper pesticides in the agriculture sector poses serious environmental, human and animal health problems (Carson 2007).

2.3.1 Synthetic pesticides

The major classes of synthetic pesticides for agricultural use include organochlorines, organophosphates, carbamates, and pyrethroids, among others (Eldridge, 2008). Most synthetic pesticides act by interfering with biochemical and physiological processes that are common to a wide range of organisms (Pretty and Bharucha 2015). Synthetic insecticides have a negative impact on farmers, consumers and the environment (Pimentel and Greiner 1997). According to Gitonga *et al.* (2010), dimethoate, abamectin, imidacloprid, alpha-cypermethrin, and beta- cyfluthrin are the most common insecticides used against insect pests in vegetable production systems. The demand for high tomato fruit quality is a factor that often increases the use of synthetic pesticides to keep pests and diseases below economic thresholds in tomato agro-ecosystems (Hamilton and Toffolon 1987). According to Pimentel and Greiner (1997), majority of smallholder vegetable farmers rely on spraying synthetic pesticides to reduce the damage from pests and this has led to development of resistance by pests, resurgence of pests and the development of secondary pests and elimination of natural enemies. There have been reports of pest resurgence on tomatoes due to high use of pesticides in different parts of the world. Examples include increased populations of African bollworms, *H. armigera* and cabbage looper, *Trichoplusia ni* (Hubner) (Lepidoptera: Noctuidae) after treatment with methomyl and carbaryl (Hoffmann *et al.* 1996). Similar increases were reported after applications of endosulfan (Campbell *et al.* 1991). Populations of leafminers, *Liriomyza salivae* also increased after methomyl treatments (Oatman *et al.* 1983) and chemical control of African bollworm resulted in tomato pest resurgences (Salas 1992). Thomas *et al.* (1990) also reported the effect of deltamethrin in reducing predator populations significantly.

Shiberu (2020) carried out a study in open farmer's fields by irrigation water for the period from October to March 2018/2019 for two consecutive years. Two new insecticides Sivanto Energy EC 85 and Delta 2.5 E.C with the doses of the former and later, 800, 1000 & 1200 ml ha^{-1} and 350, 400 & 450 ml ha^{-1} respectively; and Diazinon 60 E.C at 1000ml ha^{-1} were tested for their efficacy against sucking insect pests on tomatoes. Percent efficacy recorded after 48 hours of each spray in the fields was significantly affected by the dose applied. The percent efficacy obtained by Sivanto Energy EC 85 and Delta 2.5% E.C at the highest doses proved to be the most effective and gave better efficacy against whiteflies, thrips and aphids. Therefore, both insecticides can be used for the management of sucking pests (whitefly, thrips and aphid) on tomato crops in the field.

Magsi *et al*. (2017) carried out an experiment on the efficacy of different synthetic insecticides on tomato whitefly. The experiment was designed in Randomised Complete Block Design (RCBD) with five treatments *viz*., T_1; Transform (Sulfoxaflor) 30g/acre, T_2; Polo (Diafenthiuron) 200 ml/acre, T_3; Confidor (Imidacloprid) 200 sl/acre, T_4; Agrovista @ 100 g/acre and T_5; Control and repeated three times. The results of present study revealed that all the treatments were found effective against tomato whitefly during the 1^{st} spray. It was observed that the T_3 (Confidor 200 ml/acre) brought the highest reduction (93.24%) in whitefly population within 72 hrs of post treatment interval. The treatment T_4 (Agrovista 100 g/acre) was also found most effective to combat the whitefly population within 72 hrs of post treatment interval with (89.86%) population reduction followed by T_1 (Transform 30g/acre) with efficacy percentage (87.50%) and T_2 (Polo 200 ml/acre) with efficacy percentage (86.79%) respectively. Almost same trend of effectiveness was recorded during 2nd and 3rd spray respectively. The maximum yield (22.10 kg/plot 1860sqft) was received in plot sprayed with T_3 followed by 20.2, 14.8 and 13.3 kg/plot under T_4, T_2 and T_1 sprayed plots, respectively. Minimum crop yield (5.8 kg) was noticed for untreated plot (control) where no insecticides were applied.

Shakir *et al.* (2015) carried out a study to evaluate the effect of over application of four commonly used pesticides (emamectin benzoate, alpha-cypermethrin, lambda-cyhalothrin and imidacloprid) on the germination, seedling vigor and photosynthetic pigments in tomato. The obtained results revealed that seed germination was decreased by the pesticides and this effect was more prominent at early stages of exposure. All the tested pesticides reduced the growth of tomato when applied in higher concentration than the recommended dose, but at lower doses the pesticides had some stimulatory effects on growth as compared to the control. A similar effect of pesticides was observed on the photosynthetic pigments, i.e. a decrease in pigments concentrations was caused at higher doses but an increase was observed at lower doses of pesticides. A significant decrease in germination of seeds was observed with the increase in concentrations of pesticides as compared to the control. The concentrations of pesticides below the recommended dose promoted the germination capacity of seeds except in the case of imidacloprid where this effect was not significant as compared to the control. A signification reduction in shoot fresh and dry weight was found by exposing the seedlings to higher concentrations of pesticides. In case of root fresh and dry weight, lower concentrations of all the selected pesticides were found to increase the biomasses while at higher concentrations tremendous reduction was observed.

Hussain and Bilal (2007) conduction a field experiment to evaluate the efficacy of six insecticides at farmers field against *Helicoverpa armigera* infesting tomato. Among the treatments imidacloprid at 0.03% proved more effective followed by Deltamethrin and Fluvalinate. The sparying of these insecticides on tomato resulted in significantly higher reduction of larval population. The field data showed that Imidacloprid gave a significantly higher increase in yield (>78%) over control followed by Deltamethrin. Imidacloprid (0.03%) avoided 46% yield less on tomato crop.

Hirekuruber (2005) reported that thiamethoxam 25WG @ 25 a.i/ha was most effective against aphid, jassid infesting okra.

Dandale *et al*. (2003) carried out an experiment for testing efficacy of new insecticides *viz*., spinosad 45 SC @ 0.01%, indoxacarb 15 SC @ 0.015%, deltamethrin tablet 25% @ 0.0025%, beta cyfluthrin 2.5 EC @ 0.0025% against cotton bollworm in comparison with endosulfan. Minimum infestation of *H. armigera* in green fruiting bodies was observed in spinosad 45 SC @ 0.01 percent followed by 0.015 percent indoxacarb 15 SC.

Rao *et al*. (2001) tested commonly used insecticides chlorpyriphos, endosulfan, thiodicarb and new molecules spinosad, indoxacarb and emamectin benzoate exhibited high efficacy. Further, profenofos was also promising with enhanced activity at higher doses on *Helicoverpa armigera* in cotton.

Mehta *et al*. (2000) carried out an experiment on the management of tomato fruit borer, *Helicoverpa armigera* (Hubner) with nine insecticidal treatments for 3 seasons. Overall effectiveness expressed as reduction in borer damaged tomato fruits and increase in fruit yield indicated the superiority of deltamethrin alone or in combination all through the experimentation.

Walunj *et al*. (1999) conducted field trails to assess the efficacy of profenofos at 0.5kg/ha, profenofos + cypermethrin at 0.33- 0.44kg, lufenuron at 0.33 kg, dichlorvos at 0.76 kg and cypermethrin at 0.05 kg for control of *Helicoverpa armigera* in tomatoes cv. Namdhari Hybrid 815. Products awere applied 5 times at 15 days intervals. The results indicated that fruit damage was reduced in all treatments. Lowest infestations and highest yields of marketable fruits

(7.39 t/ha) were recorded with the 0.44 kg profenofos + cypermethrin treatment.

Ganguli and Dubey (1998) evaluated a number of insecticidal treatments against *H. armigera* on tomato and found that HaNPV 250 LE/ha and 0.07% endosufan was the most effective, resulting in 47.96 percent increase in yield and 32.52 percent avoidable losses.

Pinto *et al*. (1997) reported in that when the population exceeds the economic threshold, control can be effected using systemic products such as phosphoric esters (acephate, methomyl, dimethoate) or synthetic pyrethroids (alphamethrin [alphacypermethrin], deltamethrin); the latter must be used once only so as not to favor the build-up of mites. Agronomic methods of defense may also be used, such as weeding to kill the pupae, deep ploughing of adjacent uncultivated areas during the period of ovipositon and elimination of weeds in which females oviposit.

Mote *et al*. (1995) tested imidacloprid TWS as seed treatment @ 2 to 6%, application of carbofuran 3g @ 1kg a.i/ha and two sprays of 0.03% dimethoate against initial sucking pests of cotton i.e. aphid, jassid, leaf miner and thrips and their effects on plant growth character and found that all insecticidal treatments effectively checked the pest population upto 60 days.

Walunj and Mote (1995) tested the efficacy of imidacloprid as seed treatment and root dip against sucking pests of tomato during Kharif 1993. The treatments, included seed treatment with imidacloprid at 10,20 and 30 gm/kg seed, root dip with 0.02% and 0.04% imidacloprid at 10 gm/kg seed plus root dip at 0.02% and 0.04% and spray treatment with 0.05% monocrotophos. All insecticidal treatments reduced the number of thrips and white flies upto 45 days after transplanting. The combined treatments with imidacloprid provided most protection against these pests.

Dilbagh *et al*. (1990) conducted field trials in Punjab, India and revealed that fenvalerate, permethrin and cypermethrin applied at 50g ai/ha, or decamethrin applied at 20g ai/ha gave equal or better control of the noctuid *Helicoverpa armigera* than carbaryl or endosulfan applied at 1000 and 700g ai/ha, respectively. Yields were higher when synthetic pyrethroids were used.

2.3.2 Botanical pesticides

Botanical pesticides are naturally occurring chemicals extracted from plants, and have long been touted as attractive alternatives to synthetic chemical insecticides for pest management because they pose little threat to the environment or to human health (Isman 2006). Botanical pesticides possess an array of properties including toxicity to the pest, repellency, antifeedance and insect growth regulatory activities against pests of agricultural importance (Prakash and Rao 1996). According to Prakash and Rao (1996), there are four major types of botanical products used for insect control (neem, pyrethrum, rotenone, and essential oils).

Azadirachtin is a botanical insecticide obtained from seeds of the neem tree, *Azadirachta indica* Juss (Meliaceae) (Schmutterer 2002). It is strong anti-feedent, repellent and growth regulator of a wide variety of phytophagous insects (Mitchell *et al.* 2004). The main advantages of neem are reduced human toxicity (Raizada *et al.* 2001), fast and complete degradation in the environment, low risk for resistance and selective properties reported for some non-target organisms (Walter 1999). Currently, several neem-based products are registered as pesticides in Kenya (Knapp and Kashenge, 2003). These products have already proven to be effective against several insect pests like diamondback moth, *Plutella xylostella,* aphids, *Brevicoryne brassicae* L., *Myzuspersicae* (Kalt) and *Lipaphis erysimi* (Sulz) in cabbage, *Brassica oleracea* var capitata, and *Lyriomyza* spp. on tomatoes and cut flowers (Knapp and Kashenge 2003; Waiganjo *et al.* 2011). Neem can be used as a component in several IPM strategies. There is evidence on the synergistic effect of neem with microbial pesticides such as Nucleopolyhedrovirus (NPV) in the control of the African bollworm attacking tomato fruits (Senthilkumar *et al.* 2008).

Felicien *et al*. (2021) carried out a study to evaluate the effectiveness of some bio-pesticides in managing pests and diseases of tomato under field conditions. The field experiments were conducted over two cropping cycles between October 2020 and June 2021. The effects of selected bio-pesticides were observed. Bio-pesticides reduced the population of *Tuta absoluta* and white flies by 65%, and 73% respectively. The Bio-pesticides reduced pest and disease damage on fruits by up to 50% and 67% respectively. Success of bio-pesticides compared positively with that of the synthetic pesticides. The results showed that bio-pesticides from natural environments can be incorporated in integrated pest and disease management in tomato and can help reduce overuse of synthetic pesticides.

Vikrant *et al.* (2020) conducted a study on fruit yield, seed yield and seed quality parameters were worked out in Solan lalima variety of tomato during kharif season of the year 2018. *Trichoderma viride*, Neem Cake and oil, cow urine, *Bacillus thuringiensis* and HaNPV were used as bio-pesticides in different concentration and combinations. The applications of *Trichoderma viride* @ 50 g/plot + FYM @ 10 kg/plot + Neem oil @ 5ml/L in tomato crop is significantly better for number of healthy fruits harvested (22.80), average fruit weight per plant (79.43 g), number of seeds per fruit (95), seed yield per plant (6.22 g), seed yield per ha (184.22 kg), germination percentage (91.75%), seedling length (20.30 cm), speed of germination (19.45), dry weight of seedling (1.78 mg), seed vigour index I (1861.83) and II (163.36) and 1000 seed weight (2.92 g) over the other treatments. The results of the present study suggested that *Trichoderma viride* and neem oil in combination have a great potential to increase the yield and seed quality of tomato crop.

Nzanza and Mashela (2012) reported that whitefly (*Bemisia tabaci*, Homoptera: Aleyrodidae) and aphid (Homoptera) on tomato (*Solanum* *lycopersicum* L.) are economically important insect pests that are difficult to manage due to their resistance to a wide range of chemical pesticides. Field experiments were conducted to assess the effects of fermented plant extracts of neem (*Azadirachta indica* A. Juss.) leaf and wild garlic (*Tulbaghia v*iolacea) on whitefly and aphid population. The population of both insect pests showed two different patterns with higher counts observed during summer than winter monitoring. During both seasons, numbers of whiteflies and aphids increased regardless of the treatment, but the numbers remained significantly lower within treated than untreated plots. The mixture of neem and wild garlic was more effective in reducing population densities of whitefly and aphid than either plant extract applied alone. In conclusion, results of this study suggested a synergistic effect of fermented plant extracts of neem and wild garlic as a bio-pesticide.

Kulat *et al.* (2011) conducted an experiment on extracts of some indigenous plant materials, which are claimed important for pest control like seed kernels of neem, *Azadiracta indica*, *Pongamia glabra* [P. *pintuita]*, leaves of tobacco. *Nieotiana tabacum* and indiara, a neem based herbal product, against *H. armigera* on chickpea cv. ICCV-5 for its management. The results revealed that the crop treated with the leaf extract of *N. tabacttm* and seed extract of *P. glabra* (5%) and indiara (1%) and neem seed kernel extract (5%) exhibited low level of population built up compared to control.

Bihari and Narayan (2010) conducted an experiment on the effects of tobacco leaf extract, tea extract, neem [*Azadirachta indica*] leaf extract (NLE), neem seed kernel extract (NSKE), jatropha [*Jatropha* sp.] leaf extract, jatropha kernel extract, karanj [*Pongamia pinnata*] leaf extract, karanj kernel extract, tulsi [*Ocimum tenuiflorum*] leaf extract (TLE), onion-garlic bulb extract (OGBE) and chilli fruit extract (CFE) on the performance of tomato and incidence of fruit borer (*Helicoverpa* sp.) were studied in Allahabad. NSKE, TLE and CFE recorded the highest number of flower clusters per plant (83.45, 80.85 and 80.10) and incidence of fuirt set per plant (32.47, 32.10 and 32.00). The highest cost1benefit ratios were obtained with NLE, OGBE and CFE (1:51, 1:50 and 1:47).

Chand and Tiwari (2010) studies on cow urine and some indigenous plant leaf extract on food consumption and body weight of 10 day old *Spodoptera litura* larvae and revealed that the larvae consumed significantly less leaf area (5.20cm) when treated with neem leaf extract in comparison to untreated leaves (15.33cm) after 24 hours of feeding. The body weight of the larvae fed on neem treated leaves was reduced to 161.0 mg as against 791.0 mg in control.

Hasan and Singh (2009) reported the efficacy of cow urine decoction of botanicals against musterd saw fly *Athalia lugens proxima* Klug. The highest toxicity to 2nd instar grub of *A. proxima* was recorded on *Azadirachta indica* (LC_{50} 3.74) followed by *Allium vinaeale* (LC_{50} 4.44), Eucalyptus globules (LC_{50} 4.87), *Aegle marmelos* (LC_{50} 5.17) and *Withania somenifera* (LC_{50} 5.17) after 24 hours of treatment, whereas, after 48 hours the highest toxicity on *A. indica* followed by *Alium vineale.*

Patil *et al.* (2009) evaluated the efficacy of indigenous technology knowledge (ITK) components against major insect pests and their influence on the activity of natural enemies in soybean crop (*Glycine max*). The bio-efficacy studies of herbal asthras and extracts revealed the superiority of NSKE @ 5 percent which recorded higher larval reduction 62.97, 84.81 and 62.98, 77.35 % of *Spodoptera litura,* Fab, and *Thysanoplusia orichalcea* (Fab) respectively, after first and second spray and least percent (23.59 %) pod damage with higher seed yield (22.27 q/ha) and C:B ratio (2.59) followed by agniasthra. (10 kg neem leaf + 3 kg tobacco leaf + 3 kg garlic + 4 kg green chillies + 20 litres cow urine).

Kumar *et al.* (2007) reported that methanolic extract of neem *(Azadiracta indica* L.) and karanj *(Pongamia pinnata* Pierre) oil enriched in azadirachtin and karanjin, respectively, were tested alone and in combination against

Tetranychus sp. and chrysanthemum aphid *Macrosiphoniella sanborni*. The combined formulation of methanolic extract of neem (NSOME) and karanj oil (PSOME) was very effective (LC_{50} 0.11%) and showed 70 and 11.36 fold increase in activity over NSOME (7.7%)and PSOME (1.25%) alone in laboratory agsinst *Tetranychus. sp.* Field studies were conducted on *Tetranychus sp.* infecting *Withania somenifera.* The combined formulation provided more than 90% protection at the lowest concentration (0.25%), whereas, PSOME and NSOME provided only 78.6 and 71.9% protection even at the highest concentration (1%) tested. Combined formulation also showed synergism between NSOME and PSOME against chrysanthemum aphid, *M. sanborni* causing 100% protection compared to 68.4 and 52.9% of NSOME and PSOME, respectively, at 0.5% concentration.

Kharpuse and Bajpai (2007) reported that on the basis of overall mean percentage of leaf infestation in tomato (10.93, 11.92 and 12.59) NSKP 10% proved significantly superior against leaf miner followed by neem oil 3% and Mahua oil 3%. In case of white fly, neem oil 3% is the most effective treatment followed by the NSKP 10% and castor oil 3% with less overall mean population (2.51, 2.66 and 3.14 flies/10 twigs), respectively. The mean least overall larval population of fruit borer (5 and .05 larvae/10 plants) were also observed in neem oil 3% and NSKP 10%.

Bissdorf (2005) reported use of custard leaf extract for the control of aphid in tomato crop through boiling of 500 g of custard leaves in 2 litres of water until the remaining liquid is about ½ liter. Afterwards, the liquid was strained out and diluted with 10 -15 litres of water. These spray materials were also useful for the control of other caterpillars.

Singh and Arya (2004) reported 100 percent mortality of both nymphs and adults of mustard aphid, *Lipaphis erysimi* (Kaltenbach) with 4 percent concentration of neem leaves extract after 72 hours of treatment.

Srinivasan *et al.* (2003) carried out a study to utilize *Ocimum sanc*tum, *Calotropis gigantean* and *Ipomoea carnea* for controling rice weevil *Sitophilus oryzae*, a major store grain pest in maize of the three plant materials used in the experiment, Ipomoea had a distinct effect on the growth of *S. oryzae* adults. The developmental period of *S. oryzae* increased from 30 to 40 days. The percent trapping was significantly higher in the Ocimum (1%) treated maize compared to untreated check. The mortality percent was more in Calotropis treated feed at one percent concentration (33%) followed by the treatment at 0.1% concentration.

Shukla *et al.* (2003) revealed that fortification of cow urine with leaf extracts of various botanicals like neem, Ipomoea, Annona and Jatropha resulted in increased insecticidal property of the former against sucking pests of castor and capsule borer resulting in higher castor bean yield over control. They also reported that uplenckar (1%) and GSA formulations (1%) containing more than one botanicals along with cow urine provided an effective, economical and eco-friendly alternative to hazardous pesticides to suppress sucking pests and capsule borer in castor.

Patil and Goud (2003) observed that ten plants extract *(Acorus calamus, Annona squamosa, Azadirachta indica, Clerodendron inerme [Clerodendrum inerme*], *Lycopersicon esculentum*, *Melia azedarach*, *Ocimum sanctum* [*Ocimum tenuiflorum], Ricinus communis, Vinca rosea [Catharanthus roseus]* and *Vitex negundo)* and 2 commercial botanicals (Honge oil and Neemark) were evaluated for their ovipositional repellent property against *Plutella xylostella* under laboratory conditions. Among the plant products tested, 0.5% *Azadirachta indica* recorded maximum reduction in egg laying both under no-choice (50.33%) and free-choice (62.43%) conditions at 24 h. However, *Ricinus communis* extract was the least repellent.

Patel *et al.* (2003) reported enrichment of cow urine with various botanicals enhanced the insecticide property, neem leaf extract (10%) and Annona leaf extract (10%) along with cow urine (10%) proved better against sucking pests of cotton.

Manjula (2003) reported the efficacy of neem *[Azadirachta indica]* oil (0.5 and 0.75%), neem leaves (2.5 and 5% w/w), custard apple *[Annona reticulata]* leaves (2.5 and 5% w/w), neem seed kernel (10% w/w), neem seed coat (10% w/w) and neem cake (10% w/w) was evaluated in Anantapur, Andhra Pradesh, India, for 2 years (2001 and 2002) against the groundnut bruchid, *C. serratus,* on groundnut. Methyl parathion dust (0.1%) was included as the recommended insecticide in the first year. Methyl parathion [parathion-methyl] dust was the most effective in suppressing the pest. Neem oil, neem leaves and custard apple leaves were also effective against *C. serratus* at the concentrations used.

Inee *et al.* (2003) reported that leaf extracts (petroleum ether, chloroform and methanol) of *Pogostemon parviflorus [Pogostemon benghalensis], Pongamia glabra [Pongamia pinnata]* and *Annona squamosa,* at 4, 2, 1 and 0.5% were tested for activity against *H. theivora. Pogostemon parviflorus* showed the highest antifeedant activity in all solvents. The other 2 species also showed significant antifeedant activity. The fraction number IV (ethyl acetate/petroleum ether) *Pogostemon parviflorus* was the most toxic to the pest. Antifeedant activity was lower for petroleum ether and methanol extracts compared to chloroform extracts.

Barapatre and Lingappa (2003) evaluated, the maximum larval mortality of *S. litura* (91.66%) was caused by vitex (5%) + aloe (5%) followed by Pongamia (10%) + aloe (5%) + NSKE (10%) + cow urine (30%) (88.33%) both being statistically on par with each other, but significantly superior to all other treatments. NSKE inflicted the highest larval mortality of *H. armigera* (89.92%) and was as effective as a combined treatment of Pongamia (10%), aloe (5%), NSKE (10%) with cow urine (30%) (78.88%) whereas, cow urine and cow dung were ineffective as they were unable to inflict any mortality even after lapse of maximum post application period of 96 hours.

Sundarajan (2002) conducted a study using methanol extracts of selected plants namely *Anisomeles malabarica*, *Ocimum canum [O. americana], O. basilicum, Euphorbia hirta, E. heterophylla, Vitex negundo, Tagetes indica and Parthenium hysterophorus* for screening their insecticidal activity against the fourth instar larvae of *H. armigera* by applying dipping method of the leaf extracts at various concentrations (0.25, 0.5, 1.0, 1.5 and 20) on young tomato leaves. The larval mortality of more than 50% has been recorded for all the plant extra as in 2 percent test concentration (48 h) except *E. heterophylla* which recorded 47.3 percent mortality in 2 percent concentration. Among the plant extracts tested *V. negundo* is found to show higher rate of mortality (82.5%) at 2 percent concentration.

Barapatre (2001) observed that the mixture of extracts from Pongamia (10%), aloe (5%), NSKE (10%) and cow urine (30%) recorded highest antifeedant activity with 75.57 and 68.63 percent reduction in larval weight of *S. litura* and *H. armigera* respectively, over control.

Sundararajan (2001) carried out toxicological studies to evaluate the effect of leaf methanolic extracts of 5 indigenous plant materials namely, *Abutilon indicum, Achyramthes aspera, Ailanthus excelsa, Alstonia venenata and Azima tetracantha* against *Helicoverpa armigera*. Twenty healthy larvae collected from a tomato field were released into plastic containers containing tomato leaves treated with each of the plant extracts. The larval mortality was recorded 48 h after the release. Larval mortality on tomato leaves treated with *Azima tetracantha, Achyranthes aspera, Abutilon indicum, Ailanthus excelsa and Alstonia venenata* averaged 51, 58, 62, 67 and 73%, respectively.

Ahmed (2000) reported that aqueous neem kernel extract (ANKE) reduced the number of tomato leaves damaged by the larvae of the leaf miner *Liriomyza trifolii* significantly, while it reduced the number of aphids (40%) and white fly (33%) over the control. The product increased the weight of onion grown in the year 1999 by 15% over the control.

Ju *et al.* (2000) conducted six desert plants chosen to study their toxicity and effects on the growth and metamorphosis of the insect pest *Heliothis armigera [Helicoverpa armigera]*, An artificial diet containing 5% aqueous extracts of *Cynanchum auriculatum* or *Peganum harmala* var. multisecta showed strong toxicity to the larvae and caused mortality of 100% and 55%, respectively. These two extracts at the same dosage also significantly affected metamorphosis of the insect. An artificial diet containing 1% aqueous extracts of *C. auriculatum* or 5% aqueous extracts of *P. harmala* resulted in mortality of 85% and *55%,* respectively, and a zero emergence rate. Tests of extracts of *C. auriculatum* made at different pH showed that the pH 3 and pH 10 portions of the extracts affected the larvae growth significantly. The other plant species tested were *Euphorbia helioscopia, Sophora alopecuroides, Peganum nigellastrum and Thermopsis lanceolata;* extracts of these species caused either much lower mortality of *H. armigera* or zero mortality *(E. helioscopia).*

Sundarajan and Kumuthakalavalli (2000) conducted Petroleum ether extracts of the leaves of *Gnidia glauca* Gilg., *Leucas aspera* Link., and *Toddalia asiatica* Lam. tested against sixth in star larvae of *Helicoverpa armigera* (Huhner.) at 0.2, 0.4. 0.6, 0.8 and 1.0% by applying to okra slices. After 24 h, percentage mortality, EC50 and EC90 were calculated. Total mortality was recorded in the treatment with 0.8% of the extract of *G. glauca.* Of the three leaf extracts used, *G. glauca* showed an EC_{50} of 0.31 %.

Lopez *et al.* (1999) assayed short-term choice and no-choice feeding used to assess the anti feed ant activity of *T. havanensis* fruit extracts (at 5000 ppm) against 5^{th}-instar *H. armigera* larvae. The acetonic extract gave the highest activity and was further fractionated by silica gel column chromatography. Of the 7 fractions isolated, 5 were identified as the limonoids azadirone, trichilinone acetate, 14,15-deoxyhavancnsin-l,7-diacetatc, 14,15-deoxyhavanensinc-3,7-diacelaie and a mixture of havanensin-l,7-diacetatc and havanensin3,7-diacetatc. Choice and no-choice feeding assays of each fraction at 1000 ppm, showed that the mixture of havanensin-1,7-diaeetatc and havanensin-3,7-diacetate had the highest antifeedant activity against *H. armigera* larvae, Azadirone and trichilinone acetate were also antifeedants. No antifeedant activity was found in the remaining fractions. It is suggested that all of the limonoids with antifeedant activity have a similar mode of action, which is probably toxic.

Khorshcduzzaman *et al. (*1998) reported that neem oil @30 ml/1 of water can provide 41.11% infestation over control by the brinjal shoot and fruit borer, The neem oil provided 49.1% brinjal shoot and fruit borer infestation reduction over control.

Krishna Kumar (1998) reported that NSKE @ 4 percent spray was found to be the most effective in controlling *L. trifolii*. It was revealed that NSKE was not an ovipositional diterrent but killed first instar *L. trifolii* larvae.

Patanik (1997) tested six formulations of neem against two tomato pests, *L. trifolii* and *S. litura* on tomato and found that multineem was most effective reducing leaf infestation by 82.2 percent and nemazol was the least effective with the reduction in infestation of 73.1 percent. However, yields in treated plots were lower than those in untreated ones suggesting possible diverse effect on fruit setting.

Tomato plants (variety UC-97) were cultivated in pots and left to become naturally infested with *Bemisia tabaci* in an open field and were sprayed with various concentrations of extract. The high concentration of all the tested extracts exhibited positive response (Diemetry *et al.* 1996). Saibllon *et al.* (1995) studied the effects of extracts from *Rlcinus communis*, *Melia azadarach*, *Azadiracta indica*, and a tobacco derived commercial product against *Bemisia tabaci.* None of the treatments controlled *Bemisia tabaci,* but numbers were reduced on neem treated plants and these plots gave higher yield than others.

Botanical pesticides are becoming popular day by day. It was found that Lepidopteran insect is possible to control by botanical substances. Weekly spray application of the extract of neem seed kernel has been found to be effective against *Helicoverpa armigera* (Karim, 1994). The leaf extract of neem tested against the leaf caterpillar of brinjal, *Selepa docilis* Bult. at 5% concentration had a high antifeedent activity (Jacob and Sheila, 1994),

Chitra *et al.* (1993) reported that extract of leaves of *Argemone mexicana* (0.1%), leaves of *Azadirachia indica* (0.1%) and neem guard (0.5%) gave 76.18%, 69.55% and 55.92% control over untreated control, respectively. Butler and Henneberry (1991) reported that commercially available plant cooking oils (soybean, sunflower, com and peanut) reduced adult and immature populations of *Bemisia tabaci* in tomato for 5 days following application.

2.4 Effect of synthetic and botanical pesticides on seed quality

Ibrahim *et al*. (2016) carried out a study with three insecticides, acetamiprid, lambada-cyhalothrin, chlorpyrifos and two natural oils, clove, bitter orange and mixture of both (1:1) in supressing infestation of tomato plant by *Liriomyza trifolli*, *Bemisia argentifolii* and *Tuta absoluta* were carried out under semi field conditions. According to general mean of mortality, clove oil was the highest (60.5%) effect against *L. trifolli* followed by mix oil (48.3%), while acetamiprid had the lowest toxic effect with 39.6% of reduction. Also, data clarified that lambada and mix oil (clove and bitter orange oils 1:1) were the highest effective against eggs of *B. argentifolii*, both caused 85.4 and 85.3% reduction in eggs count, respectively, while acetamiprid was the lowest (50.9%). Clove gave satisfactory results against *L. trifolli*, *B. argentifolii* and *T. absoluta*, respectively, thereby; it was concluded that the use them for control tested insects on tomato plants.

Kumar *et al.* (2010) reported 85.21 and 91.03 percent reduction of cabbage aphid, *Brevicoryne brassicae* Linnaeus population one day after first and second spray with oxy-demeton methyl @ 0.025 percent followed by neem leaf extract @ 5 percent (75.96 and 74.74% reduction), lantana leaf extract @ 5 percent (75.06 and 58.74%) calotrophis leaf extract @ 5 percent (69.08 and 57.53%), nerium leaf extract @ 5 percent (55.73 and 53.78%), parthenium leaf extract @ 5 percent (52.78 and 48.34%) and tulsi leaf extract @ 5 percent (44.80 and 43.93%). Similar trend in population reduction was observed three and five days after spray.

Barde *et al.* (2009) while conducting field studies to evaluate neem based insecticide in comparison with endosulfan 35 E.C. against *Helicoverpa armigera* (Hubbner) on tomato revealed that neem oil (5%) and neem kernel powder WDP (5%) provided maximum protection and higher yield.

Ravi *et al.* (2008) showed that different sequential application of microbials and neemazol were equally effective as that of sequential application of synthetic chemical insecticides *viz.*, endosulfan 35 EC (@ 350 g a.i./ha), quinalphos 25 EC (@ 250 g a.i./ha) and indoxacarb 14.5 SC (@ 75 g a.i./ha) in reducing *H. armigera* larval population and fruit damage. Relatively higher number of predatory mirids (*Macrolophus* spp.) and spiders (*Argiope* spp and *Thomisus* spp.) were recorded in microbials and neem applied plots compared to the chemical insecticides treated plot. Thus the microbials and neem could be the best alternatives for the sustainable management of *H. armigera* on tomato with less impact on the naturally occurring predatory arthropods.

Reddy *et al.* (2004) reported the effectiveness of IPM in tomato comprising of trap crop (marigold) after every 16 rows of tomato, NPV, NSKE and 0.07% endosulfan spray at 28 and 35 days after planting. This helped in reducing in the number of sprays to 8 from 16 in non-IPM fields.

Kankal *et al*. (2003) investigated bio-efficacy of newer insecticides against *H. armigera* in pigeon pea. They tested spinosad 45 SC @ 56,73 and 90 ai/ha, indoxacarb 14.5 SC @ 500 g ai/ha, quinalphos 25 EC @ 500 g ai/ha, chlorpyriphos 20 EC @ 500 g ai/ha and endosulfan 35 EC @ 525 g ai/ha and found all treatment significantly superior over control in reducing larval population.

Raut (2000) conducted a field experiment with some insecticides and neem products against *H. armigera* on tomato and found that though 0.04% chlorpyriphos 20EC showed good results in minimizing the larval population of *H. armigera* and reduced the percent fruit damage, it was toxic and left some residues. So, the alternative best treatments with 0.15% Neemactin 5 ml/liter of water and Neem Gold 3 ml per liter of water was recommended for control of *H. armigera* larvae and increased the yield.

Gopal *et al.* (1997) conducted field trials to determine the efficacy of insecticides (endosulfan and diflubenzurun), neem products and nuclear polyhedrosis virus (NPV) alone or in combination for the control of fruit borer. *Helicoverpa armigera*, on tomatoes. Neem seed kernel extract (NSKE) 3% + endosulfan 0.035% + NPV at 250 larval equivalents (LE) ha^{-1} applied 3 times at 45, 55 and 65 days after planting gave the highest larval mortality, reduced fruit damage and the highest fruit yield, followed by neem oil 3% + endosulfan 0.035% + NPV at 250LE ha^{-1} and endosulfan 0.07% gave the highest cost:benefit ratio, followed by NSKE 3% + NPV at 250LE ha^{-1} and NSKE 3% + endosulfan 0.035% + NPV at 250 LE ha^{-1}.

Pawar *et al*. (1996) conducted the experiment with seven insecticides including 5% NSKE and 0.07% endosulfan and reported that the treatment with NSKE was most effective for control of leaf miner and increase in yield of tomato over untreated control. The cost benefit ratio was maximum (1:14) in 5% NSKE treated plot as compared to 1:10 in 0.07% endosulfan treated plot.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2019 to March 2020 to study the effect of some selected insecticides and botanicals on yield and seed quality of tomato. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.* 1979). Details on the meteorological data of airtemperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar and presented in Appendix II.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil

Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix III.

3.4 Test crop

Seeds of BARI tomato-14 was used as plant materials for the present study.

3.5 Treatments

Single factor experiment consisted of 7 treatments were as follows:

1. T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval
2. T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval
3. T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval
4. T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval
5. T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval
6. T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval and
7. UC = Untreated control

3.6 Variety used and seed collection

BARI tomato-14, a high yielding variety of tomato (*Solanum lycopersicum* L.) developed by Bangladesh Agricultural Research Institute (BARI), Gazipur was used as test crop. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.7 Raising of seedlings

The land selected for nursery beds were well drained. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well decomposed cowdung at the rate of 5 kg/bed. Seed bed size was 3 m × 1 m raised above the ground level. One seed bed was prepared for raising the seedlings. Ten (10) grams of seeds were sown in the seed bed on 22 October, 2019. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place within 5 days after seed sowing. Necessary shading was providing by bamboo mat (chatai) from scorching sunshine or rain.

3.8 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the treatments assigned for the study. The 6 treatments and an untreated control of the experiment were assigned at random into 21 plots. The size of each unit plot was 1.5 m × 2.0 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively. The layout of the experiment field is presented in Figure 1.

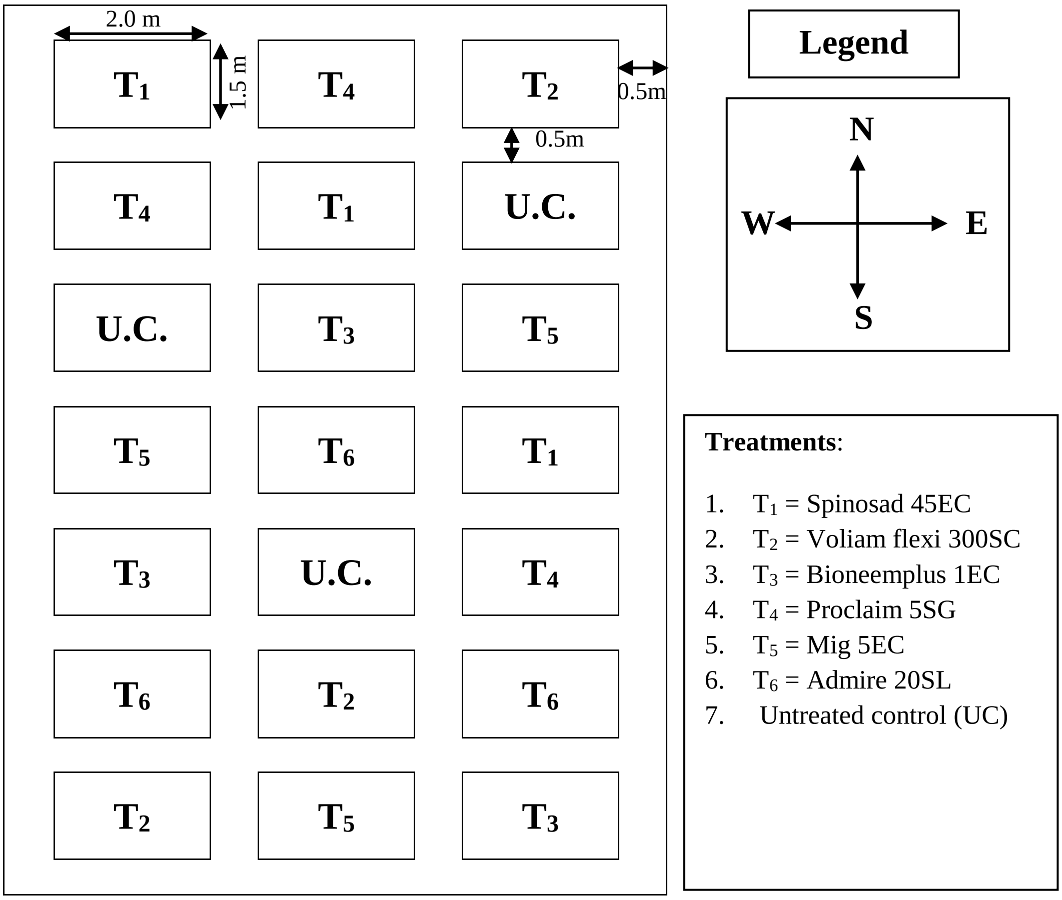

Figure 1. Layout of the experimental plot

3.9 Preparation of the main field

The plot selected for the experiment was opened in the 6 November, 2019 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 13 November 2019. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.10 Fertilizers and manure application

The N, P, K, and S nutrients were applied through urea, Triple super phosphate (TSP), Muriate of potash (MoP) and Gypsum, respectively according to KrishiProjukti Hat Boi, 2016. Name and doses of nutrients were as follows:

Plant nutrients	Manure and fertilizer	Doses ha^{-1}
--	Cowdung	10 t
N	Urea	550 kg
P	TSP	150 kg
K	MoP	250 kg
S	Gypsum	10 kg

3.11 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 14 November, 2019 maintaining a spacing of 60 cm × 40 cm. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.12 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the tomato.

3.12.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was pulverized.Gaps were filled by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.12.2 Irrigation

Irrigation was done three times. The first irrigation was given in the field at 25 days after transplanting (DAT) through irrigation channel. The second irrigation was given at the stage of maximum vegetative growth (40 DAT). The final irrigation was given at the stage of fruit formation (60 DAT).

3.12.3 Application of chemical and botanicals

All the treatments of the present study were applied with water and were sprayed by Knapsack Sprayer at 7 days interval.

3.13 Harvesting

Fruits were harvested at 5 days intervals during maturity to ripening stage. The maturity of the crop was determined on the basis of red colouring of fruits. Harvesting was started from 15 February, 2020 and completed by 25 March, 2020.

3.14 Data collection and recording

Five plants were selected randomly from each unit plot for recording data on different crop parameters. The data were also recorded on the incidence of white fly, aphid and leaf miner infested leaves and fruit borer infested shoots and fruits, infested and healthy fruit and yield contributing characters and yield of tomato. The following parameters were recorded during the study:

3.14.1 Incidence of whitefly plant^{-1}

For recording data on whitefly, five (5) plants from each plot were randomly selected and tagged. Five fully expanded compound leaves from top, middle and bottom of each plant were checked silently without jerking the plant at an interval of 10 days commencing from vegetative to ripening stage and counted the number of whitefly up to the last harvesting of the fruit.

3.14.2 Incidence of aphid plant^{-1}

For recording data on aphid, five (5) plants from each plot were randomly selected and tagged. Five fully expanded compound leaves from top, middle and bottom of each plant were checked silently with an interval of 10 days beginning from vegetative to ripening stage and calculate the number of aphid up to the last harvesting of the fruit.

3.14.3 Incidence of leaf miner plant^{-1}

For recording the data on leaf miner incidence, five (5) plants from each plot were randomly selected. Five fully expanded compound leaves from top, middle and bottom of each plant were checked silently with an interval of 10 days beginning from vegetative to ripening stage and calculate the number of leaf miner up to the last harvesting of the fruit.

3.14.4 Percent insect infestation decrease over control

The incidence of insect for each treated plot and untreated control plot were recorded and the percent reduction insect infestation by number over control was calculated using the following procedure:

$$\text{\% Infestation reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = Mean value of the treated plot

X_2 = Mean value of the untreated control plot

3.14.5 Fruit borer infestation

Total number of fruits and infested fruits (bored) 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 sorted out by the presence of holes made by the larvae. The percentage of borer infested fruits was calculated using the following formula:

$$\text{\% Borer infested fruit (by number)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

$$\text{\% Borer infested fruit (by weight)} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

3.14.6 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of 5 plants of each plot. The height was measured from the ground level to the tip of the leaves.

3.14.7 Number of branches plant^{-1}

The total number of branches was counted from 5 plants of each plot. The average branches number was calculated which is termed as number of branches plant^{-1}.

3.14.8 Number of flower clusters plant^{-1}

The number of flower clusters was counted from 5 plants of each plot and the average number of clusters produced per plant was calculated.

3.14.9 Number of fruits cluster^{-1}

The number of fruits and clusters from first harvest to last harvest was recorded from the five plants, and the average number of fruits cluster^{-1} was recorded by the following calculation:

$$\text{Number of fruits cluster}^{-1} = \frac{\text{Total number of fruits from 5 plants}}{\text{Total number of clusters from 5 plants}}$$

3.14.10 Single fruit weight (g)

Randomly 10 fruits were selected from sample plants from each treatment and then average single fruit weight was calculated by the following formula:

$$\text{Single fruit weight (g)} = \frac{\text{Weight of randomly selected ten fruits (g)}}{\text{Number of sample fruits}}$$

3.14.11 Healthy and infested fruit

The number of the healthy and infested fruit was counted at each harvest and continued up to the last harvest from the plants. Healthy fruits recorded at each observation were pooled and finally expressed in percentage.

3.14.12 Fruit weight plant^{-1} (kg)

At first the total weight of fruit was taken from the 5 selected plants harvested at different dates using an electric balance and then weight plant^{-1} (kg) was calculated by following formula:

$$\text{Fruit weight plant}^{-1} \text{(kg)} = \frac{\text{Total weight of fruits from selected 5 plants (kg)}}{\text{Number of sample plants}}$$

3.14.13 Fruit yield ha^{-1} (t)

After collection of per plot yield, it was converted to ton per hectare by the following formula:

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000 \text{ m}^2}{\text{Plot size (m}^2) \times 1\,000 \text{ kg}}$$

3.14.14 Seed weight fruit^{-1} (g)

At first the total weight of seeds was taken from randomly selected 10 fruits using an electric balance and then average weight was calculated by following formula:

$$\text{Seed weight fruit}^{-1} \text{ (g)} = \frac{\text{Total weight of seeds from selected 10 fruits (g)}}{\text{Number of sample fruits}}$$

3.14.15 See weight plant^{-1} (g)

At first the total weight of seeds was taken from the 5 selected plants using an electric balance and then seed weight plant^{-1} (g) was calculated by following calculation:

$$\text{Yield plant}^{-1} \text{ (kg)} = \frac{\text{Total weight of fruits from selected 5 plants (g)}}{\text{Number of sample plants}}$$

3.14.16 Seed yield (kg ha^{-1})

At first all seeds were separated from collected all fruits of each plot. Per plot yield of seeds was then converted to kg ha^{-1} with the following procedure:

$$\text{Seed yield per hectare (kg)} = \frac{\text{Seed yield per plot (kg)} \times 10000 \text{ m}^2}{\text{Plot size (m}^2) \times 1\,000 \text{ kg}}$$

3.14.17 Seed quality test

3.14.17.1 Percent (%) seed germination

Seed germination test was done using seeds that were obtained from field experiment of the present study. Germination test was done using 20 seeds placed in the petridish and replicate thrice. The number of sprouted and germinated seeds (Seedling emergence) was counted daily commencing. Germination was recorded at 24 hrs interval and continued up to 12^{th}. More than 2 mm long plumule and radicle was considered as germinated seed. The germination rate (seedling emergence) was calculated using the following formula:

$$\text{Rate of germination (\%)} = \frac{\text{Total number of germinated seeds}}{\text{Total seed placed for germination}} \times 100$$

3.14.17.2 Root length (cm)

The Root length of five seedlings from each sample was recorded finally at 12 DAS. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

3.14.17.3 Shoot length (cm)

The shoot length of five seedlings from each sample was measured finally at 12 DAS. Measurement was done using the unit centimeter (cm) by a meter scale.

3.14.17.4 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = RL+SL \times GP,$$

Where,

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to study the effect of some selected insecticides and botanicals on yield and seed quality of tomato. Data on incidence and infestation of whitefly, aphid, leaf miner and fruit borer on leaf and fruit and their effect on yield and seed quality characters were recorded. The results of different parameter under the experiment have been presented, discussed, and possible interpretations are given under the following headings:

4.1 Incidence of white fly plant^{-1}

During the cropping duration of tomato, significant variation was found on incidence of whitefly plant^{-1} at vegetative stage and fruiting stage and also total number of whitefly plant^{-1} (Table 1 and Appendix IV).

At vegetative stage, the lowest number of whitefly plant^{-1} (1.10) was recorded from the treatment T_6 (Admire 20SL) which was significantly different from other treatments. No-significant difference was found among the effects of T_3 (Bioneemplus 1EC) (1.40) and T_4 (Proclaim 5SG) (1.53) and also showed comparatively better performance in controlling whitefly at vegetative stage. On the other hand, the highest number of whitefly plant^{-1} (2.83) was recorded from untreated control plot which was followed by T_2 (Voliam flexi 300SC) (2.43) treated plot(Table 1)

At fruiting stage, T_6 (Admire 20SL) treated plot showed the lowest number of whitefly plant^{-1} (1.87) that was significantly differed from other all treatments. Treatment T_3 (Bioneemplus 1EC) also showed relatively better performance in controlling whitefly plant^{-1}. Treatment T_1 (Spinosad 45EC), T_4 (Proclaim 5SG) and T_5 (Mig 5EC) treated plot were not significantly different among them and showed mid level control of whitefly at fruiting stage. On the other hand, untreated control treatment showed highest incidence of whitefly plant^{-1} (7.93) that was followed by T_2 (Voliam flexi 300SC) (6.13) treated plot.

As a result, incidence of total number of whitefly plant^{-1} in tomato following different treatments showed statistically significant differences (Table 1 and Appendix IV). Results revealed that the total whitefly plant^{-1} during cropping duration of vegetative to fruiting stage, T_6 (Admire 20SL) treatment showed the best performance and gave the lowest number of whitefly plant^{-1} (2.97) that was significantly different from other treatments. Treatment T_3 (Bioneemplus 1EC) treated plot also showed relatively better result (4.07) in controlling whitefly plant^{-1} whereas the plot under untreated control treatment showed the highest total number of whitefly plant^{-1} (10.77) during vegetative to fruiting stages of crop.

Table 1. Incidence of whitefly on tomato plant under different treatment of selected insecticides and botanicals

Treatment	Number of white fly plant^{-1}		
	Vegetative stage	Fruiting stage	Total
T_1 (Spinosad 45EC)	2.03 c	4.50 c	6.53 c
T_2 (Voliam flexi 300SC)	2.43 b	6.13 b	8.57 b
T_3 (Bioneemplus 1EC)	1.40 d	2.67 d	4.07 e
T_4 (Proclaim 5SG)	1.53 d	3.93 c	5.47 d
T_5 (Mig 5EC)	1.83 c	4.30 c	6.13 c
T_6 (Admire 20SL)	1.10 e	1.87 e	2.97 f
Untreated control	2.83 a	7.93 a	10.77 a
$LSD_{0.05}$	0.252	0.649	0.494
CV(%)	7.58	8.15	4.36

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

In terms of % reduction of whitefly plant^{-1} over control by different treatments, significant variation was found (Figure 2 and Appendix IV). The highest reduction (72.45%) of whitefly over control was recorded from T_6 (Admire 20SL) treatment followed by T_3 (Bioneemplus 1EC) (62.24%) whereas T_2

(Voliam flexi 300SC) treatment performed the lowest reduction of whitefly over control (20.45%).

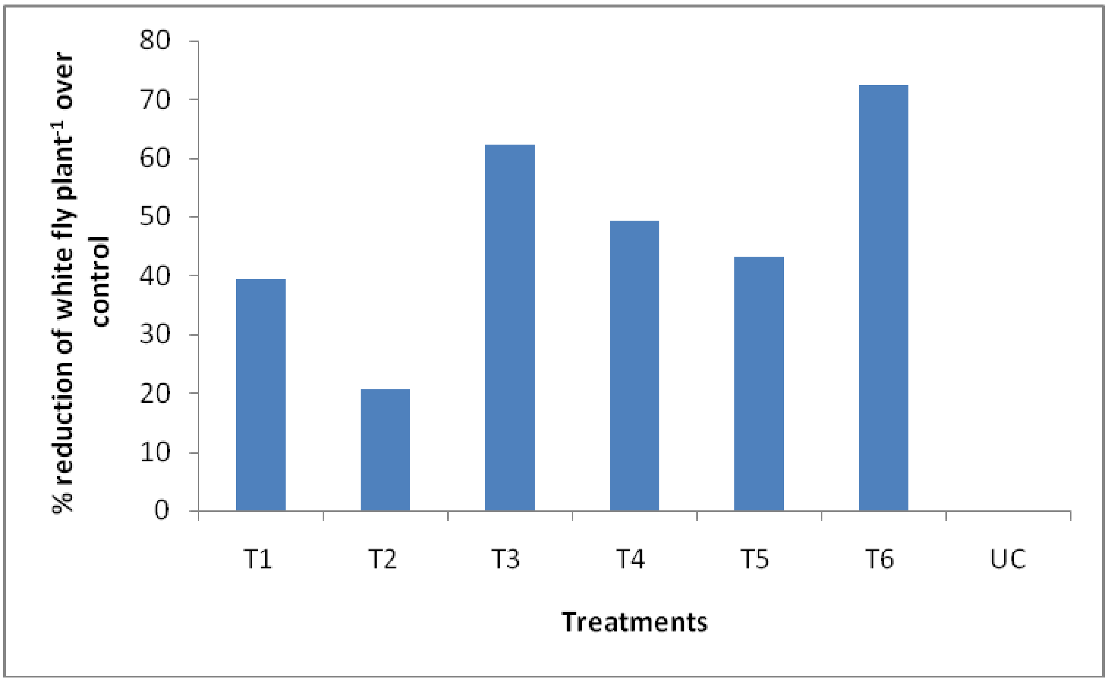

Figure 2. Percent reduction of whitefly by number over control on tomato plant after applying different treatment of selected insecticides and botanicals ($LSD_{0.05}$ = 1.362)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

From the findings it is revealed that treatment T_6 (Admire 20SL) treated plot the lowest incidence of whitefly as well as the highest reduction of whitefly over control followed by T_3 (Bioneemplus 1EC) whereas in control treatment the situation is reverse. Similar result was also observed by Ibrahim *et al.* (2016) reported more effectiveness of botanical pesticides compared to synthetic chemicals. Shiberu (2020) and Magsi *et al.* (2017) reported higher effectiveness of synthetic compounds against whitefly whereas Felicien *et al.* (2021) reported that the bio-pesticides reduced the population of white flies by 73%.

4.2 Incidence of aphid plant^{-1}

Significant statistical variation was found on the incidence of white aphid plant^{-1} at vegetative stage and fruiting stage and also total number of aphid plant^{-1} during the cropping duration of tomato, as infected by the treatment (Table 2 and Appendix V).

At vegetative stage, the lowest number of aphid plant^{-1} (2.00) was recorded from the treatment T_6 (Admire 20SL) which was significantly different from all other treatments. Treatment T_3 (Bioneemplus 1EC) and T_4 (Proclaim 5SG) treated plot also showed comparatively higher performance (2.45 and 3.09, respectively) in controlling aphid plant^{-1}. On the other hand, the highest number of aphid plant^{-1} (8.87) was recorded from untreated control plot which was followed by T_1 (Spinosad 45EC) (5.75) and T_2 (Voliam flexi 300SC) (5.87) treated plot. Treatment T_1 (Spinosad 45EC) (5.75) and T_2 (Voliam flexi 300SC) (5.87) showed no-significant difference among them in controlling aphid plant^{-1} and formed less effectiveness for aphid control.

At fruiting stage, the lowest number of aphid plant^{-1} (2.00) was recorded from T_6 (Admire 20SL) treated plot that was significantly differed from all other treatments. Treatment T_3 (Bioneemplus 1EC) also showed relatively better performance in controlling aphid plant^{-1} (3.77) whereas treatment T_4 (Proclaim 5SG) and T_5 (Mig 5EC) showed non-significant difference among them (5.03 and 5.46, respectively) in controlling aphid plant^{-1} at fruiting stage. On the other hand, untreated control treatment showed highest incidence of aphid plant^{-1} (11.70) that was followed by T_2 (Voliam flexi 300SC) (9.31) and T_1 (Spinosad 45EC) (6.64) treatment.

As a result, incidence of total number of aphid plant^{-1} in tomato for different treatments showed statistically significant differences (Table 2 and Appendix V). Results revealed that the total aphid plant^{-1} during cropping duration of vegetative to fruiting stage, T_6 (Admire 20SL) treatment showed best performance and gave the lowest number of aphid plant^{-1} (4.00) that was significantly different from other treatments. Accordingly, Treatment T_3 (Bioneemplus 1EC) treated plot also showed relatively better result (6.23) in controlling aphid plant^{-1} whereas the plot under untreated control treatment (UC) showed the highest total number of aphid plant^{-1} (20.58) during vegetative to fruiting stages of crop duration followed by T_2 (Voliam flexi 300SC) (15.20) and T_1 (Spinosad 45EC) (12.39).

Table 2. Incidence of aphid on tomato plant after application of different treatment with selected insecticides and botanicals

Treatment	Number of aphid plant^{-1}		
	Vegetative stage	Fruiting stage	Total
T_1 (Spinosad 45EC)	5.75 b	6.64 c	12.39 c
T_2 (Voliam flexi 300SC)	5.87 b	9.31 b	15.20 b
T_3 (Bioneemplus 1EC)	2.45 e	3.77 e	6.23 e
T_4 (Proclaim 5SG)	3.09 d	5.03 d	8.12 d
T_5 (Mig 5EC)	3.88 c	5.46 d	9.34 d
T_6 (Admire 20SL)	2.00 f	2.00 f	4.00 f
Untreated control	8.87 a	11.70 a	20.58 a
$LSD_{0.05}$	0.365	0.554	1.291
CV(%)	8.25	9.09	6.70

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

Again, significant variation was found in % reduction of aphid plant^{-1} over control by different treatments (Figure 3 and Appendix V). The highest reduction (80.55%) of aphid over control was recorded from T_6 (Admire 20SL) treatment followed by T_3 (Bioneemplus 1EC) (69.74%) whereas T_2 (Voliam flexi 300SC) treatment performed the lowest reduction of whitefly over control (26.14%).

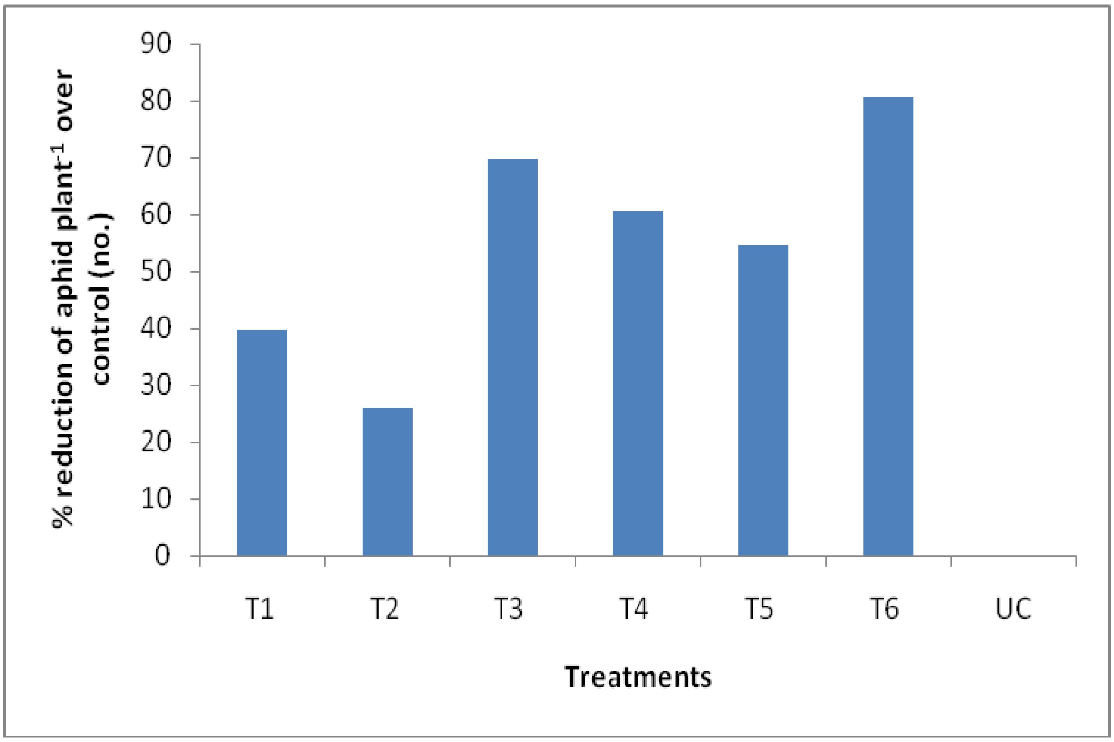

Figure 3. Percent reduction of aphid by number over control on tomato plant as affected by different treatment of selected insecticides and botanicals ($LSD_{0.05}$ = 2.671)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

The result of the present study on incidence of aphid in tomato suggests that the highest effectiveness was given by T_6 (Admire 20SL) and next to T_2(Voliam flexi 300 SC) for controlling aphids whereas reverse result was found in control treatment. Raut (2000) reported that synthetic pesticides were more effect then bio-pesticides but it was toxic and left some residues. He also reported higher effectiveness of bio-pesticides against insect pest. Nzanza and Mashela (2012) reported higher performance of bio-pesticides against aphid which was supported by Kumar *et al.* (2010) whereas Shiberu (2020) and Hirekuruber (2005) reported higher performance of synthetic pesticides against aphid.

4.3 Incidence of leaf miner plant^{-1}

After applying treatment the presence of leaf miner plant^{-1} in tomato during the cropping duration showed significant variation at vegetative stage and fruiting stage (Table 3 and Appendix VI).

At vegetative stage, treatment T_6 (Admire 20SL) showed the lowest number of leaf miner plant^{-1} (0.213) which was not significantly similar to T_4 (Proclaim 5SG) treatment (0.36) followed by treatment T_3 (Bioneemplus 1EC) which also showed relatively higher performance against leaf miner (0.45 plant^{-1}). On the other hand, the highest number of leaf miner plant^{-1} (1.19) was recorded from untreated control plot that was statistically similar to T_5 (Mig 5EC) (1.07) followed by T_1 (Spinosad 45EC) (0.81) and T_2 (Voliam flexi 300SC) (0.72) treated plot.

Table 3. Incidence of leaf miner on tomato plant after using different treatment of selected insecticides and botanicals

Treatment	Number of leaf miner plant^{-1}		
	Vegetative stage	Fruiting stage	Total
T_1 (Spinosad 45EC)	0.81 b	2.56 b	3.37 b
T_2 (Voliam flexi 300SC)	0.72 b	1.97 c	2.70 c
T_3 (Bioneemplus 1EC)	0.45 c	1.89 c	2.33 c
T_4 (Proclaim 5SG)	0.36 cd	1.37 d	1.73 d
T_5 (Mig 5EC)	1.07 a	2.62 b	3.69 b
T_6 (Admire 20SL)	0.21 d	1.00 e	1.21 e
Untreated control	1.19 a	3.18 a	4.37 a
$LSD_{0.05}$	0.211	0.195	0.373
CV(%)	5.90	5.18	4.02

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

At fruiting stage, T_6 (Admire 20SL) treated plot showed the lowest number of leaf miner plant^{-1} (1.00) that was significantly differed to other treatments. Treatment T_4 (Proclaim 5SG) also showed relatively better performance in controlling leaf miner. Reversely, untreated control treatment showed highest incidence of leaf miner plant^{-1} (3.18) that was followed by T_1 (Spinosad 45EC) (2.56) and T_5 (Mig 5EC) (2.62) treated plot. Treatment T_1 (Spinosad 45EC) and T_5 (Mig 5EC) treated plot showed non-significant difference among them and showed poor control performance of leaf miner at fruiting stage.

As a result, incidence of total number of leaf miner plant^{-1} in tomato for different treatments showed statistically significant differences (Table 3 and Appendix VI). Results revealed that the total leaf miner plant^{-1} during cropping duration of vegetative to fruiting stage, T_6 (Admire 20SL) treatment showed best performance and gave the lowest number of leaf miner plant^{-1} (1.21) that was significantly different from other treatments. Treatment T_4 (Proclaim 5SG) treated plot also showed relatively better result (1.73) in controlling leaf miner plant^{-1} whereas the plot under untreated control treatment showed the highest total number of leaf miner plant^{-1} (4.37) during vegetative to fruiting stages of crop.

In terms of % reduction of leaf miner plant^{-1} over control by different treatments, significant variation was found (Figure 4 and Appendix VI). The highest reduction (72.26%) of leaf miner over control was recorded from T_6 (Admire 20SL) treatment followed by T_4 (Proclaim 5SG) (60.44%) whereas T_5 (Mig 5EC) treatment performed lowest reduction of leaf miner over control (15.69%).

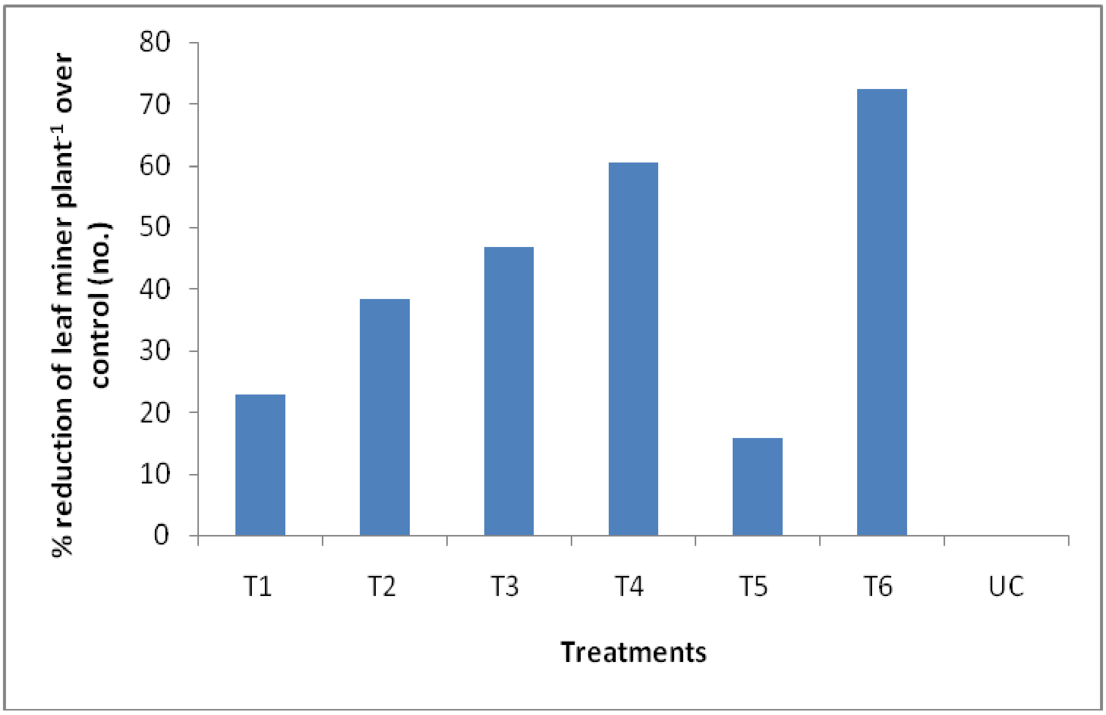

Figure 4. Percent reduction of leaf miner by number over control on tomato plant as influenced by different treatment of selected insecticides and botanicals ($LSD_{0.05}$ = 2.159)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

From the present investigation, higher performance of T_6 (Admire 20SL), T_4 (Proclaim 5SG) and T_3 (Bioneemplus 1EC) were observed against leaf miner compared to control. Mote *et al*. (1995) reported more effectiveness of synthetic chemical against leaf miner whereas Felicien *et al*. (2021) achieved higher performance of bio-pesticides against leaf miner (*Tuta absoluta*) and obtained 65% reduction over control. Ibrahim *et al*. (2016) obtained higher efficacy of botanicals compared to synthetic compounds against *Tuta absoluta*.

4.4 Fruit infestation status in number by fruit borer

4.4.1 Healthy fruits by number

Statistically significant variation was recorded in number of healthy fruit during cropping season of tomato using different botanicals and chemicals as pest management practices against tomato fruit borer (Table 4 and Appendix VII). Results revealed that the treatment T_6 (Admire 20SL) treated plot showed the highest number of healthy fruit plant^{-1} (25.87) that was statistically identical to T_3 (Bioneemplus 1EC) (24.66) followed by T_4 (Proclaim 5SG) (22.84). On the other hand, the lowest number of healthy fruits plant^{-1} (16.83) was recorded from untreated control treatment that was significantly same to T_2 (Voliam flexi 300SC) (17.60) treated plot. Hussain and Bilal (2007) and Vikrant *et al.* (2020) also found similar result with the present study which was supported by the findings of Dandale *et al*. (2003), Rao *et al*. (2001) Sundarajan and Kumuthakalavalli (2000) and Barde *et al.* (2009).

4.4.2 Infested fruits by number

Statistically significant variation was recorded for number of infested fruits plant^{-1} using different botanicals and chemicals as pest management practices against tomato fruit borer (Table 4 and Appendix VII). Results indicated that the lowest number of infested fruits plant^{-1} (0.90) was recorded from the treatment T_6 (Admire 20SL). Treatment T_3 (Bioneemplus 1EC) and T_4 (Proclaim 5SG) also showed comparatively better results against tomato fruit borer. Again, the highest number of infested fruits plant^{-1} (3.37) was recorded from untreated control plants that was statistically similar to that of T_2 (Voliam flexi 300SC) (3.11) treatment.

4.4.3 Total fruits by number

The number of total tomato fruits was influenced significantly due to application of different botanicals and chemicals as pest management practices (Table 4 and Appendix VII). Results revealed that the treatment T_6 (Admire

20SL) treated plot gave the highest total number of fruit plant^{-1} (26.77) that was statistically identical to T_3 (Bioneemplus 1EC) (26.27) followed by T_4 (Proclaim 5SG) and T_5 (Mig 5EC). The lowest total number of fruits plant^{-1} (20.20) was recorded from untreated control treatment (UC) that was significantly same to T_1 (Spinosad 45EC) (21.43) and T_2 (Voliam flexi 300SC) (20.70) treated plot.

Table 4. Effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect (fruit borer) that affecting fruits plant^{-1} by number

Treatment	Number of fruits plant^{-1}		
	Healthy	Infested	Total
T_1 (Spinosad 45EC)	18.93 d	2.50 b	21.43 c
T_2 (Voliam flexi 300SC)	17.60 e	3.11 a	20.70 c
T_3 (Bioneemplus 1EC)	24.66 a	1.61 d	26.27 a
T_4 (Proclaim 5SG)	22.84 b	1.93 cd	24.77 b
T_5 (Mig 5EC)	21.33 c	2.37 bc	23.70 b
T_6 (Admire 20SL)	25.87 a	0.90 e	26.77 a
Untreated control	16.83 e	3.37 a	20.20 c
$LSD_{0.05}$	1.294	0.481	1.350
CV(%)	6.71	12.02	9.63

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

4.4.4 Percent (%) fruit infestation by number

Application of different botanicals and chemicals as pest management practices of tomato showed significant variation on % fruit infestation by number (Figure 5 and Appendix VII). Results showed that the T_6 (Admire 20SL) treated plot gave lowest fruit infestation (3.36%) by number. Treatment T_3 (Bioneemplus 1EC) also showed relatively better performance whereas untreated control treatment showed highest % fruit infestation by number

(16.68%) that was statistically same to T_2 (Voliam flexi 300SC) (15.02%) followed by T_1 (Spinosad 45EC) and T_5 (Mig 5EC).

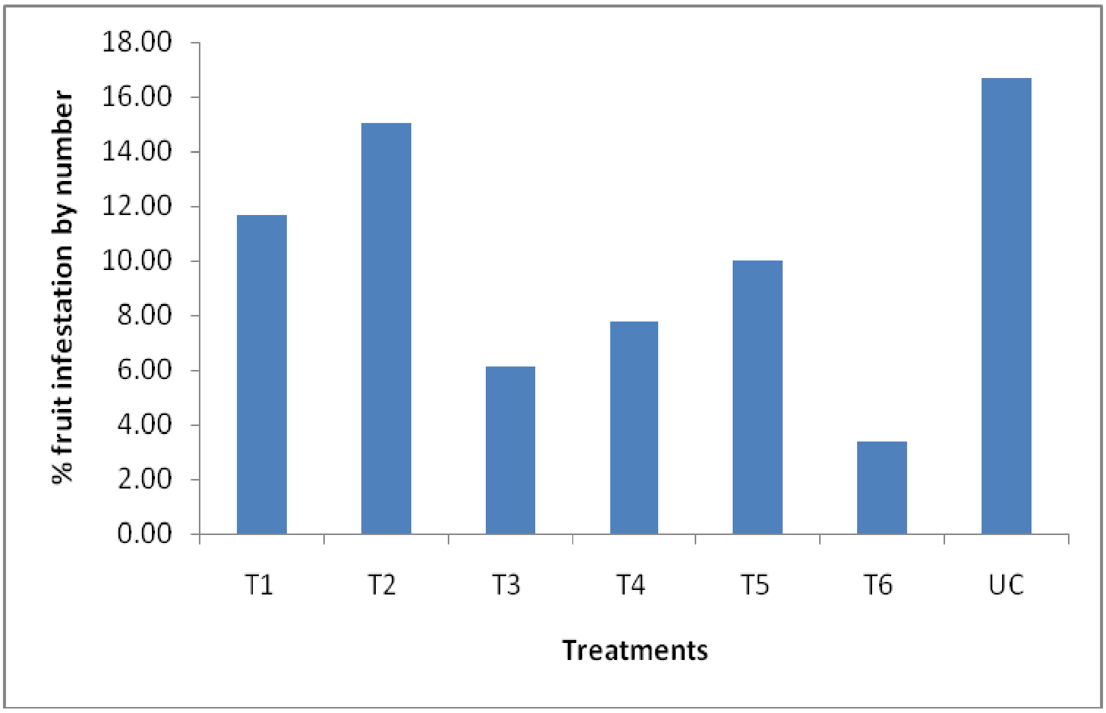

Figure 5. Effect of some selected insecticides and botanicals as pest management options on percent fruit infestation plant^{-1} by number ($LSD_{0.05}$ = 1.743)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

4.5 Fruit infestation status by weight by fruit borer

4.5.1 Weight of healthy fruits

Significant variation was found for weight of healthy fruit of tomato against tomato fruit borer using different botanicals and chemicals as pest management practices (Table 5 and Appendix VIII). Results revealed that the treatment T_6 (Admire 20SL) treated plot showed the maximum weight of healthy fruits plant^{-1} (1.72 kg) that was statistically identical to T_3 (Bioneemplus 1EC) (1.61 kg) followed by T_4 (Proclaim 5SG). On the other hand, the minimum weight of healthy fruits plant^{-1} (1.02 kg) was recorded from untreated control treatment that was significantly similar to T_2 (Voliam flexi 300SC) (1.08 kg). Shakir *et al.* (2015) found similar result with the present study and reported higher efficacy of synthetic chemicals against fruit borer to obtain higher amount of healthy fruits which was supported by Hussain and Bilal (2007). Again, Vikrant *et al.* (2020) reported obtained higher amount of healthy fruits using bio-control agents. Barde *et al.* (2009) and Ravi *et al.* (2008) observed higher efficiency in controlling fruit borer compared to using synthetic chemicals.

Table 5. Effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect (fruit borer) on fruits per plant by weight

Treatment	Weight of fruits plant^{-1} (kg)		
	Healthy	Infested	Total
T_1 (Spinosad 45EC)	1.17 d	0.15	1.33 d
T_2 (Voliam flexi 300SC)	1.08 de	0.19	1.27 d
T_3 (Bioneemplus 1EC)	1.61 a	0.11	1.72 a
T_4 (Proclaim 5SG)	1.47 b	0.12	1.60 b
T_5 (Mig 5EC)	1.34 c	0.15	1.49 c
T_6 (Admire 20SL)	1.72 a	0.06	1.78 a
Untreated control	1.02 e	0.20	1.22 e
$LSD_{0.05}$	0.126	0.018 ^{NS}	0.011
CV(%)	6.77	12.24	8.81

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

4.5.2 Weight of infested fruits

No-significant variation was recorded for weight of infested fruits plant^{-1} against tomato fruit borer using different botanicals and chemicals as pest management practices (Table 5 and Appendix VIII). However, the minimum infested fruits weight plant^{-1} (0.06 kg) was recorded from the treatment T_6

(Admire 20SL) whereas the maximum weight of infested fruits plant^{-1} (0.20 kg) was recorded from untreated control treatment (UC).

4.5.3 Total fruit weight

Weight of total tomato fruits was affected significantly due to application of different botanicals and chemicals as pest management practices (Table 5 and Appendix VIII). Results revealed that the treatment T_6 (Admire 20SL) gave the highest total fruit weight plant^{-1} (1.78 kg) that was statistically identical to T_3 (Bioneemplus 1EC) (1.72 kg) followed by T_4 (Proclaim 5SG) (1.60 kg). The lowest total weight of fruits plant^{-1} (1.22 kg) was recorded from untreated plant.

4.5.4 Percent (%) fruit infestation by weight

Application of different botanicals and chemicals as pest management practices on tomato pests showed significant variation on % fruit infestation by weight (Figure 6 and Appendix VIII). Results showed that the T_6 (Admire 20SL) treatment gave lowest fruit infestation by weight (3.37%) that was significantly differed to other treatments. T_3 (Bioneemplus 1EC) and T_4 (Proclaim 5SG) treatment also gave comparatively better result against % fruit infestation (6.23% and 7.67%, respectively) whereas untreated control treatment (UC) showed highest % fruit infestation by weight (16.60%) that was statistically same to T_2 (Voliam flexi 300SC) (15.00%) followed by T_1 (Spinosad 45EC) and T_5 (Mig 5EC).

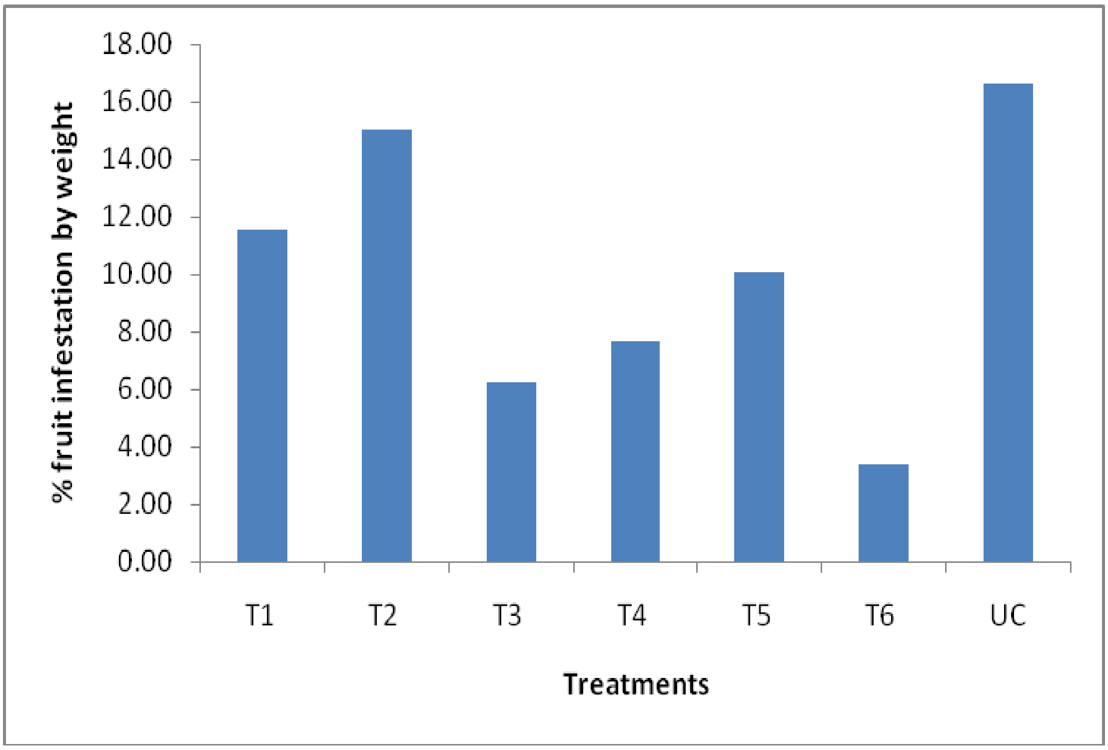

Figure 6. Effect of some selected insecticides and botanicals as pest management options on percent fruit infestation plant^{-1} by weight ($LSD_{0.05}$ = 1.621)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

4.6 Fruit yield of tomato (t ha^{-1})

4.6.1 Healthy fruit yield

Significant variation was found for healthy fruit yield of tomato due to application of different botanicals and chemicals as pest management practices (Table 6 and Appendix IX). Results showed that the treatment T_6 (Admire 20SL) treated plot showed the maximum healthy fruit yield (86.18 t ha^{-1}) that was significantly differed to other treatments followed by T_3 (Bioneemplus 1EC) (80.54 t ha^{-1}). The minimum healthy fruit yield (51.05 t ha^{-1}) was recorded from untreated control treatment that was significantly same to T_2 (Voliam flexi 300SC) (53.81 t ha^{-1}). From the findings it is revealed that treatment T_6 (Admire 20SL) produced the highest healthy fruit followed by T_3 (Bioneemplus 1EC) and the lowest was in control treatment. Walunj *et al*. (1999) reported lower fruit damage using synthetic compound and obtained higher yields of marketable fruits whereas Vikrant *et al.* (2020) recorded higher healthy fruit yields using botanical. Similarly, Raut (2000) reported non-significant difference between synthetic compound (chlorpyriphos 20EC) and botanical compound (Neemactin) on percent fruit damage which resulted higher healthy fruited yield for both cases but considering the use of synthetic compound, it was toxic and left some residues, so, the alternative treatments as botanical compound can be recommended for higher healthy fruit yield.

4.6.2 Infested fruit yield

Application of different botanicals and chemicals as pest management practices of tomato, significant influence was recorded for infested fruit yield (Table 6 and Appendix IX). Results showed that the minimum infested fruit yield (3.02 t ha^{-1}) was recorded from the treatment T_6 (Admire 20SL) and next to T_3 (Bioneemplus 1EC) (5.26 t ha^{-1}) whereas the maximum infested fruit yield (10.18 t ha^{-1}) was recorded from untreated control treatment that was statistically similar to T_2 (Voliam flexi 300SC) (9.50 t ha^{-1}).

4.6.3 Total fruit yield

Total fruit yield of tomato was significantly affected by the application of different botanicals and chemicals as pest management practices (Table 6 and Appendix IX). Results indicated that the highest total fruit yield (89.20 t ha^{-1}) was recorded from the treatment T_6 (Admire 20SL) followed by T_3 (Bioneemplus 1EC) (85.80 t ha^{-1}) whereas the minimum total fruit yield (61.23 t ha^{-1}) was recorded from untreated control plot that was significantly same to T_2 (Voliam flexi 300SC) (63.31 t ha^{-1}).

Table 6. Effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect on tomato of fruits per plant by number

Treatment	Fruit yield (t ha^{-1})		
	Healthy	Infested	Total
T_1 (Spinosad 45EC)	58.49 e	7.73 b	66.22 e
T_2 (Voliam flexi 300SC)	53.81 f	9.50 a	63.31 f
T_3 (Bioneemplus 1EC)	80.54 b	5.26 c	85.80 b
T_4 (Proclaim 5SG)	73.75 c	6.24 c	80.00 c
T_5 (Mig 5EC)	67.10 d	7.49 b	74.59 d
T_6 (Admire 20SL)	86.18 a	3.02 d	89.20 a
Untreated control	51.05 f	10.18 a	61.23 f
LSD0.05	3.117	1.245	2.725
CV(%)	10.60	11.76	8.80

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

4.6.4 Percent (%) increase of healthy fruit yield over control

Application of different botanicals and chemicals as pest management practices of tomato showed significant variation on % increase of healthy fruit yield over control (Figure 7 and Appendix IX). Results showed that the treatment T_6 (Admire 20SL) gave highest % increase of healthy fruit yield over control (68.81%) that was significantly differed to other treatments followed by T_3 (Bioneemplus 1EC) (57.77%) whereas treatment T_2 (Voliam flexi 300SC) showed lowest % increase of healthy fruit yield over control (5.41%).

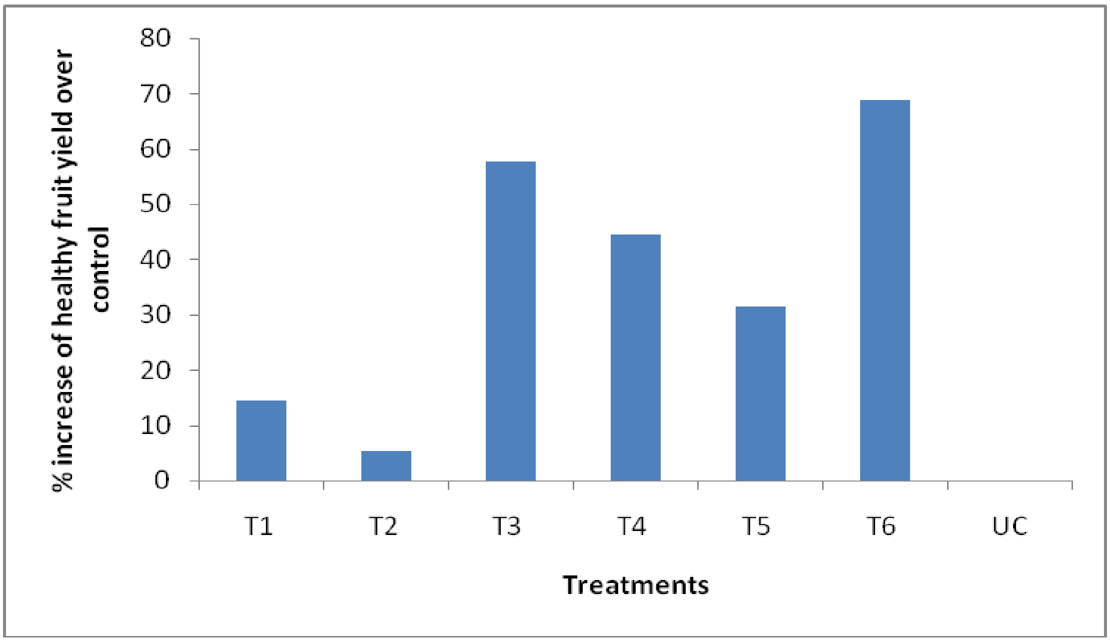

Figure 7. Effect of some selected insecticides and botanicals as pest management options on percent % increase of healthy fruit yield plant^{-1} over control by number ($LSD_{0.05}$ = 3.154)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

4.7 Yield contributing characters

4.7.1 Plant height (cm)

Plant height of tomato was significantly influenced by the application of different botanicals and chemicals used as pest management practices (Table 7 and Appendix X). It was observed that the highest plant height (94.29 cm) was recorded from the treatment T_6 (Admire 20SL) that was significantly differed to other treatments which was followed by T_3 (Bioneemplus 1EC) whereas the lowest plant height (77.75 cm) was recorded from untreated control plot

4.7.2 Number of branches plant^{-1}

Significant variation was observed in number of branches plant^{-1} of tomato as influenced by using different botanicals and chemicals as pest management practices (Table 7 and Appendix X). Results exhibited that the treatment T_6 (Admire 20SL) gave the highest number of branches plant^{-1} (11.25) which was significantly different from all other treatments followed by T_3 (Bioneemplus 1EC) (10.70). Again, the lowest number of branches plant^{-1} (7.49) was recorded from untreated control plot that was significantly differed to other treatments.

Table 7. Effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect on the of yield contributing characters

Treatment	Yield contributing characters				
	Plant height (cm)	No. of branches plant^{-1}	No. of flower clusters plant^{-1}	No. of fruits cluster^{-1}	Single fruit weight (g)
T_1 (Spinosad 45EC)	82.59 de	8.26 e	6.73 d	5.03 d	61.81 d
T_2 (Voliam flexi 300SC)	81.06 e	8.01 e	6.19 e	4.58 e	61.17 de
T_3 (Bioneemplus 1EC)	91.11 b	10.70 b	8.11 b	6.05 b	65.31 b
T_4 (Proclaim 5SG)	88.19 c	9.99 c	7.68 b	5.82 b	64.59 b
T_5 (Mig 5EC)	84.62 d	9.49 d	7.20 c	5.44 c	62.93 c
T_6 (Admire 20SL)	94.29 a	11.25 a	8.63 a	6.37 a	66.64 a
Untreated control	77.75 f	7.49 f	5.28 f	4.05 f	60.62 e
$LSD_{0.05}$	2.686	0.509	0.450	0.318	1.030
CV(%)	7.62	6.08	10.81	5.45	7.04

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

4.7.3 Number of flower clusters plant^{-1}

Different botanicals and chemicals application as pest management practices, number of flower clusters plant^{-1} of tomato was significant (Table 7 and Appendix X). Results showed that the highest number of flower clusters plant^{-1} (8.63) was recorded from the treatment T_6 (Admire 20SL) followed by T_3 (Bioneemplus 1EC) and T_4 (Proclaim 5SG) whereas the lowest number of flower clusters plant^{-1} (5.28) was recorded from untreated control plot which was significantly different from other treatments.

4.7.4 Number of fruits cluster^{-1}

Statistically significant variation was recorded for number of fruits cluster^{-1} influenced by application of different botanicals and chemicals as pest management practices (Table 7 and Appendix X). It was observed that the treatment T_6 (Admire 20SL) gave the highest number of fruits cluster^{-1} (6.37) which was significantly different from other treatments followed by T_3 (Bioneemplus 1EC) (6.05) and T_4 (Proclaim 5SG) (5.82). Again, the untreated control plot gave the lowest number of fruits cluster^{-1} (4.05).

4.7.5 Single fruit weight (g)

Single fruit weight of tomato affected significantly due to application of different botanicals and chemicals as pest management practices (Table 7 and Appendix X). Results revealed that the highest single fruit weight (66.64 g) was recorded from the treatment T_6 (Admire 20SL) followed by T_3 (Bioneemplus 1EC) and T_4 (Proclaim 5SG) whereas the untreated control plot showed the lowest single fruit weight (60.62 g).

4.8 Seed yield parameters

4.8.1 Seed weight fruit^{-1}

No-significant variation was observed on seed weight fruit^{-1} of tomato influenced by the use of different botanicals and chemicals as pest management practices (Table 8 and Appendix XI). However, the highest seed weight fruit^{-1} (0.57 g) was recorded from the treatment T_6 (Admire 20SL) followed by T_3 (Bioneemplus 1EC) whereas the lowest seed weight fruit^{-1} (0.40 g) was recorded from untreated control plot.

4.8.2 Seed weight plant^{-1}

The effect of different botanicals and chemicals as pest management practices on seed weight plant^{-1} of tomato was significant (Table 8 and Appendix XI). Results exhibited that the treatment T_6 (Admire 20SL) gave the highest seed weight plant^{-1} (12.73 g) which was significantly different from other treatments followed by T_3 (Bioneemplus 1EC) (12.00 g). Again, the lowest seed weight plant^{-1} (7.93 g) was recorded from untreated control treatment that was significantly differed to other treatments. The present study suggested that the treatment T_6 (Admire 20SL) showed the highest seed weight plant^{-1} followed by T_3 (Bioneemplus 1EC) The use of bio pesticides was supported by the findings of Vikrant *et al.* (2020) and they obtained higher seed weight plant^{-1} (6.22 g) using bio-pesticides.

4.8.3 Seed yield ha^{-1}

Significant variation was found on seed yield ha^{-1} of tomato by the application of different botanicals and chemicals as pest management practices (Table 8 and Appendix XI). Results showed that the highest seed yield (636.70 kg) was recorded from the treatment T_6 (Admire 20SL) followed by T_3 (Bioneemplus 1EC) (600.00 kg) but they were statistically different whereas the lowest seed yield (396.30 kg) was recorded from untreated control treatment (UC) which was significantly different from other treatments. T_3 (Bioneemplus 1EC) is considered as bio-pesticide. Under the present study, T_6 (Admire 20SL) which was considered as synthetic chemicals and gave the highest seed yield ha^{-1} whereas T_3 (Bioneemplus 1EC), considered as botanical compound gave the second highest seed yield ha^{-1}, with this support Vikrant *et al.* (2020 obtained higher highest seed yield ha^{-1} using bio-pesticides.

Table 8. Effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect in terms of seed yield parameters

Treatment	Seed yield parameters		
	Seed weight fruit^{-1} (g)	Seed weight plant^{-1} (g)	Seed yield (kg ha^{-1})
T_1 (Spinosad 45EC)	0.51	10.00 e	500.00 e
T_2 (Voliam flexi 300SC)	0.50	9.73 e	486.70 e
T_3 (Bioneemplus 1EC)	0.54	12.00 b	600.00 b
T_4 (Proclaim 5SG)	0.53	11.53 c	576.70 c
T_5 (Mig 5EC)	0.50	10.53 d	526.30 d
T_6 (Admire 20SL)	0.57	12.73 a	636.70 a
Untreated control	0.40	7.93 f	396.30 f
$LSD_{0.05}$	NS	0.298	15.01
CV(%)	4.89	5.59	7.59

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 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

4.8.4 Percent (%) increase of seed yield over control

Percent (%) increase of seed yield of tomato over control showed significant variation due to application of different botanicals and chemicals as pest management practices (Figure 8 and Appendix XI). It was observed that the treatment T_6 (Admire 20SL) gave the highest % increase of seed yield over control (60.66%) which was significantly different from other treatments followed by T_3 (Bioneemplus 1EC) (51.40%). Again, the treatment T_2 (Voliam flexi 300 SC) gave the lowest % increase of seed yield over control (4.05).

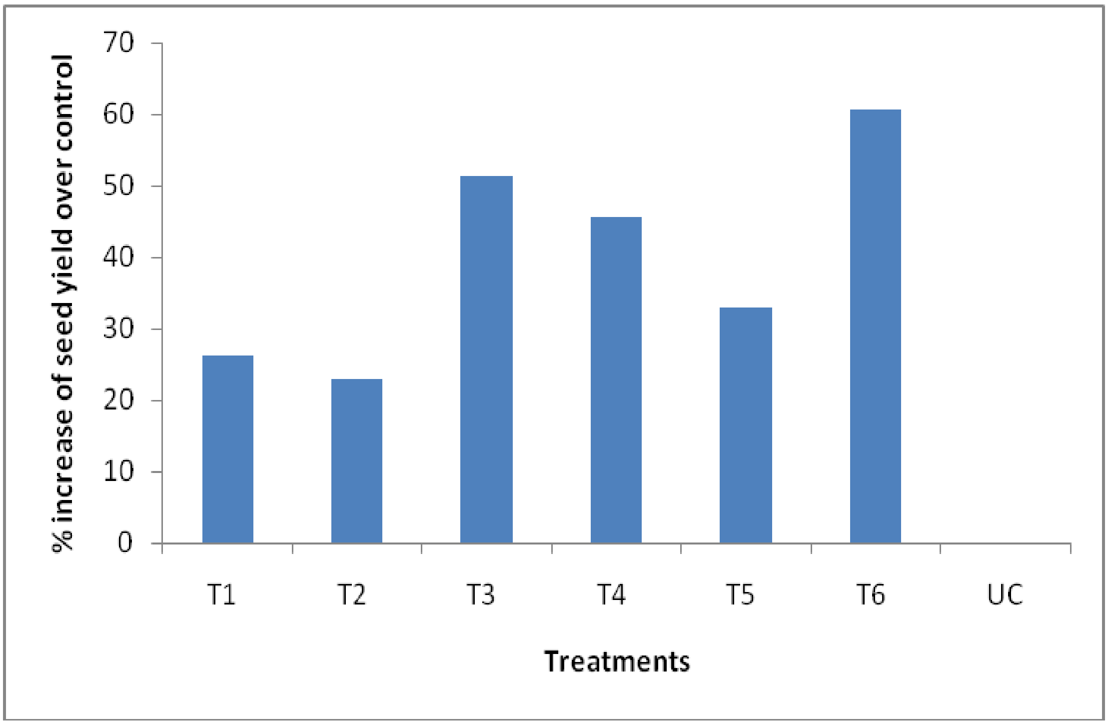

Figure 8. Effect of some selected insecticides and botanicals applied as pest management options on percent % increase of seed yield ha^{-1}over control ($LSD_{0.05}$ = 2.144)

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval, Untreated control

4.9 Seed quality parameters

4.9.1 Seed germination

Seed obtained from the present study after applying different treatments, germination test was done as seed quality parameter to observe which treatment showed best quality seeds. Significant variation was recorded for seed germination among the treatments (Table 9 and Appendix XII). Results showed that the maximum seed germination (97.23%) was recorded from the treatment T_3 (Bioneemplus 1EC) that was statistically identical to T_6 (Admire 20SL) (96.00%) followed by T_4 (Proclaim 5SG) (93.83%) whereas untreated control plot showed the minimum seed germination (83.80%) which was significantly different from other treatments. Vikrant *et al.* (2020) also obtained the highest seed germination from bio-pesticide produced seeds which was supported by Shakir *et al.* (2015).

4.9.2 Root length

Root length was observed at 12 days of seedlings after germination. Significant variation was recorded for root length due to different treatments (Table 9 and Appendix XII). Results exhibited that the highest root length (3.41 cm) was recorded from the treatment T_3 (Bioneemplus 1EC) that was statistically identical to T_6 (Admire 20SL) (3.29 cm) followed by T_4 (Proclaim 5SG) (3.07 cm) whereas the untreated control showed the lowest root length (1.91 cm) which was significantly differed to other treatments.

4.9.3 Shoot length

Shoot length was registered at 12 days of seedlings after germination. Different treatments showed significant variation on shoot length (Table 9 and Appendix XII). It was observed that the treatment T_3 (Bioneemplus 1EC)gave the highest shoot length (5.25 cm) which was significantly same to T_6 (Admire 20SL) (4.96 cm) which was followed by T_4 (Proclaim 5SG) (4.96 cm) whereas the lowest shoot length (3.75 cm) was given by untreated control treatment (UC) which was significantly lower from all other treatments.

4.9.4 Seed vigor index

Seed vigor index of seeds as quality parameter, significant variation was calculated due to different treatments (Table 9 and Appendix XII). Results indicated that the highest seed vigor index (842.70) was recorded from the treatment T_3 (Bioneemplus 1EC) followed by T_6 (Admire 20SL) (809.30) and they statistically identical whereas the lowest seed vigor index (473.70) was recorded from untreated control plot which was significantly different from other treatments. Similar result was also observed by the findings of Vikrant *et* *al.* (2020) who obtained highest seed vigor index using bio-pesticides that was supported by Shakir *et al.* (2015).

Table 9. Effect of some selected insecticides and botanicals applied as pest management practices in controlling tomato insect on seed quality parameters

Treatment	Seed quality parameters (seed quality test at 12 days of germination or seedling emergence)			
	Seed germination or seedling emergence (%)	Root length (cm)	Shoot length (cm)	Seed vigor index
T_1 (Spinosad 45EC)	87.67 d	2.08 e	3.91 e	525.40 f
T_2 (Voliam flexi 300SC)	90.80 c	2.43 d	4.41 d	621.10 e
T_3 (Bioneemplus 1EC)	97.23 a	3.41 a	5.25 a	842.70 a
T_4 (Proclaim 5SG)	93.83 b	3.07 b	4.96 b	753.80 c
T_5 (Mig 5EC)	92.33 bc	2.79 c	4.70 c	691.90 d
T_6 (Admire 20SL)	96.00 a	3.29 a	5.14 a	809.30 b
Untreated control	83.80 e	1.91 e	3.75 f	473.70 g
$LSD_{0.05}$	1.704	0.178	0.149	19.88
CV(%)	6.04	5.77	6.33	8.66

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

T_1 = Spinosad 45EC @ 0.4 ml/L of water at 7 days interval, T_2 = Voliam flexi 300SC @ 0.5 ml/L of water at 7 days interval, T_3 = Bioneemplus 1EC @ 0.5 ml/L of water at 7 days interval, T_4 = Proclaim 5SG @ 1.0 g/L of water at 7 days interval, T_5 = Mig 5EC @ 1.0 ml/L of water at 7 days interval, T_6 = Admire 20SL @ 0.5 ml/L of water at 7 days interval,Untreated control

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted to evaluation of some botanicals and chemical as pest management practices against pest complex in tomato in the farm of Sher-eBangla Agricultural University, Dhaka during the period from October 2019 to March 2020. The experiment consists of 7 treatments such as (i) T_1 (Spinosad 45EC @ 0.4 ml/L of water), (ii) T_2 (Voliam flexi 300SC @ 0.5 ml/L of water), (iii) T_3 (Bioneemplus 1EC @ 0.5 ml/L of water), (iv) T_4 (Proclaim 5SG @ 1.0 g/L of water), (v) T_5 (Mig 5EC @ 1.0 ml/L of water), (vi) T_6 (Admire 20SL @ 0.5 ml/L of water) and Untreated control. Each of the treatments was applied at 7 days interval. The experiment was laid out in Randomized Complete Block Design with three replications. Data on the incidence of white fly, aphid, leaf miner and fruit barer infestation and their effect of yield contributing characters and yield and also on seed quality parameters like seed germination, root length, shoot length and seed vigor index were recorded.

In case of the incidence of whitefly, treatment T_6 (Admire 20SL) showed the lowest number of total whitefly plant^{-1} (2.97) representing 1.10 at vegetative stage and 1.87 at fruiting stage whereas untreated control plot gave the highest number of total whitefly plant^{-1} (10.77) representing 2.83 at vegetative stage and 7.93 at fruiting stage. Treatment T_6 (Admire 20SL) also showed the highest % reduction of whitefly over control (72.45%) followed by T_3 (Bioneemplus 1EC) (62.24%) whereas T_2 (Voliam flexi 300SC) gave the lowest % reduction of whitefly over control (20.45%).

Regarding the incidence of aphid, treatment T_6 (Admire 20SL) showed the lowest number of total aphid plant^{-1} (4.00) having 2.00 at vegetative stage and 2.00 at fruiting stage whereas untreated control treatment gave the highest number of total aphid plant^{-1} (20.58) representing 8.87 at vegetative stage and

11.70 at fruiting stage. Treatment T_6 (Admire 20SL) also showed the highest % reduction of aphid over control (80.55%) followed by T_3 (Bioneemplus 1EC) (69.74%) whereas T_2 (Voliam flexi 300SC) gave the lowest % reduction of aphid over control (26.14%).

Again, at vegetative and fruiting stage, the lowest number of leaf miner plant^{-1} (0.21 and 1.00, respectively) which was in total (1.21) leaf miner in T_6 (Admire 20SL) treated plot whereas Untreated control plot showed the highest number of leaf miner plant^{-1} (1.19 and 3.18 at vegetative and fruiting stage, respectively) which was in total (4.37). The highest, 72.26% reduction leaf miner over control was achieved by the treatment T_6 (Admire 20SL) whereas T_1 (Spinosad 45EC) showed the lowest (22.94%).

In case borer infested fruits plant^{-1} by number, the highest number of healthy fruit plant^{-1} (25.87) was recorded from T_6 (Admire 20SL) treatment and it also gave lowest infested fruits plant^{-1} (0.90) that was in total 26.66 fruits plant^{-1} resulted 3.36% infestation which was lowest among the treatments. Similarly, untreated control treatment (UC) gave the lowest number of healthy fruits plant^{-1} (16.83) and highest number of infested fruits plant^{-1} (3.37) that was in total 20.20 fruits plant^{-1} resulted 16.68% infestation which was highest among the treatments.

Regarding borer affected fruits plant^{-1} by weight, the maximum healthy fruit weight plant^{-1} (1.72 kg) was recorded from T_6 (Admire 20SL) treatment and it also gave minimum infested fruits weight plant^{-1} (0.06 kg) that was in total 1.78 kg fruits plant^{-1} resulted 3.37% infestation which was lowest among the treatments. Similarly, untreated control plot gave the minimum healthy fruits weight plant^{-1} (1.02 kg) and highest infested fruit weight plant^{-1} (0.20 kg) that was in total 1.22 kg fruits plant^{-1} resulted 16.60% infestation which was highest among the treatments.

Considering fruit yield of tomato, T_6 (Admire 20SL) gave the highest healthy fruit yield (86.18 t ha^{-1}), minimum infested fruit yield (3.02 t ha^{-1}) and highest total fruit yield (89.20 t ha^{-1}) followed by T_3 (Bioneemplus 1EC) whereas untreated control plot gave the minimum healthy fruit yield (51.05 t ha^{-1}), maximum infested fruit yield (10.18 t ha^{-1}) and lowest total fruit yield (61.23 t ha^{-1}). Treatment T_6 (Admire 20SL) also gave the highest % increase of healthy fruit yield over control (68.81%) followed by T_3 (Bioneemplus 1EC) (57.77%) which was the lowest % increase of healthy fruit yield over control (5.41%).

In case of the performance on yield contributing characters and seed yield of tomato, the highest plant height (94.29 cm), number of branches $plant^{-1}$ (11.25), number of flower clusters $plant^{-1}$ (8.63), number of fruits $cluster^{-1}$ (6.37), single fruit weight (66.64 g), seed weight $fruit^{-1}$ (0.57 g), seed weight $plant^{-1}$ (12.73 g) and seed yield (636.70 kg ha^{-1}) were recorded from the treatment T_6 (Admire 20SL) which was followed by T_3 (Bioneemplus 1EC) for the parameters whereas untreated plot showed the lowest plant height (77.75 cm), number of branches $plant^{-1}$ (7.49), number of flower clusters $plant^{-1}$ (5.28), number of fruits $cluster^{-1}$ (4.05), single fruit weight (60.62 g), seed weight $fruit^{-1}$ (0.40 g), seed weight $plant^{-1}$ (7.93 g) and seed yield (396.30 kg ha^{-1}). Accordingly, the treatment T_6 (Admire 20SL) gave the highest % increase of seed yield over control (60.66) whereas T_2 (Voliam flexi 300SC) showed the lowest % increase of seed yield over control (22.81%).

Considering seed quality parameters, treatment T_6 (Admire 20SL) showed the highest seed germination (97.23%), root length (3.41 cm), shoot length (5.25 cm) and seed vigor index (842.70) followed by T_3 (Bioneemplus 1EC) whereas untreated control plot showed the lowest seed germination (83.80%), root length (1.91 cm), shoot length (3.75 cm) and seed vigor index (473.70).

From the above result, it may be concluded that depending on the availability of the application of botanicals and chemicals as pest management in tomato, the treatment T_6 (Admire 20SL) showed best performance against the incidence of whitefly, aphid, leaf miner and fruit borer which resulted higher healthy fruit yield, lower fruit infestation, better yield contributing parameters and seed yield. The other treatment like T_3 (Bioneemplus 1EC) also showed relatively better performance in relation to above mentioned parameters whereas the least performance was recorded from untreated control plot. Considering quality parameters of seeds from the study, T_3 (Bioneemplus 1EC) showed the best performance on seed germination, root length, shoot length and seed vigor index followed by treatment T_6 (Admire 20SL) whereas untreated control showed the poorest esults on seed quality parameters.

Considering this results of the present study, further studies in the following areas may be suggested:

1. Similar study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other botanical extraction and non-hazardous chemicals may be used in the future study
3. Different concentration and interval of application of botanicals and chemicals may be considered for further study

REFERENCES

Ahmed, M.M.M. (2000). Studies on the control of insect pests in vegetables (okra, tomato, and onion) in sudan with special reference to neem preparation. Ph. D. Dissertation. Faculty of Agrarwissenschaften, Okotrophlogie und Umweltmanagement University of Gissen Germany.

Allahyari, M.S. (2017). Farmers' Technical Knowledge about Integrated Pest Management (IPM) in Olive Production. *J. Agric*. **7:** 101.

Ateyyat, M.A., Al-Mazraawi, M., Abu-Rjai, T. and Shatnawi, M.A. (2009). Aqueous extracts of some medicinal plants are as toxic as Imidacloprid to the sweet potato whitefly, Bemisia tabaci. *J. Insect Sci*. **9**: 15-20.

Bajracharya, A.S., Bhat, B., Mainali, R.P., Bista, S., Shashank, P.R. and Meshram NM. (2016). The first record of South American tomato leaf miner, Tuta absoluta (Meyrick, 1917) (Lepidoptera: Gelechiidae) in Nepal. *J. Entomol. Zool. Stud*. **4**(4): 1359-1363.

Ballal, C.R., Gupta, A,. Mohan, M., Lalitha, Y. and Verghese, A. (2016). The new invasive pest *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India and its natural enemies alongwith evaluation of Trichogrammatids for its biological control. *Curr. Sci*. **110**(11): 2155-2159.

Barapatre, A. and Lingappa, S. (2003). Larvicidal and antfeedant activity of indigenous plant protection practices for *Helicoverpa armigera* (Hub.). In: Proceedings of National. Symposium on Fronterier Areas of Entomological Research, November 5-7, 2003. pp. 335-336.

Barapatre, A.B. (2001). Evaluation of indigenous technology for management of *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (Fab). M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Barde, S.K., Singhal, H.C., Parasai, S.K. and Dehariya, S.K. (2009). Management of tomato fruit borer *Helicoverpa armigera* (Hubner) with neem based insecticide. *J. Insect Sci.* **22**(1):104-106.

Barrientos, Z.R., Apablaza, H.J., Norero, S.A. and Estay, P.P. (1998). Threshold temperature and thermal constant for development of the South American tomato moth, *Tuta absoluta* (Lepidoptera, Gelechiidae). *Ciencia e Investigacion Agraria*. **25**(3): 133-137.

BBS. (2017). Yearbook of Agricultural statistics of Bangladesh. Bangladesh Bureau of Statistics, Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. pp. 301-302.

Beale, M.H., Birkett, M. A., Bruce, T. J., Chamberlain, K., Field, L. M., Huttly, A.K. (2006). Aphid alarm pheromone produced by transgenic plants affects aphid and parasitoid behavior. *Proc. Natl. Acad. Sci. U.S.A.* **103**: 10509–10513.

Berxolli, A. and Shahini, S. (2017). Population dynamic of tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Albanian Journal of Agricultural Sciences (Special Edition). pp. 85-89.

Bhattacharjee R, Dey U (2014). An overview of fungal and bacterial bio-pesticides to control plant pathogens and diseases. *Afric. J. Micro. Res*. **8**(7): 1749-1769.

Bihari, M. and Narayan, S. (2010). Evaluation of biocidal efficacy of botanicals against tomato fruit borer (Helicoverpa armigera Hubner) at field level. *J. Interacademicia*. **14**(3): 293-297.

Biondi, A., Guedes, R. and Wan, F. (2018). Ecology, worldwide spread, and management of the invasive South American tomato pinworm, Tuta absoluta: Past, present, and future. *Annual Rev. Entomol*. **63**: 239-258.

Birhan, A. (2018). Tomato leafminer [(*Tuta absoluta* Meyrick) (Lepidoptera: Gelechiidae)] and its current eco-friendly management strategies: A review. *J. Agric. Biotechnol. Sustain. Dev*. **10**: 11–24.

Bissdorf, J. (2005). Field Guide to Non-chemical pest management in tomato production, Pesticide Action Network (PAN) Germany Hamburg.

Bock, K. R. (1982). Gcminivirus diseases in tropical crops. *Plant Disease.* **66**: 266-270.

Brown**,** J.K. and Bird, J. (1992). Whiiefly-transmilted geminiviruses and associated disorder in the Americans and the Caribbean Basin. *Plant Disease.* **76**(3): 220-225.

Butani, D. and Jotwani, M.G. (1984). Insects in vegetables. Periodical Expert Book Agency, D 42, Vivck Vihar, Delhi-110032 (India). p.356.

Butler G.D., Puri, S.N. and Henneberry, T.J. (1991). Plant derived oil and detergent solution as control agents for *Bemisia tabaci* and *Aphis gossypii* on cotton. *South Western Entomol.* **16**(4): 331-337.

Campbell, C.D., Walgenbach, J.F. and Kennedy, G.G. (1991). Effect of parasitoid on lepidopterous pests in insecticide-treated and untreated tomatoes in western North Carolina. *J. Econ. Entomo.* **84**: 1662-1667.

Carson, R. (2007). ENVIS-NIOH. *News Letter*. **2**(1): 1-8.

Chand, A. and Tiwari, R. (2010). Influence of cow urine and indeginous plant leaf extracts on feeding potential and larval weight of *Spodoptera litura* (Fabricius). *J. Insect Sci.* **23**(3): 313-317.

Chitra J.J. Cohen, S, and Berlinger, M.J. (1993). Transmission and cultural control of whitefly - borne viruses. *Agric. Ecasyst. Environ.* **17**: 89-97.

Dandale, H.G. and Kadam, P. (2003). Role of new insecticide in the management of cotton bollworm. State level seminar on pest mgmt. for sustainable agriculture, MAU, Parbhani Feb 6-7[th] 2003. pp. 131-134.

Dar, S.A., Sajad, H.W., Sajad, H.M., Abid, S., Tashi, D. and Tashi, D. (2021). Bio-pesticides: Mode of Action, Efficacy and Scope in Pest Management. *J. Adv. Res. Biochem. Pharmacol*. **4**(1): 1-8.

Desneux, N., Wajnberg, E., Wyckhuys, K.A., Burgio, G., Arpaia, S., Narvaez-Vasquez, C.A., Gonzalez-Cabrera, J., Ruescas, D.C., Tabone, E., Frandon, J. (2010). Biological invasion of European tomato crops by Tuta absoluta: Ecology, geographic expansion and prospects for biological control. *J. Pest Sci*. **83**: 197–215.

Dhamo, A, Divokar, B J. and Pawar, A. D. (1984). Biocontrol of tomato fruit borer. *HeUothis armigera* (Hb) in Karnataka. *Indian J. Plant Protec.* **15**(1): 57-61.

Dhandapani, N. and Balasubramanium, M. (1984). Life table studies of gram pod borer, *Heliothis armigera* (Hub.) on tomato. *Indian. J. Ent.* **46**(4): 447-451.

Dharumarajan, S., Dikshit, A.K. and Singh, S. B. (2009) Persistence of Combine- Mix (beta-Cyfluthrin + imidacloprid) on Tomato *(Lycopersicon esculentum), Pesticide Res. J*. **21**(1): 83-85.

Diemetry, K., Ganguli, R. N., Kaushik, U. K. Dubey, V. K, Chandrakar, G. (1996). Management of tomato fruit borer, *Helioihis armigera* Hubner. using bio pesticides. *J. Appl. Zool. Res.* **10**(2): 105-107.

Dilbagh, S., Narang, D. D. and Singh, D. (1990). Control of tomato fruit borer, Helicoverpa armigera (Hubner) with synthetic pyrethroids. Indian J. Entom **52**(4): 534-540.

Eldridge, F. B. (2008). Pesticide application and safety training for applicators of public health pesticides, Vector-Borne Disease Section.

Engindeniz, S. and Ozturk, G.C. (2013). An economic comparison of pesticide application for processing and table tomatoes, a case study for Turkey. *J. Plant Prot. Res*. **53**(3): 230-237.

EPA. (2021). Ingredients Used in Pesticide Products: Pesticides. What Are Biopesticides? Available online: https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides (accessed on 26 September 2021).

Ewing, K. P., Parencia, C. R. Jr. and Ivy, E. E. (1947). Cotton insects control with benzene hexachloride, along or in mixture with DDT. *J. Econ. Ent*. **40**: 374-381.

FAO. (2018). Food and Agriculture Organization of the United Nations. Faostat. Production/yield quantities of Tomatoes in World + (Total).

Farrar, C.A., Perring, T.M. and Toscano, N.C. (1986). A midge predator of aphids on tomatoes. California Agriculture, November-December 1986.

Felicien, N., Aline, M., Vedaste, C. and Eric, M. (2021). Effect of bio-pesticides and antagonistic synthetic pesticides in managing tomato pests and fungal diseases under agro-climatic conditions of Huye District-Rwanda. *Adv. J. Agric. Res. (AJAR*). **8**(4): 237-243.

Gajanana, T.M., Krishna Moorthy, P.N., Anupama, H.L., Raghunatha, R. and Prasanna-Kumar, G.T. (2006). Integrated Pest and Disease Management in Tomato: An Economic Analysis. *Agric. Econ. Res. Rev*. **19**: 269–280.

Ganguli, R.N. and Dubey, V.K. 1998. Management of tomato fruit borer Helicoverpa armigera Hubner in Chattisgarh region in Madhya Pradesh. *Insect Environ*. **4**(1): 25.

Garcia-Martinez, S., Andreani, L., Garcia-Gusano, M., Geuna, F and Ruiz, J.J. (2006). Evaluation of amplified fragment length polymorphism and simple

Gitonga, Z.M., Chabi-Olaye, A., Mithofer, D., Okello, J.J., Ritho, C. N. (2009). Control of invasive *Liriomyza* leafminer species and compliance with food safety standards by small scale snow pea farmers in Kenya. *J. Crop Protection.* **29**: 1472-1477.

Gopal, C. Asokan, R, Reddy, P.P., Kumar. N.K.K. and Verghese, A. (1997). On-iamt trials with HaNPV against *Helicoverpa armigera* (Hubner.) (Lcpidoptcra: Noctuidae) on tomato. Advances in IPM for horticultural crops. Proceedings of the First National Symposium on Pest Management in Horticultural Crops: environmental implications and thrusts, Bangalore, India. pp. 215-217.

Haider, M. Z. (1996). Effectiveness of some IPM packages for the management of virus-disseminating whitefly on tomato. An MS thesis submitted to Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. p. 64.

Hamilton, J.T. and Toffolon, R.B. (1987). Pests of tomatoes. Agfacts, Department of agriculture, New South Wales. p. 19.

Hammad, E.M.A., Nemer, N.M., Haw, Z.K. and Hanna, L.T. (2000). Responses of the sweetpotato whitefly, *Bemisia tabaci*, to the chinaberry tree (*Melia azedarach* L.) and its extracts. *Ann. appl. Biol*. **137**: 79-88.

Haque, M.M, (1995). Insect pest of tomato. In: Curriculum Outline and Training Support Materials, Training Manual: Winter Vegetables and Spices Production. Horticulture Research and Development Project, DAE, BADC, Dhaka, pp. 180-181.

Hasan, W. and Singh, C. P. (2009). Efficacy of Cow urine Decoctions of Botanicals against Mustard Sawfly. *Ann. Plant. Protect. Sci.* **17**(1): 225-274.

Hirekuruber, R.B. (2005). Evaluation of Newer Insecticides for their effectiveness against pest complex of Okra M.Sc. (Agri.) thesis submitted to M.P.K.V., Rahuri.

Hoffmann, M.P., Wilson, L.T., Zalom, F.G., Hilton, R.J. and Weakley, C.V. (1996). Parasitoids helps control fruitworm in Sacramento Valley processing tomatoes. *California Agric. J*. **44**: 20-23.

Hossain, M.S., Mian, M.Y., and Muniappan, R. (2016). First Record of *Tuta absoluta* (Lepidoptera: Gelechiidae) from Bangladesh. *J. Agric. Urban entomol*. **32**(1): 101-105.

Hummel, N.A. (2004). Aphid, in tomatoes: Plant canopy distribution and binomial sampling on processing tomatoes in California. *J. Econ. Entomol*. **97**(2): 490-495.

Husain, M. and Begum, M. (1988). Effect of sowing lime on the incidence of pud borer, *Euchrysops cmjus* on mungbean. *Bangladesh J. Nucleir Agric*. **4**: 14-18.

Husain, M., Begum, M. and Jahangir, M. (1998). Comparative susceptibility of several strains/varieties of tomato fruit borer, *Helcoverpa armigera*. *Bangladesh J. Nuclear Agric*. **14**: 91-93.

Hussain, B. and Bilal, A. S. (2007). Efficacy of different insecticids on Tomato fruit borer Helicoverpa armigera. *J. Entomol*. **4**: 64-67.

Ibrahim, M.E., Shehata E.M.S. and Sawsan S.M. (2016). Impact of certain natural plant oils and chemical insecticides against tomato insect pests. *J. Entomol*. **13**: 84-90.

Inee, G., Rahman, I. and Dolui, A.K. (2003). Antifeedant properties of some plant extracts against tea mosquito bug, *Helopeltis theivora* Waterhouse. *J. Entomol. Res.* **27**(4): 321-324.

Isman, M.B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Ann. Rev. Entomol.* **51**: 45-66.

Jacob, Y, and Sheila, K. (1994). Comparison of capsules of sex pheromonc of *HeUothis (Helicoverpa armigera* (Hubner.) (Lepidoptera: Noctuidae). *Boktin de Sanidad Vegetal Plagas.* **18**(2): 427-434.

Jazzar, C. and Hammad, E.A.F. (2003). The efficacy of enhanced aqueous extracts of *Melia azedarach* leaves and fruits integrated with the Camptotylus reuteri releases against the sweetpotato whitefly nymphs. *Bull. Insectol*. **56**: 269-275.

Jenkins, J.A. (1948). The origin of cultivated tomato. *Econo. Bot*. **2**(4): 379-392.

Jitender, K. Sharma, S. D., Jamwal, R .S. and Kumar, J. (1999). Estimation of avoidable yield loss due to fruit borer, *Helicoverpa armigera* (Hubner) in tomato planted at different dates in tower Kuflu valley, Himachal Pradesh. *Pest Manag. Econ. Zool.* **7**: 2, 155-159.

Joshi, A., Thapa, R.B. and Kalauni, D. (2018). Integrated management of South American tomato leaf miner [*Tuta absoluta* (meyrick)]: a review. *J. Plant Protec. Soc*. **5**: 70-86.

Ju, Y.W., Zhao, B. G., Cheng, X.F. and Bi, Q.S. (2000), Bioactivitics of six desert plants extracts to *Heliothis armigera* Hubner. *J. Nanjing Forest. Univ*. **24**(5): 81-83.

Kajita, Hi. and Alam, M.Z. (1996). Whiteflies on guava and vegetables in Bangladesh and their Aphclinid parasitoids. *Appl Entomoi. Zool.* **31**(1): 159-162.

Kaloshian, I. and Walling, L.L. (2005). Hemipterans as plant pathogens. *Annu. Rev. Plant Biol*. **43**: 491-521.

Kandil, M.A., Rania, N.A., Moataz, A.M.M. (2020). Lethal and sub-lethal effects of bio-and chemical insecticides on the tomato leaf miner, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae). *Egyptian J. Biol. Pest Control*. **30**: 76.

Kankal, S.M., Kausale, P.P. and Sarkate, M.B. (2003). Bioefficiency of newer insecticides against Gram pod borer (*H. armigera*) in pigeon-pea. State level seminar on pest mgmt. for sustainable agriculture, MAU, Parbhani Feb. 6-7th 2003. pp: 156-158.

Karim, M.A. (1994). Insect pest management of vegetable crops. Proceeding of a symposium on resent advances in vegetable development of Bangladesh, 24-25 April. pp. 198-199.

Kashyap, R. K. (1983). Studies on resistance behavior of tomato genotype against fruit borer *Heliothis armigera* (Hub.). Ph.D. Dissertation HAU.

Kashyap, R.K. and Verma, A.N. (1986). Screening of tomato germplasm for susceptibility to fruit borer, *Heliothis armigera* (Hub.). *Indian J. Ent.* **48**(1): 46-53.

Kavanaugh, C.J., Trumbo, P.R. and Ellwood, K.C. (2007). The US food and drug administration's evidence-based review for qualified health claims: tomatoes, lycopene, and cancer. *J. Nat. Cancer Inst*. **99**(14): 1074-1085.

Khan, R.A. (2018). Sustainable management approach for controlling thrips (Thy-sanoptera: Thripidae) and their transmitted to spoviruses in tomatoes in south Florida. Ph.D. Dissertation (in progress). Entomology and Nematology Department, University of Florida, Gainesville, Florida, USA.

Khan, M.F.R. and Griffin, R.P. (1999). Efficacy of insecticides at controlling insect pests of tomato in South Carolina, *J. Agric. Urban Entomol.* **16**(3): 165-170.

Kharpuse, Y. K. and Bajpai, R. (2007). Efficacy of botanicals against major insect pest of tomato. *JNKV. Res. J.* **41**(2): 190-194.

Kh**ors**heduzzaman, G. Ganguly, R.N. and Dubey, V.K. (1998). Management of tomato fruit borer, *Helicoverpa armigera* IHubner. in Chhattisgarh region of Madhya Pradesh. *Insect Environ.* **4**(1): 25.

Kirk, W. D. J and Terry, L. I. (2003).The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). *J. Agril. Forest Entomol.* **5**: 301-310.

Knapp, M. (1999). Biology, pest status and control of mites in tomatoes in Eastern and Southern Africa, International Centre of Insect Physiology and Ecology, Nairobi, Kenya, May 1999.

Knapp, M. and Kashenge, S. S. (2003). Effects of different neem formulations on the twospotted spider mite, *Tetranychus urticae* Koch, on Tomato *(Lycopersicon esculentum* Mill.). *Int. J. Tropic. Insect Sci.* **23**: 1-7.

Krishna-Kumar, N.K. (1998). Bioecology and management of Sarpentine leaf miner ‘Liriomyza trifolii on vegetable crop. Final report of ICAR Adhoc Scheme, IIHR, Hessarghatta, Banglore.

Kulat, S., Nandanwar, V.N., Zade, N.N. and Tirthkar, S.S. (2001). Evaluation of some indigenous plant products for the management ol *Helicoverpa armigera* Hubn, on chickpea. *J. Appl. Zool. Res.* **12**(2-3): 96-98.

Kumar, G., Anadhi, P., Verma, S. and Elamathi, S. (2010). Management of cabbage Aphid *Brevicoryne brassicae* Linnaeus with Indigenous plant products on cabbage. *J. Insect Sci.* **23**(1): 66-69.

Kumar, V., Chandrashekar, K. and Sidhu, O.P. (2007). Synergistic action of neem and karaj to aphids and mites. *J. ent. Res.* 13(2): 121-124.

Lanny, G. (2001). Fruit vegetables. In: Crop Production in Tropical Africa. Raemaekers, R.H. (eds). Brussels, Belgium. pp.1540.

Liu, X., Cao, A., Yan, D., Ouyan,g C., Wang, Q. and Li, Y. (2021). Overview of mechanisms and uses of biopesticides. *Int. J. Pest Manag*. **67**: 65–72.

Lopez, O.J., Tone, M.C. Vimiela, E., Castancra, P. and Torre, M.C. (1999). Activity of seed extracts of *Trichilia havanetmis* Jacq, (Meliaccac) on larvae of *Helicoverpa armigera* (Hubner). *Boletin de Sanidad Vegetal, Plagas.* **24**(3): 629-636.

Magsi, F.H., Lashari, K.H., Chandio, M.A. and Bhutto, Z.A. (2017). Effectiveness of different synthetic insecticides against *Bemisia tabaci* (genn) on tomato crop. *Int. J. Fauna Biol. Stud*. **4**(3): 06-09.

Manjula, K. (2003). Management of groundnut bruchid, *Caryedon serratus* (Olivier) with botanicals in stored groundnut. *Pest Manag. Econ. Zool.* **11**(2): 115-118.

Manjunath, T.M., Bhatnagar, V.S., Pawar, C.S. and Sithanatham, S. (1985). Economic importance of *Helioihis* sp. in India and an assessment oi their natural enemies and host plants, Proc. Workshop. *Biol. Contr*. *Helioihis, ICRISAT*. Nov. pp. 11-15.

Megido, R.C., Haubruge, E. and Verheggen, F.J. (2013). Pheromone-based management strategies to control the tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae): A review. *Biotechnol. Agron. Soc. Environ*. **17**(3): 475-482.

Mehta, P. K., Rah, P. C. and Nath, P. (2000). Influence of plant and fruit characters of tomato on fruit borer infestation. Bull Entom New Delhi. **36**(1-2): 60-62.

Midingoyi, S., Kifouly, G., Kassie, M., Muriithi, B., Diiro, G. and Ekesi, S. (2019). Do Farmers and the Environment Benefit from Adopting Integrated Pest Management Practices? Evidence from Kenya. *J. Agric. Econ*. **70**: 452–470.

Miller, E.C., Hadley, C.W., Schwartz, S.J., Erdman, J.W., Boileau, T.M.W. and Clinton, S.K. (2002). Lycopene, tomato products, and prostate cancer prevention. Have we established causality? *Journal of Pure and Applied Chemistry* **74**: 1435-1441.

Mishra, S. N,, Nandanwar, V. N. and Mishra, N. C. (1996). Genetic parameters and varietal performance of tomato in North Eastern Ghal Zone of Orissa. *Environ. Ecol.* **13**(1):182-187.

Mitchell, P. L., Gupta, R., Singh, A. K and Kumar, P. (2004). Behavioural and developmental effects of neem extracts on *Clavigralla scutellaris* (Hemiptera: Heteroptera: Coreidae) and its egg parasitoid, *Gryon Fulviventre* (Hymenoptera: Scelionidae). *J. Econ. Entomol.* **97**: 916-923.

Mote, U.N., Dawkhar, R.V. and Lolage, G.R. 1995. Efficacy of imidacloprid as seed treatment against initial pests of cotton. *Pestology*. **XIX**(1): 5-8.

Nachiappan, R. M. and Subramanium, T. R. (1974). Studies on massculturing of *Heliothis armigera* (Hub.) (Noctuidae: Lepidoptera), on semi-synthetic diets. II. Effects on the development of per-imaginal instars. *Madras Agric. J*. **61**(1-2): 813.

Naika, S., de Jeude, J., de Goffau, M., Hilmi, M., van Dam, B. (2005). Cultivation of Tomato: Production, Processing and Marketing; Agromisa Foundation and CTA: Wageningen, The Netherlands. pp. 91.

Nault, B.A. and Speese, J. (2001). Evaluation of insecticides to control aphid in fall-grown tomato, 2000. Arthropod Management Tests, Report E86, 2001.

Nzanza, B. and Mashela, P.W. (2012). Control of whiteflies and aphids in tomato (*Solanum lycopersicum* L.) by fermented plant extracts of neem leaf and wild garlic. *African J. Biotechnol*. **11**(94): 16077-16082.

Oatman, E.R., Wyman, J.A., van Steenwyk, R.A. and Johnson, M.W. (1983). Integrated control of the tomato fruitworm and Integrated control of the tomato fruitworm (Lepidoptera: Noctuidae) and other lepidopterous pests on fresh-market tomatoes in Southern California. *J. Econ. Entomol.* **76**: 1363-1369.

Oloan, R.M., Mangili, T.K. and Tudayan, S.V. (2003). Bureau of Plant Industry Baguio National Crop Research and Development Center, Guisad Valley, Baguio City. p. 41.

Parihar, S.B.S., Verma, K.D, and Singh, R.P. (1994). Leaf cage lor the studies on cotton whitefly *Bemisia tabaci* Genn. *Indian J. Entomol.* **56**(2): 201-203.

Patel, P.S., Shukla, N.P. and Patel, G.M. (2003). Enhancing insecticide properties of cow urine against sucking pests of cotton. In: Proceedings of the National Symposium on Fronterier Areas of Entomological Research. 5-7 November. p. 227.

Patil, R. H., Santosh, M. N. and Anthoni, B. K. (2009). Indigenous technical knowledge components for the management of defoliators in the soybean. *Karnataka J. Agric. Sci.* **22**(3-spl.Issue): 491-494.

Patil, R.S. and Goud, K.B. (2003). Efficacy of me-thanolic plant extracts as ovipositional repellents against diamondback moth, *Plutella xylostella* (L.). *J. Entomol. Res.* **27**(1): 13-18.

Patnaik, H.P. 1997. Studies on neem formulations against serpentine leaf miner and tobacco caterpillar on tomato. *Insect Environ*. **3**(1):10.

Pawar D.B., Lawande K.E. and Warade S.D. 1996. Control of Liriomyza trifolii on tomato. *J. Maharashtra Agric. Univ*. **21**(1): 165-166.

Peralta, I.E., Spooner, D.M., Knapp, S., Anderson, C. (2008). Taxonomy of wild tomatoes and their relatives (Solanum sect. Lycopersicoides, sect. Juglandifolia, sect. Lycopersicon; Solanaceae). *Systematic Bot. Monographs*. **84**: 1-186.

Pickel, C., Miyao, G. and Zalom, F. (1994). Aphid damage assessment in processing tomatoes, California Tomato Research Institute, CTRI #94-66, Final Project Report-1994.

Pimentel, D. and Greiner, A. (1997). Environmental and socio-economic costs of pesticide use. In: Pimentel D (Ed) Techniques for Reducing Pesticides: Environmental and Economic Benefits, John Wiley and Sons, UK, pp. 51-78.

Pinto, M., Agro, A., Salerno, G., Peri, E. and Pinto, M. (1997). Serious attacks of the tomato moth *Helicoverpa armigera* (Hubncr). *Informa tore Agrario*. **53**(9): 67-69.

Prakash, A and Rao, J. (1996). Botanical pesticides in agriculture. CRC press.

Pretty, J and Bharucha, Z.P. (2015). Integrated Pest Management for Sustainable Intensification of Agriculture in Asia and Africa. *Insects*. **6**: 152-182.

Raizada, R. B., Srivastava, M. K., Kaushal, R. A., Singh, R. P. (2001). Azadirachtin, a neem biopesticide: subchronic toxicity assessment in rats. *J. Food Chemic. Toxicol*. **39**: 477-483.

Ramphal, S., Khan, C.B. and Jatav, A.A. (2003). Effects of abiotic and biotic factors on the germination, seedling length and seed vigour index during storage of tomato seeds. *Progres. Agric*. **3**: 89-91.

Rao, A.V. and Agarwal, S. (1999). Role of Lycopene as antioxidant Carotenoids in the prevention of chronic diseases. *J. Nutr. Res. Rev.* **19**: 305-323.

Rao, N.H.P., Hanumanantha, R.V. and Gopal, S.V.S. (2001). Utility of insecticides as ovicide against Helicoverpa armigera on cotton in Andhra Pradesh. *Pestology*. **25**(2): 7-9.

Raut, S.K. (2000). Bioefficacy of some insecticides and neem products against Heliothis armigera Hubner on tomato. *Pestology*. **XXIV**(8): 30-31.

Ravi, M., Santharam, G. and Sathiah, N. (2008). Ecofriendly management of tomato fruit borer, *Helicoverpa armigera* (Hubner). *J. Biopestic.* **1**(2): 134 - 137.

Reddy, P.P., Kumar, S., Joshi, P.K. and Pal, S. (2004). Vegetable research in India an IIHR perspective. *In Proceed. Impact Veg. Res. India.* pp.45-58.

Reed, W. and Pawar, C. S. (1982). Heliothis: a global problem, pp. 9-14. In: Reed, W. and V. Rumble (Eds.). Proceeding of International Workshop on *Heliothis* Management. Pantanchera, India, ICRISAT.

Retta, A.N. and Berhe, D.H. (2015). Tomato leaf miner– *Tuta absoluta* (Meyrick), a devastating pest of tomatoes in the highlands of Northern Ethiopia: A call for attention and action. *Res. J. Agril. Environmental Manag*. **4**(6): 264-269.

Rouphael, Y., Schwarz, D., Krumbein, A. and Colla, G. (2010). Impact of grafting on product quality of fruit vegetables. *Scientia Horticulturae*. **127**: 172-179.

Rutinganga. (2015). Pesticides use and regulations in Rwanda status and potential for promotion of biological control methods. Kigali, Rwanda.

Saberi, F., Marzban, R., Ardjmand, M., Pajoum, S.F., Tavakoli, O. (2020). Optimization of culture media to enhance the ability of local Bacillus thuringiensis var. tenebrionis. *J. Saudi Soc. Agric. Sci*. **19**: 468–475.

Saeed, A., Hayat, K., Khan, A.A and Iqbal. (2007). Heat tolerance Studies in Tomato *(Lycopersicon esculentum* Mill). *International Journal of Agric. Biol.* **9**: 649-652.

Saibllon. Y.K., Krishnamoortliy, A. and Mani, M. (1995). Biosuppression of *Helicoverpa armigera* (Hubner.) on tomato using two egg parasitoids, *Trichogramma brasiliensis* (Ashm.) and *T. pretiosum* (Riley). *J. Entomol. Res.* **20**(1): 37-41.

Saikia, P.D., Das, D. and Saikia, L. (2000). Evaluation of botanicals and fish oil formulations against bean aphid, Aphis craccivora Koch. *J. Agric. Sci. Soc. North-East.* **13**: 79-90.

Salas, J. (1992). Integrated pest-management program for tomato crops (*Lycopersicon esculentum* Mill.) Lara State, Venezuella. *Acta Hort.* **301**: 199-203.

Schmutterer, H. (2002). The Neem Tree. Mumbai: Neem Found. p. 892.

Scholthof, K.B.G., Adkins, S., Czosnek, H., Palukaitis, P. and Jacquot, E. (2011). Top 10 plant viruses in molecular plant pathology. *Molecular Plant Pathol.* **12**: 938-954.

Senthilkumar, N., Murugan, K. and Zhang, W. (2008). Additive interaction of *Helicoverpa armigera* Nucleopolyhedrovirus and Azadirachtin. *J. Biol. Control.* **53**:869-880.

Shakir, S.K., Kanwal, M., Murad, W., Rehman, Z., Rehman, S., Daud, M.K. and Azizullah, A. (2015). Effect of some commonly used pesticides on seed germination, biomass production and photosynthetic pigments in tomato (*Lycopersicon esculentum*). *J. Ecotoxicol*. Springer Science+Business Media New York. DOI 10.1007/s10646-015-1591-9.

Shiberu, T. (2020). Evaluation of Insecticides on Management of some Sucking Insect Pests in Tomato (Lycopersicon esculentum Mill.) in West Shoa Zone, Toke kutaye District, Ethiopia. *J. Sci. Sust. Dev. (JSSD)*. **8**(2): 43-49.

Shukla, N.P., Patel, P.S. and Patel, G.M. (2003). Fortification of cow urine for enhancing insecticidal properties against pests of castor. In: Proceedings of National Symposium on Fronterie Areas of Entomological Research, 5-7 November. pp. 216.

Singh, D. and Narang, N. D. (1990). Control of tomato fruit borer, *Heliothis armigera* (Hub.) with synthetic pyrethroids. *Indian J. Entomol.* **52**(4): 534-540.

Singh, H. and Singh, G. (1977). Biology studies on tomato fruit borer, *Helicoverpa armigera* Hub. In Punjab. *Indian J. Entomol*. **27**(ii): 154-164.

Singh, K. and Arya, H. (2004). Aphidicidal activity petroleum ether extract of *Azadirachta indica* A. Juss (Neem) and *Madhuka indica* Gemelin (Mahua) seed against mustard aphid, *Lipaphis erysimi* (Kaltenbatch) (Homoptera:Aphididae). *J. Aphidol.* **18**: 55-59.

Singh, S.R. (1972). The cotton bollwonn, *Heliothis armigera* Hub. (Lepidoptera: Nociuidac) on cabbage. *Entom. Rev*. **51**: 27.

Sivkumar, R., Nachiappan, R.M. and Verma, V. (2003). Profenofos, A potential insecticide against tomato fruit borer *H. armigera* (Hub.). *Pestolo.* **27**(11): 13-16.

Srinivasan, R., Uthamasamy, S., Mohan, S. and Usha Rani, B. (2003). The effects of three plant products on *sitophilus oryzae* (L.) in maize. *Plant protection bulletin.* **55**(1+2): 23-26.

Sundarajan, G. (2002). Control of caterpillar *Helicoverpa armigera* using botanicals. *J. Ecotoxicol. Environ. Monitor.* **12**(4): 305-308.

Sundarajan, G. and Kumuthakalavalli. R. (2000). Effect of leaf extracts of selected plants against the larvae of *Helicoverpa armigera* (Hubner.), *Environ. Ecol.* **18**: 1.

Sundarajau, G. (2001). Evaluation or some plant extracts against *Helicoverpa armigera* (Hubner). *Environ. Ecol.* 19(1): 210-212.

Sutton, A. (1991). Tomatoes. Vegetable Market Development Team, C1BA-GE1GY. AG 6.82 Basel, Jammy, 1991. pp. 6-60.

Syed, A.H.R. and Saleem, J. (2015). Efficacy of some selected chemical insecticides and bio-pesticides against tomato fruit worm, (Heli cover paarmigera) under the agro climatic condition of Gilgit Baltistan. *Pakistan. J. Entomol. Zool. Stud*. **3**(4): 50-52

Taha, A.M., Afsah, A.F.E. and Fargalla, F.H. (2013). Evaluation of the effect of integrated control of tomato leaf miner Tuta absoluta with sex pheromone.

Talekar, N.S., Ying F. and Song, T. (1983). Tomato insect pest: major management strategies. In: Proc. Symp. *Insect Control of Vegetables* (Tiwan). pp. 1-19.

Tewari, G.C. (1984). Field efficacy of synthetic pyrethroids against *Heliothis armigera* (Hubner) infesting tomato. *Singapore J. Prim. Indust.* **13**: 1, 51-56.

Thomas, C.F.G., Hol, E.H.A. and Everts, J.W. (1990). Modelling the diffusion component of dispersal during recovery of a population of linyphiid spiders from exposure to an insecticide. *J. Functional Ecol.* **4**: 357-368.

Tonnang, H.E.Z., Mohamed, S.A., Khamis, F. and Ekesi, S. (2015). Identification and risk assessment for worldwide invasion and spread of Tuta absoluta with a focus on Sub-Saharan Africa: Implications for Phytosanitary measures and management. *Plos. one*. **10**(9): e0138319.

Tumuhaise, V., Khamis, F.M., Agona, A., Sseruwu, G. and Mohamed, S.A. (2016). First record of Tuta absoluta (Lepidoptera: Gelechiidae) in Uganda. *Int. J. Trop. Insect Sci*. **36**: 135–139.

Tumwine, J., Frinking, H.D. and Jedger M.J. (2002). Integrated cultural control methods for tomato late blight (*Phytophthora infestans*) in Uganda. *Annals Appl. Biol.* **141**: 225-236.

USEPA (US Environment Protection Agency). (2005). What is a Pesticide? www.epa. gov/pesticides/about/index.html.

Varela, A.M., Serf, A. and Lohr, B. (2003). A guide to IPM in tomato production in eastern and southern Africa. International Centre of Insect Physiology and Ecology, ISBN 9290641495.

Vikrant, Rana, R.S., Kumar, R.V., Naik, S.B. and Ramesh, V.M. (2020). Efficacy of Bio-Pesticides on Tomato (*Solanum lycopersicum* L.) Var. Solan Lalima, Fruit Yield and Seed Quality under Mid Hill Conditions of Himachal Pradesh. *Int.J.Curr.Microbiol.App.Sci*. **9**(6): 1739-1747.

Waiganjo, M., Waturu, C., Mureithi, J., Muriuki, J., Kamau, J and Munene, R. (2009). Use of entomopathogenic fungi and neem bio-pesticides for

Brassica pests control and conservation of their natural enemies. *East African Agril. Forestry J.* **77**: 545-549.

Waiganjo, M.M., Wabule, N.M., Nyongesa, D., Kibaki, J.M., Onyango, I., Wepukhulu, S.B. and Muthoka, N.M. (2006).Tomato production in Kirinyaga district, Kenya. A baseline Survey report. pp. 3-4.

Walling, L.L. (2008). Avoiding Effective Defenses: Strategies Employed by Phloem-Feeding Insects. *Plant Physiol*. **146**: 859-866.

Walter, J.F. (1999). Commercial experience with neem products. In: Methods in Biotechnology. Vol. 5: Biopesticides. Ed. by Hall, F. R., Menn, J. J. Totowa, NJ: Humana Press. pp. 155-170.

Walunj, A. R., Pawar, S. A., Khaire, V. M. and Dareker, K. S. (1999). Evaluation of insecticides mixtures for control of tomato fruit borer. Tests of Agrochemicals and cultivars. CH. **20**: 10-11.

Walunj, A.R and Mote, U.N. (1995). Evaluation of imidacloprid against thrips and whitefly on tomato. *Pestology*. **XIX**(11): 21-23.

Zaki, F.N. (2008). Field application of plant extracts against the aphid, B. brassicae and the whitefly, B. abaci and their side effects on their predators and parasites. *Arch. Phytopathol. Plant Prot.* **41**: 462-466.

Zalom, F. (2003). Aphid control in processing tomatoes, 2002. Arthropod Management Tests, Report E92, 2003.

Zappala, L., Biondi, A., Alma, A., Al-Jbooryl, J., Arno, J. and Bayram, A. (2013). Natural enemies of the South American moth, Tuta absoluta, in Europe, North Africa and Middle East, and their potential use in pest control strategies. *J. Pest Sci*. **86**(4): 635-647.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

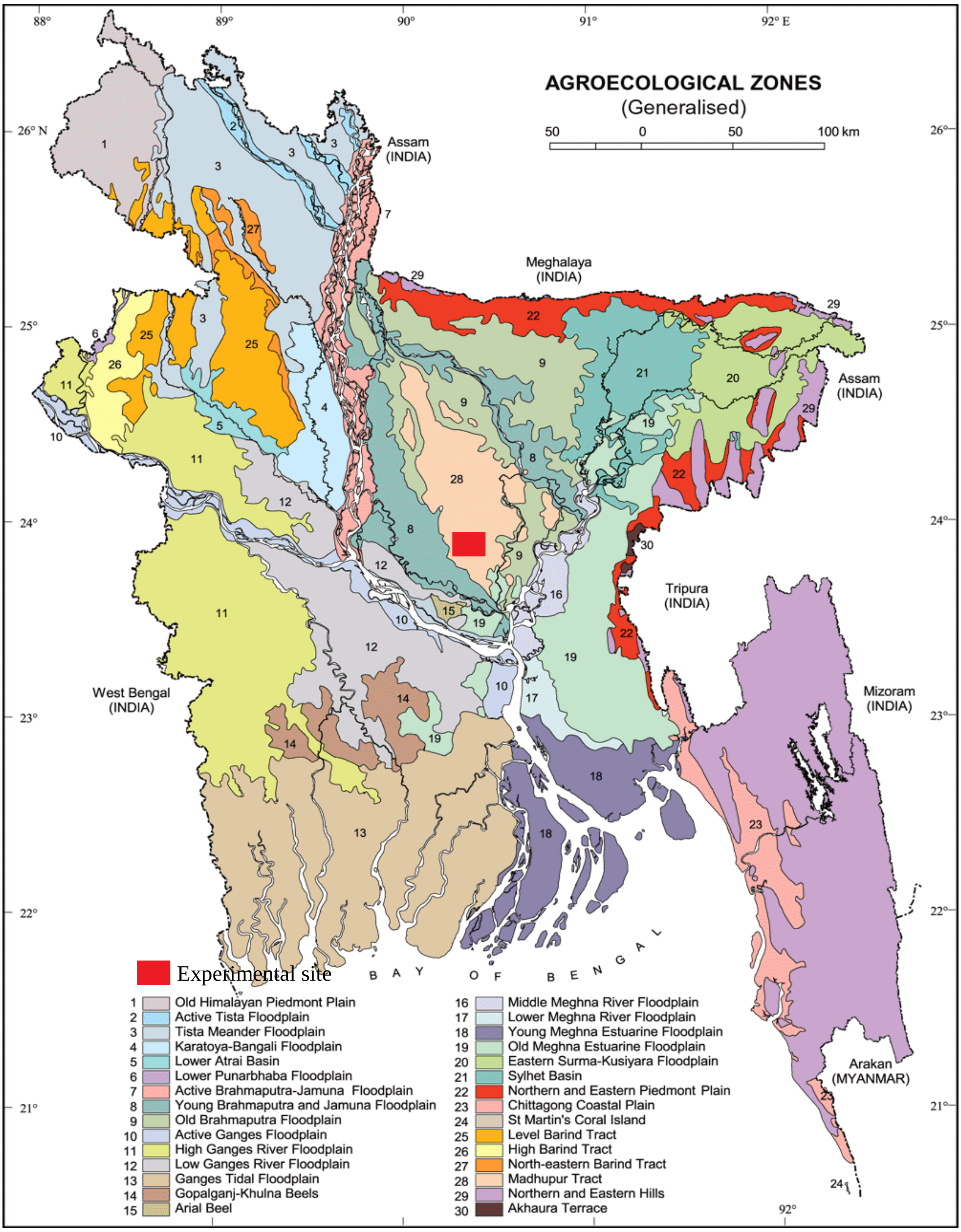

Figure 9. Showing experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from October 2019 to March 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	October	30.42	16.24	23.33	68.48	52.60
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0
2020	March	35.20	21.00	28.10	52.44	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of incidence of whitefly on tomato plant under different treatment of selected insecticides and botanicals

Sources of variation	Degrees of freedom	Mean square of number of white fly plant^{-1}			% reduction over control
		Vegetative stage	Fruiting stage	Total	
Replication	2	0.095	0.009	0.053	3.072
Factor A	6	1.100**	12.55*	20.97*	77.53*
Error	12	0.020	0.133	0.077	2.781

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of incidence of aphid on tomato plant under different treatment of selected insecticides and botanicals

Sources of variation	Degrees of freedom	Mean square of number of aphid plant^{-1}			% reduction over control
		Vegetative stage	Fruiting stage	Total	
Replication	2	0.582	1.382	0.375	4.073
Factor A	6	17.76*	32.74*	97.01*	64.17*
Error	12	0.142	0.897	0.527	2.921

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of incidence of leaf miner on tomato plant under different treatment of selected insecticides and botanicals

Sources of variation	Degrees of freedom	Mean square of number of leaf miner plant^{-1}			% reduction over control
		Vegetative stage	Fruiting stage	Total	
Replication	2	0.004	0.018	0.005	2.534
Factor A	6	0.404**	1.725**	3.736*	72.34*
Error	12	0.002	0.012	0.044	3.144

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of effect of some selected insecticides and botanicals as pest management practices in controlling tomato fruit borer in terms of fruits plant^{-1} by number

Sources of variation	Degrees of freedom	Mean square of number of fruits plant^{-1}			% fruit infestation by number
		Healthy	Infested	Total	
Replication	2	0.032	0.361	0.579	5.248
Factor A	6	36.83*	2.202**	21.45*	106.3*
Error	12	0.529	0.073	0.576	4.014

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of effect of some selected insecticides and botanicals as pest management practices in controlling tomato fruit borer in terms of fruits plant^{-1} by weight

Sources of variation	Degrees of freedom	Mean square of weight of fruits plant^{-1}			% fruit infestation by weight
		Healthy	Infested	Total	
Replication	2	0.012	0.002	0.022	6.244
Factor A	6	0.219**	0.007^{NS}	0.149**	102.43*
Error	12	0.005	0.001	0.002	3.247

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect in terms of fruits per plant by number

Sources of variation	Degrees of freedom	Mean square of fruit yield ha^{-1}			% increase of healthy fruit yield over control
		Healthy	Infested	Total	
Replication	2	30.686	5.002	55.148	4.277
Factor A	6	548.50*	18.24*	371.82*	72.46*
Error	12	3.070	0.690	4.347	2.837

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Mean square of effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect in terms of yield contributing characters

Sources of variation	Degrees of freedom	Mean square of yield contributing characters				
		Plant height	No. of branches plant^{-1}	No. of flower clusters plant^{-1}	No. of fruits cluster^{-1}	Single fruit weight
Replication	2	17.662	2.229	0.380	0.640	21.932
Factor A	6	102.42*	6.215*	3.993**	2.068**	15.461*
Error	12	2.279	0.082	0.064	0.032	0.335

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XI. Mean square of effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect in terms of seed yield parameters

Sources of variation	Degrees of freedom	Mean square of seed yield parameters			% increase of seed yield over control
		Seed weight fruit^{-1}	Seed weight plant^{-1}	Seed yield ha^{-1}	
Replication	2	0.001	0.083	208.333	8.924
Factor A	6	0.018^{NS}	7.818*	19545.3*	97.24*
Error	12	0.011	0.028	71.222	3.246

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XII. Mean square of effect of some selected insecticides and botanicals as pest management practices in controlling tomato insect in terms of seed quality parameters

Sources of variation	Degrees of freedom	Mean square of seed quality parameters			
		Seed germination	Root length	Shoot length	Seed vigor index
Replication	2	0.943	0.022	0.023	105.357
Factor A	6	66.77*	1.046**	1.046**	59222.7*
Error	12	0.917	0.010	0.007	124.819

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Plate 1. Field view of experimental field

Plate 2. Application of pesticides in experimental field

Plate 3. Intercultural operation in experimental Tomato field